

## REVITALIZING THE NAVY'S R&D CENTERS-- OPPORTUNITIES FOR UNIVERSITY COLLABORATIONS

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### Background

The Department of the Navy is one of a growing number of Federal agencies which is expressing concern about its ability to meet their future Science and Technology (S&T) workforce needs. The recent trends in the number of Ph.D.s awarded in engineering given in the figure below illustrate the nature of the problem.

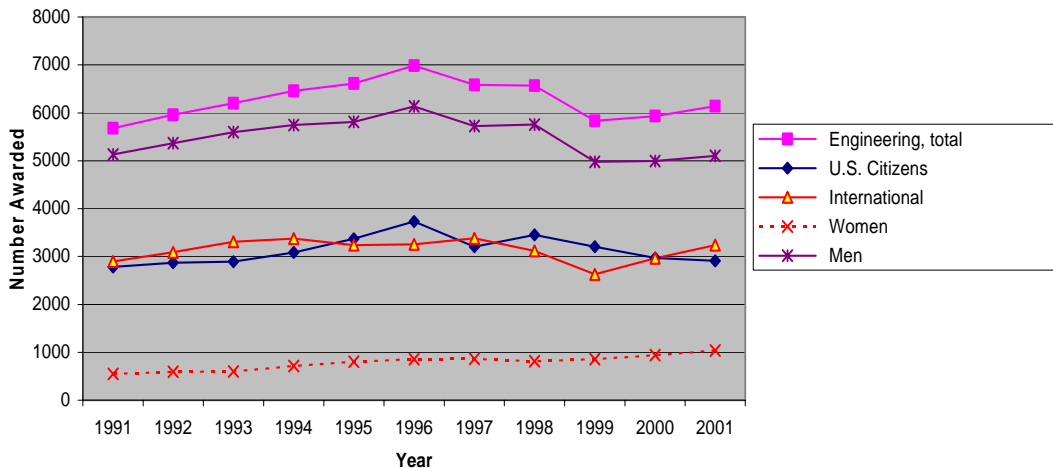


Fig. 1 Engineering Ph.D.s by Gender and National Origin. (AAES data).

This figure shows that whereas the growth in the number of Ph.D.s awarded since 1999 appears to have addressed the sharp declines of the middle nineties, this growth has been almost entirely due to sharp increases in the number of international students. The number of U.S. students earning Ph.D.s in engineering has continued to drop almost continuously since 1996. Coincidentally, 1996 also marked the year in which the number of international students returning to their home countries with science and technology degrees earned in the US began to increase (1). With improved economic conditions and professional development opportunities now available to many international students in their home countries, this trend can be expected to continue. Played out against the background of the widely-acknowledged graying of the

Nation's technological workforce in which a significant portion of the science and technology employees are eligible for retirement in the next few years, this situation takes on a particularly urgent nature.

### **The Navy's Response**

Specifically, Department of the Navy estimates place the number of engineers, scientists, and computer specialists retiring in the next five years to between 47 and 70 percent (2). Motivated by the need to maintain its science and technology enterprise in the face of these factors, the Navy has undertaken an initiative with the goal of adding approximately 400 new research employees per year to its R&D centers located throughout the United States, comprising the Naval Surface Warfare Center, Naval Undersea Warfare Center, Naval Air Warfare Center, Space and Naval Warfare Systems Center, the Naval Research Laboratory, the Naval Medical Research Center, and the Naval Medical Health Center.

Internal studies (3) of the Navy's science and technology (S&T) needs have pointed to factors which must be addressed if this objective is to be met. Some of these factors are internal, such as limitations imposed by the Civil Service System on the flexibility to hire new employees and the ability to reward research productivity, but often these factors relate to external changes such as the need to establish closer connections with universities.

Under the direction of the second author, the Office of Naval Research and the Navy's Warfare Centers are currently exploring a program of S&T Revitalization directed at its R&D Centers in which enhanced relationships and interactions with the Nation's universities and their students is expected to play an important role. Among the strategies being considered are: 1) Providing scholarships and fellowships to increase the number of US students (including female and minority students) who obtain science and engineering degrees; 2) Providing enhanced undergraduate and graduate co-op opportunities; 3) Promoting exchanges of technical personnel between universities and the R&D Centers; and, 4) Enhancing research connections with the university community for the purpose of recruiting M.S. and Ph.D. graduates who are trained in areas of interest to the Navy.

