



**OCCUPATIONAL SAFETY AND HEALTH  
TRAINING GRANT**

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**FINAL PROGRESS REPORT**

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## **ABSTRACT**

This report describes relevant activities during the period of 7/1/98 through 6/30/01 for the Master of Science (M.S.) program in Industrial and Systems Engineering (ISE). We offer a specialized 'track' in Safety Engineering that is part of the Human Factors Engineering and Ergonomics program (HFEE), along with a certificate of completion. Program funds provided by NIOSH were used to support 2-3 students in this academic option, in accordance with the proposals submitted on a yearly basis. Several changes to the leadership of this program, as well as to the M.S. curriculum have occurred. Some of these changes were made in response to feedback received by reviewers of the grant proposal, while others occurred during a substantial revision of our overall HFEE M.S. program and normal faculty turnover. All of these changes are summarized in the following report. HFEE faculty teach the majority of the required safety courses, and direct the required research conducted by all M.S. students. Safety Engineering has been, and continues to be, an integral part of the HFEE graduate option within ISE.



## SIGNIFICANT FINDINGS

Significant developments and accomplishments of the program during the funded period are provided here in terms of administration, faculty participation, curriculum, facilities, and trainees. Additional details are provided in the subsequent section. Virginia Tech has received funding from NIOSH training grants since 1992, and this funding has served a vital role in maintaining the Safety Engineering program, which is the only one of its kind in the state of Virginia. The core goal of the program continues to be the generation of well-trained students with a Master degree, specializing in Safety Engineering with more general exposure to Human Factors and Ergonomics. Primary highlights of the program have always been: 1) the diversity of faculty expertise participating in student training; 2) the requirement of at least 27 semester hours of safety-relevant coursework; and 3) a required safety-relevant M.S. thesis, involving human subjects, and which contributes towards hazard recognition, avoidance, or control.

Several administrative and leadership changes have occurred. Initially led by Drs. Tom Dingus and John Casali, the program is now led by Dr. Maury A. Nussbaum. Dr. Nussbaum joined the Virginia Tech faculty in 1996, initially served as a research advisor, and now has primary fiscal and administrative responsibility both for the NIOSH grant and the Safety Engineering graduate option. Dr. Tonya Smith-Jackson joined the faculty in 1999, and currently acts as Co-director on both the grant and graduate option. Dr. Casali continues to provide administrative oversight. Drs. Kari Babski-Reeves and Thurmon Lockhart joined Virginia Tech in 2000, and are serving as research advisors. Current faculty and staff participation is now both high and diverse, covering a wide range of topics within safety engineering, human factors, and ergonomics. Additional administrative changes include the formalization of an internal advisory committee, and the development of an external advisory committee consisting of local industrial and professional representatives in the areas of safety and industrial hygiene. Procedures have also been regularized to evaluate and improve the effectiveness of training, and new procedures have been generated to evaluate the regional impact of the program.

The curriculum has always emphasized Safety Engineering, and in particular, ergonomics and human factors aspects related directly to safety issues. This emphasis has allowed us to draw upon the diverse faculty expertise in addition to traditional safety courses. A three credit-hour course on Industrial Hygiene has been added, and is taught by Ms. Deborah Young, an Industrial Hygienist In Training (IHIT) and Co-Director of Environment Health and Safety Services at Virginia Tech.

Training facilities include six laboratories that are used on a regular basis for safety-related research and instruction. Dr. Smith-Jackson has created a new Assessment and Cognitive Ergonomics Laboratory, which addresses risk perception and cultural aspects of ergonomics and safety among other topics. This and the other laboratories continue to be active in a range of research projects, sponsored both by governmental and industrial sponsors.

During the project period, seven students completed the Safety Engineering graduate option, and seven different students were supported using program funds. Eight publications were generated by students supported under the grant, with an additional two under current review.

# REPORT

## Overview

The Safety Engineering Option within the Department of Industrial and Systems Engineering has been active in one form or another for almost 20 years. The program, which has always emphasized safety engineering, and more specifically the human factors and ergonomics aspects of safety engineering, has been very successful over its life. Well over 100 M.S. engineers have graduated with a "Safety Certificate" from our program, and the vast majority of these are currently working in areas directly or indirectly related to safety engineering. This is the best measure of the relevance and need for our program.

Primary highlights of the program have always been: 1) the diverse range of faculty who actively participate in the training of the students; 2) the requirement of no fewer than 27 semester hours of specific, safety-relevant course material; and, 3) the requirement for all students to conduct a safety-relevant thesis involving human subjects which adds to the general knowledge base of hazard recognition, avoidance, or control.