This last strategy has provoked a good deal of discussion within the Navy community, and it is safe to say that, whereas it is by no means clear how such connections should be made, it is clear that the university community needs to join this discussion if this effort is to be successful. In order to encourage this involvement, this paper provides 1) two examples of collaborative research between Virginia Tech and the Naval Surface Weapons Center in Dahlgren, Virginia (NSWCDD) both from the perspective of a Virginia Tech faculty member (the third author, ALW) who was involved in both projects and from the perspective of two Dahlgren engineers (the fourth and fifth authors, BJM and CRG) with whom he has worked, and 2) a table obtained with the help of Dahlgren's S&T director (the last author) which contains several brief examples of NSWCDD connections with other universities.

It is important to pause here to add an important disclaimer and a *request*. We make no claim that this is a comprehensive list of university/Navy R&D Center connections. We have focused on one center and (mostly) on one university and even at that, it is inevitable that we have missed

many examples of mutually-beneficial research connections. Secondly, it is the hope of the first author (EFB) that that addressing these omissions by acquiring additional examples of successful collaborative program we can assist our Navy colleagues in identifying the features which such programs have in common and thereby assist in defining a basis for developing plans for future collaborative programs. Obviously, with such connections come opportunities for faculty to pursue possibilities for enhanced research funding. In short, as faculty members, we have a chance to help ourselves and to help the Navy at the same time. I would like to add to this list of successful projects and I need your help to do this—both from our university and from our Navy R&D Center readers. *Please let me hear from you.*

## **An Excavator Project**



Fig 2. Remote-Controlled Case Excavator

*Faculty Perspective (ALW):* A project to develop a remote-control capability for a CX160 Case excavator was initiated in January of 2002 based on the belief that undocumented materials buried at sites prior to 1953 might be dangerous, requiring the use of a remote-controlled excavator. The project began in February 2002 with four undergraduate students and a graduate student. I was joined in this effort by Dr. Charles Reinholtz from the mechanical engineering department at Virginia Tech. George Clotfelter, G-64, NSWCCD, directed the project. Over the following 6 months, the students, faculty, and Navy personnel, modified the Case excavator for fully remote operation, including start up, shut down and zoom-video feedback. The remote site, which could be located more than a kilometer from the working excavator, was designed to function with the same 'feel' for the operator as though the operator was operating the excavator in the normal hands-on fashion. A hydraulic manifold was designed that ported the hydraulics for each degree of freedom of the excavator to a set of servo-valves. These valves were controlled through FieldPoint hardware and LabVIEW software, products of National Instruments. The project was completed ahead of schedule and under budget.

To demonstrate the effectiveness of the design, the students operated the excavator from the main stage at the NI WEEK 2002 conference in Austin, Texas, using an internet link to the

excavator located in Blacksburg ,Virginia. This demonstration and accompanying paper, won the National Instruments' Best Paper Award at the conference. Continuing support for the excavator including software maintenance and hardware upgrades are currently being performed under an extension of the original contract. The excavator is currently being used at NSWCDD exploring several hazardous sites.

This and the following project have resulted in funded research and fruitful collaboration between highly-qualified graduate students and Navy personnel. Over the last ten years no less than ten projects have supported at an average of two students a year. Since many of these projects have an applied component, my students have expanded their educational experience by linking the research with the functionality of the real world. The typical project involves a design component, a modeling effort, and an experimental verification. This results in a broad-based learning experience for the student. In addition the requirement of a 'deliverable' and a deadline expands the learning experience by placing accountability on the students and their progress.

The mechanical engineering department has benefited from the funding produced from these projects and the intellectual stimulation provided by these 'real-life' projects both on the graduate and undergraduate levels. The unique nature of the projects, focusing on applied research, gives the students and faculty the opportunity to develop new technology and skills as well as expand the experience base. Since many of the projects are applied in nature, undergraduate students can benefit directly with in-class projects relating to the research as well as paid participation in the project.

*NSWCDD Perspective (BLM):* My experience of working with Dr. Wicks and his colleagues has been outstanding. College students are used to living on a low budget and tend to treat your project budget as though it was theirs. They will put forth an extra effort to ensure you get the best product at the lowest cost. They tend not to over specify required items and vendors. Suppliers are very willing to work with college students. Case went out of their way to accommodate the project and the Case manufacturer (in Japan) modified the software for the students at no charge. There is also a recruiting aspect associated with such projects in that they offer the students and NSWCDD an opportunity to look one another over from the perspective of their attractiveness for future employment. As the University staff and its students continue to develop relationships at Federal facilities, spin-off projects become a reality as we understand their capabilities and they understand our needs. I am working with Dr. Wicks on several follow-on projects. The cost to the tax payers is minimized through these efforts and the very latest technologies are being applied. If we are successful in pulling the universities into the loop we greatly increase NSWCDD's intellectual capabilities at minimal cost since infrastructure, buildings, labs, etc. are already in place at the university.

## A Warhead Project

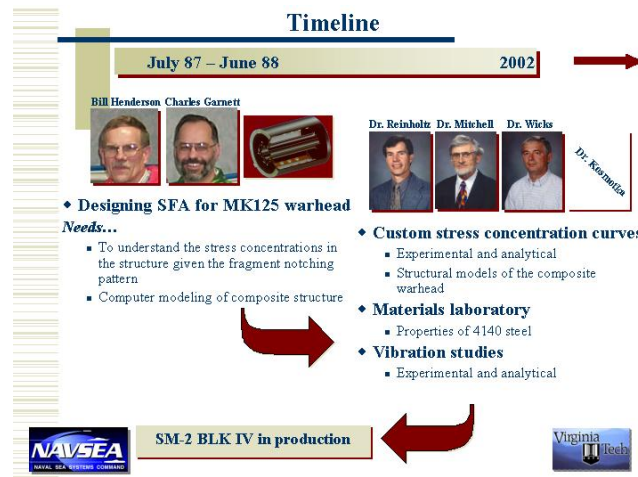


Fig. 3. The Mk 125 Warhead Project

*Faculty perspective(ALW):* My involvement in the Navy's Mk 125 Warhead missile program began in 1986. The desired features included the use of new materials and the use of the warhead as a load-bearing component. These design variations required advanced analysis and test techniques as well as material characteristics necessary for structural modeling. Mr. Charles Garnett of NSWCDD contacted Dr. Larry Mitchell who formed a team of five Virginia Tech faculty and their graduate students to assist in the required tasks. A comprehensive program was initiated that included finite element (FE) modeling of the warhead complemented by the dynamic testing necessary to validate the models, as well as material property testing to provide stress concentration data. Static and dynamic finite element models were developed, and experimental modal analysis was used extensively to 'tune' these FE models.

This effort, lasting over a period of three years, had a major technology transfer component. Navy personnel participated in the project, not only as contract monitors, but as technical contributors to the effort. As we developed FE models, Leonard Wilson and other G-22 personnel expanded their expertise in this type of modeling. Much of the dynamic testing was performed at Dahlgren involving Navy personnel in the testing process.

As the Navy's expertise in structural mechanics improved, the connection between Virginia Tech and NSWCDD evolved into other technical areas such as the data acquisition systems which were developed to support the static bend tests required by the STANDARD missile program. This system featured the use of software known as LabVIEW that has lead the way in the evolution of software-based instrumentation. LabVIEW is now used extensively at Dahlgren. As the FE modeling expertise developed, better material data was required for the models. A Split-Hopkinson bar test facility was developed and expansion of the data acquisition frequency range and the addition of a laser based sensor to the apparatus was done through projects at Virginia Tech.

In addition, signal processing projects have developed techniques for parameterizing specific detonators. We have also tested a transduction approach for use in measuring the explosive properties of reactive materials. In all of these projects, the graduate students and faculty have worked closely with NSWCDD personnel, exchanging ideas and technology.

*NSWC Perspective(CRG):* The new ordnance section for STANDARD Missile was to incorporate many new technologies and numerous trade studies and design compromises were being evaluated. The design's structural efficiency and ordnance requirements were dictating the inclusion of many stress concentration features within the airframe. While NSWCDD had the expertise in warhead design and missile system integration, there was a deficiency in high-end Finite Element analysis and structural mechanics. Dr. Larry Mitchell and his colleagues in the mechanical engineering department at Virginia Tech were contacted to support the design.