Funding provided by the NIOSH training grant, which began in 1992, has served a vital role in our Safety Engineering program. In addition to the obvious advantage of providing funding to students interested in Safety, who would not otherwise have had an opportunity to participate in our program, the NIOSH program has allowed us to:

- 1) attract the best students from our own undergraduates as well as from other universities,
- 2) create the critical mass of personnel necessary to establish an award-winning student chapter of ASSE,
- 3) expand our curriculum to include such topics as industrial hygiene and injury epidemiology,
- 4) create "hands-on" safety projects associated with two courses, often performed in conjunction with local safety professionals, to improve the relevance of our safety training, and
- 5) conduct meaningful safety research in the form of numerous student Master theses and resulting refereed publications, research which may not otherwise have been conducted due to a relative lack of external funding opportunities.

As described in the following sections, there are several prior and ongoing refinements to the program that we trust will continue its successful history. These refinements have been based on feedback from the NIOSH reviewers, industry and peer review, and additional opportunities presented by the hiring of new personnel. Three primary critiques were made in an earlier review of our program. *First*, there was a need to expand and strengthen course material related to Industrial Hygiene. In response, we have formalized a regular course entitled "Principles of Industrial Hygiene". This course now contains a comprehensive review of IH, and case-studies and projects that provide students with extensive hands-on experiences. *Second*, there was a need to create opportunities for interdisciplinary interactions with other professions in the safety and health fields. At the M.S. level, students are required to have 2 of 3 committee members that are core teaching faculty in the Human Factors and Ergonomics Option. The third member can

be any faculty or professional, and the majority of students in the Safety Engineering curriculum choose a member with expertise in safety and health. Ms. Deborah Young and Dr. Scott Geller (Psychology and Safety), for example, have served on committees in the past, as have external professionals from industry. To create further opportunities, students are encouraged to seek out members from other disciplines (a process that is now facilitated by the External Advisory Committee described below). The *third* critique was to develop an operating Advisory Committee. While an Internal Committee had existed, consisting of the core participants in the Safety Engineering Program, we have recently formed an External Advisory Committee of six local safety, health, and IH professionals. The structure and function of this new Committee is described further below, and is helping us assess the performance of our program and aiding in its continuous improvement.

### **Program Leadership and Faculty**

Dr. Maury A. Nussbaum of the Industrial and Systems Engineering Department directs the Training Program Grant, serves as the NIOSH liaison, and manages budgetary issues. Additional budget assistance is provided by Ms. Marty Simpson, the Department Business Manager. Along with each student's primary advisor, Dr. Nussbaum serves as a point-of-contact for all students funded under this grant, and is responsible for tracking and follow-up of all program trainees. Dr. Nussbaum assumed the directors role in 1999, after being an active participant and serving as co-director for several prior years. Dr. Nussbaum also acts as coordinator of students pursuing the Safety Engineering 'track' within the Human Factors and Ergonomics Graduate Option. Dr. Smith-Jackson co-directs both the grant and graduate option, and has a central role in coordinating with the new External Advisory Committee and implementing procedures developed to evaluate training effectiveness. The co-director from earlier awarded grants (1993-1999), Dr. John G. Casali, continues to participate and play an active role, including oversight of the program, teaching core courses, and directing student research. Dr. Tom Dingus, the other former co-director, has moved to the Civil Engineering Department at Virginia Tech.

An internal advisory committee has been in place for several years to help guide the operation of the program. This committee consists of the six core program participants. In addition to the faculty previously noted, the remaining board members include: Dr. Tonya L. Smith-Jackson, a specialist in safety and cognitive ergonomics; and, Ms. Deborah E. Young, an Industrial Hygienist In Training (IHIT), who provides a real-world tie for our program. The internal advisory committee discusses the status of the program at least once per year, though typically each semester, to review the program performance and address any substantial operational issues. Smaller-scale issues are discussed by email, moderated by the program director. Continuing feedback regarding the operations of the program and opportunities for improvement are obtained through a new *external* advisory committee and a formal feedback mechanism involving students from the Safety Engineering option (further details below).

Additional support is provided by: Dr. Kari Babski-Reeves, a new faculty member with expertise in upper extremity disorders and risk assessment; Dr. Thurmon Lockhart, another new faculty member whose research is in the area of slips and falls and biomechanical modeling; and, Dr.

Robert Williges, whose research and teaching include human-computer interaction, design for the disabled, and experimental design.