Dr. Mitchell assembled a team consisting of Dr. Wicks, Dr. John Kosmatka, Dr. Robert Fries, and Dr. Charles Reinholtz. Together, this team took on three major roles: 1) To build and validate a detailed Finite Element Model of the warhead structure, 2) To develop custom stress concentration curves to be used for this and future warhead design efforts, and 3) To conduct experimental modal analysis on the components and all-up structure to provide validation of the code work. These efforts were to provide design insight for the upcoming qualification test series. This system went into production in 1991 and is still one of the most advanced and lethal warhead designs flying.

From these efforts, NSWCDD has steadily upgraded and refined our expertise in structural mechanics. As a consequence, much of this work can today be done within the lab. The Virginia Tech team provided both the immediate skills needed to develop the Mk 125 Warhead and the guidance on the areas on which to focus the NSWCDD resources.

Over the last 15 years the relationship has evolved. For example, When NSWCDD began to look more closely at structural composites, Dr. Wicks was asked to help. He participated in the analysis and bend testing of several designs. During this effort, a need to automate the bend-test fixture was identified. The obvious tool was LabVIEW, however NSWCDD did not have engineers proficient with this software. Dr. Wicks wanted his graduate students to have this skill set and the LabVIEW software task was given to Virginia Tech. With the success of these efforts, several Engineers within the warhead branch have employed LabVIEW on other projects and LabVIEW is now simply another tool within NSWCDD.

In parallel with the modal testing and structural testing, NSWCDD had purchased a Split-Hopkinson Bar test fixture to develop constitutive material models. The design was obtained from UC San Diego; however, the instrumentation was not sufficient for the NSWCDD mission. Since Virginia Tech was already working on strain-gage instrumentation via the bend test automation effort, Dr. Al Wicks teamed with Mr. Leonard Wilson on the instrumentation design. A description of this work and the laser-based data acquisition system won best paper at the 3rd Joint Classified Ballistics Symposium. This co-authored paper is a good example of work growing out of a long-term relationship with Virginia Tech.

This covers some major points but doesn't do justice to the many small projects and efforts the Warheads Branch has had with the mechanical engineering department, as well as some spin-offs to other departments at Virginia Tech. For example, Dr Wicks had a post doc do some outstanding modeling of a high voltage, high frequency pulse power system. This work evolved into a small task in electrical engineering department. Efforts to look at single-shot devices evolved into a small project with the statistics department,. And finally, the aging characteristics of the pulse power system evolved into a project in the chemistry department.

In short, Virginia Tech has repeatedly brought expertise to NSWCCD. In some cases, the early efforts were used to develop our own capability. In some cases the areas are not within NSWCCD's core mission but are needed to complete the project. In all cases the access to world-class professors and top graduate students has been integral to many success stories.

### **Brief Examples of Additional Projects**

| <i>NSWCDD Connection</i>                       | <i>Research Area/Accomplishment</i>  |
|--|--|
| George Mason Univ.                             | Prof. George Wegman/supervised dissertations of four NSWC employees/co-author of five journal papers/co-author of numerous conference papers/co-author of three book chapters/co-author of book in preparation.  |
| Johns Hopkins Univ.                            | Prof. Cary Priebe/co-author of seven journal papers/co-author of numerous conference papers/co-author of one book and a book in preparation/assisted with development of new mathematical methodologies that foster classifier-driven sensor adaptation related to chemical agent detection. |
| Tennessee Tech                                 | Provided theoretical insight into operation of data-networking protocols related to a number of topics including inter-domain multicast routing, unicast routing protocols for tactical networking, and buffer management within computers connected to a LAN                                |
| Univ. of Virginia                              | Human decision-making support and overall human-automation interaction with application to monitoring an re-targeting of in-flight Tactical Tomahawk missiles/MS thesis/PhD dissertation.  |
| Univ. of Washington                            | Ram Accelerator Gun/experiments, technical alternatives, definition, modeling/weaponization studies for possible application to ship defense and naval fire support  |
| Mary Washington /Univ. of MD, Baltimore County | Coop students/exploratory low-cost, text-to-speech prototype.  |
| Univ. of Michigan                              | Solid-state steerable antenna for semi-active seeking at 95 GHz  |
| New Mexico Tech                                | Lethality testing of missile war heads and projectiles   |
| Univ. of Texas                                 | Electro-Magnetic gun technology  |
| Southern Methodist Univ.                       | Computer fault detection   |