*Faculty Commitment/Breadth.*

The faculty listed below (Table 1) are each committed to the success of this Safety Engineering program. With the exception of Ms. Young, who is currently the Co-Director of Environmental, Health and Safety Services for Virginia Tech, each is a full-time, on-campus faculty member in the Department of Industrial and Systems Engineering at Virginia Tech. This faculty represents a truly unique combination of talents in the area of occupational safety.

*Faculty Reputation.*

The program faculty enjoy both a national and an international reputation. Professors Williges and Casali are both award-winning Fellows of the Human Factors and Ergonomics Society. The program has continued to grow in reputation over the past year, with growing corporate participation and rapid student placement. Our Human Factors and Ergonomics program was recently re-endowed by the United Parcel Service, Inc. This endowment provides student fellowships, equipment, and support funding for the next three years. A scholarship (\$1000) is given each year to an outstanding graduate student in the Safety Engineering area, by the local chapter of the American Society of Safety Engineers. Both the endowment and scholarship exemplify the quality of the program as viewed by outside industry and professionals.

TABLE 1. Faculty expertise.

<b>Core Faculty</b>	<b>Areas of Expertise</b>
Dr. Maury A. Nussbaum	Occupational Biomechanics; Lifting/Back Injury Protection; Work Physiology
Dr. Tonya L. Smith-Jackson	Risk Perception; Cognitive Ergonomics; Cultural Ergonomics and Safety
Dr. John G. Casali	Hearing Protection and Evaluation; Industrial Hygiene/Acoustics; Transportation Safety
<b>Supporting Faculty</b>	<b>Areas of Expertise</b>
Dr. Kari Babski-Reeves	Upper Extremity WMSDs; Occupational Safety and Injury Prevention
Dr. Thurmon Lockhart	Biomechanics of Slip and Fall Accidents; Motor Control; Aging
Ms. Deborah E. Young	Industrial Health and Hygiene

**Program Description**

Our program has always emphasized Safety Engineering and more specifically ergonomics/human factors aspects directly related to safety issues. This emphasis allows us to draw upon a diverse range of safety-relevant courses, including human physical capabilities and human audition, in addition to more traditional safety courses. Additional highlights of our program take advantage of the strengths afforded, and include:

- 1) A three credit-hour course on Industrial Hygiene. An earlier criticism of our program had been a lack of substantial health and hygiene material. Ms. Deborah Young, an Industrial Hygienist In Training (IHIT), teaches this course in our program. Our industrial hygiene component now includes two and one-half courses of directly relevant material.
- 2) Hands-on laboratory experiences, including several major projects. We have included this hands-on experience as part of two courses to make the projects more coherent with course material to facilitate exposure to real-world problems and tools.
- 3) Applied experience in industry through interaction with industrial partners to address safety problems. In one of our courses, students are assigned semester-long projects selected by industry partners. These projects are presented as problem cases that are addressed by students who apply knowledge and methods gained from the course and other relevant sources.
- 4) Diversification of the program curriculum to include additional faculty involvement. Involvement by more faculty allows a broader range of topics for student exposure.

The program is open to M.S. students in Industrial and Systems Engineering, with course requirements of 34 units above the baccalaureate. Trainees must also complete a safety-related thesis involving human subjects as experimental participants. At least three graduate committee members are required, two of which must be core teaching faculty in Industrial and Systems Engineering (Human Factors and Ergonomics Option). Graduation is typically in 2 – 2.5 years following enrollment. All those completing the requirements, whether or not under NIOSH program support, receive a certificate of completion. Students in the program are trained in several fields through a range of safety-relevant courses, course projects, and directed research. These fields are listed below (Unique Program Contribution), and additional details can be found in the description of the current curriculum provided below.

#### ***National/Regional Needs***

This program is the only safety engineering program in the State of Virginia. Graduates have been placed in both Virginia and throughout the nation. At the present time, one of our primary problems is that employers hire our students almost as soon as they complete their coursework, while their theses are still in progress. This is testimony to the need for graduates provided by our program.

#### ***Unique Program Contribution***

Graduates of this program are equipped to recognize, evaluate, and control industrial hazards. They receive special knowledge in diverse areas, such as: system safety analysis, industrial fire control, ergonomics, toxicology, acoustics and hearing protection, industrial hygiene, injury epidemiology, accident analysis, occupational biomechanics, low-back and repetitive stress injuries, radiation protection, machine guarding, electrical hazards, experimental design, behavior-based safety methods, and statistical analysis. It is this combination and breadth of interdisciplinary material that makes our graduates unique and in demand. The combined Virginia Tech faculty are among the strongest in the world in ergonomics and human factors because of the breadth and interdisciplinary backgrounds they bring to the program.