## Conclusions

Based on the examples of collaborative research which have been collected to date, there appear to be features which a number of these projects have in common. From the point of view of the Navy's R&D Center, these projects have:

- Enhanced and expanded the Center's technical capabilities and skills
- Introduced new technical tools
- Provided advanced degree opportunities for employees
- Resulted in co-authored papers and books
- Provided opportunities to recruit new employees
- Provided a cost-effective research and development mechanism

From the point of view of the universities, these projects have:

- Provided a source of research funding for the faculty member
- Provided financial support for undergraduate and graduate students
- Enhanced the educational experiences of the students involved
- Provided the students with contact with "real-world" problems
- Provided access to a source of additional graduate students
- Increased the level of the university's sponsored research activities

An analysis of these common features is a first step toward assisting the Navy in structuring its S&T Revitalization Program in a way such that both the R&D Centers and the universities will be advantaged in the process. Additional examples of mutually-beneficial research projects would clearly be helpful. We sincerely hope that the readers of this paper will respond to our request for assistance in this regard.

In addition to enhanced research connections, strategies which are expected to be addressed by the S&T Revitalization Program include, as previously mentioned, increasing the number of US students obtaining science and engineering degrees, providing enhanced co-op opportunities, and promoting university/Center technical personnel exchanges. We hope if you have any thoughts along these lines, or on any other topic related to these issues which reading the paper has evoked, that you will use the email addresses in the authors' bibliographies which follow to contact us. Let the dialog begin!

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## **Biographies**

Eugene F. Brown

Eugene F. Brown is a Professor of Mechanical Engineering at Virginia Tech and a former Chair of ASEE's Graduate Studies Division. He teaches undergraduate and graduate courses in thermodynamics and fluid mechanics and is the author of many papers and reports describing his research in the areas of computational fluid dynamics and aircraft propulsion. He can be reached at [efbrown@Virginia Tech.edu](mailto:efbrown@Virginia Tech.edu).

Robert Kavetsky

Robert Kavetsky is currently on a two-year assignment to ONR, where he is directing an initiative focused on revitalizing the S&T base in the Navy's Warfare Centers. He is a mechanical engineering graduate of Catholic University, and has worked in the fields of hypersonic aerodynamics, explosives, undersea warheads, and mine countermeasures. He can be reached at [Robert\\_Kavetsky@onr.navy.mil](mailto:Robert_Kavetsky@onr.navy.mil).

Al Wicks

Alfred L. Wicks is an Associate Professor of Mechanical Engineering at Virginia Tech. He teaches undergraduate and graduate courses in structural dynamics, electronics, signal processing and instrumentation. He has authored of many papers and reports describing his research in the areas modal analysis and instrumentation. He can be reached at [awicks@vt.edu](mailto:awicks@vt.edu).

Barry J. Mohle

Barry Mohle is the Branch Head for the Weapons Dynamics Branch at NSWCDD. He has been associated with explosive testing since 1986. In addition to his explosive testing experience he has extensive experience relative to environmental regulations. The group specializes in safety and hazardous assessment and recently applied its expertise to the area of explosive remediation. He can be reached at [mohlebj@nswc.navy.mil](mailto:mohlebj@nswc.navy.mil).

Charles R. Garnett

Charles R. Garnett is the head of the Missile Warheads Branch of NSWCDD. He is a mechanical engineering graduate of Virginia Tech and has conducted research and development in the field of warhead design and characterizations. He can be reached at [garnettcr@nswc.navy.mil](mailto:garnettcr@nswc.navy.mil).

Larry Triola

Larry C. Triola is Director of Science and Technology at NSWCDD. Previously he has served in the OPNAV office for RDT&E and as Deputy Chief Scientist for DRPM AEGIS/PEO Surface Combatants. He holds degrees in Psychology and Electrical Engineering from the University of Houston and has taken graduate courses at Baylor College of Medicine and Rice University. He can be reached at [triolalc@nswc.navy.mil](mailto:triolalc@nswc.navy.mil).