### ***Interdisciplinary Interaction***

This program interacts with several disciplines. We cooperate in particular with civil engineering, computer science, statistics, and psychology. This cooperation takes place through exchange of students, encouraging students to take classes in other areas, cross-discipline research, and committee work. For example, safety engineering students and faculty have shared recently with civil engineering in transportation safety, crane safety, and construction safety. Dr. Williges has joint appointments with Computer Science as well as Psychology. Dr. Smith-Jackson also has a joint appointment in Psychology. Many students take Dr. Scott Geller's course on safety management principles in the Department of Psychology, and students have also attended local seminars taught by health professionals. Allowing M.S. students to freely select one of their required three committee members has also promoted some level of interdisciplinary interaction. For example, Ms. Deborah Young and Dr. Scott Geller have been members on recent committees.

Virginia Tech has very active student chapters of the American Society of Safety Engineers (ASSE) and Human Factors and Ergonomics Society (HFES). The ASSE chapter was the National Student Section of the Year in 1999, and the HFES chapter is the largest in the nation. These chapters regularly conduct site visits to local industries and engineering laboratories, and host formal seminars and 'brown-bag' lunches by safety researchers and professionals. These interdisciplinary exchanges occur on a continuing basis and are a vital part of both faculty and student experience. In addition, it must be emphasized that the faculty in this program are interdisciplinary. They come from degree backgrounds in engineering and psychology. These backgrounds tend to naturally encourage interdisciplinary activity among program participants.

Additional interdisciplinary interaction with safety and health professionals is facilitated by the new External Advisory Committee. Members of this committee represent several industries throughout Southwest Virginia, and are expected to participate on a regular basis with students as well as coordinate plant tours and visiting seminars.

### ***External Advisory Committee***

A program advisory committee (Table 2) has been established to provide joint feedback and oversight of the NIOSH Training Grant Program. Advisory committee members were selected from industries in the surrounding region on the basis of their expertise in occupational safety and health and their involvement with the continued growth and development of occupational safety and health professions and professional societies. The committee credentials include Certified Industrial Hygienists and Certified Safety Professionals. In addition to general occupational safety expertise, the committee also presents credentials in process and facilities safety.

The advisory committee works with the faculty to establish criteria to define measurable outcomes and evaluate program quality. This information is applied to curriculum development during the Spring semester of the academic year. A summary report of performance indicators from summative evaluations conducted by students, faculty, and industry was submitted to the advisory committee. This report was provided 60 days prior to the annual meeting of the advisory committee. The advisory committee then provided feedback and suggestions to the faculty for program revision at the Annual meeting. Revisions implemented within the

curriculum were included in the next annual summary report. At this meeting, advisory committee members were also surveyed to elicit their impressions of the quality of the program to date, particularly in areas related to preparation for careers in industry. This information was also used as input towards program revisions.

TABLE 2. External advisory committee members.

<b>Member</b>	<b>Affiliation</b>	<b>Specialty Area or Title</b>	<b>Location</b>
Brennan Bowen	Wolverine Gasket	Process Engineer	Blacksburg, VA
Tom Johnson, CIH	Celanese Acetate	Industrial Hygiene	Narrows, VA
Roseanne Kryczkowski, CIH	ITT Night Vision	Manager, Environmental Health & Safety	Roanoke, VA
Jim Davis	Celanese Acetate	Process Safety Engineer	Blacksburg, VA
John Patterson	Wolverine Gasket	Environmental Health & Safety Coordin.	Blacksburg, VA
Natalie Young	Dupont	Safety Specialist; ASSE Chapter President	Ashland, VA

***Methods to Evaluate Effectiveness of Training***

The effectiveness of the training provided to students in the NIOSH Training Grant Program now includes two forms of evaluation – formative and summative. We apply an iterative approach to our program evaluation such that final summative evaluations and graduate performance feedback are applied to further outcomes development and assessment as well as program revision.

First, both the faculty and the advisory committees helped establish criteria reflecting successful preparation for occupational safety and health careers. These criteria were applied to courses offered in the Safety curriculum and are used as outcome measures subject to evaluation (i.e., examination, project requirements, etc.). For example, a previous evaluation by the advisory committee revealed that students needed more hands-on experience, particularly experience that would embed them in the practice of safety engineering within the occupational setting. In response to this feedback, one of our core courses was updated to include projects from industrial partners. Each year, based upon the formative and summative evaluations, faculty and advisory committee members update the Program Criteria and revise the program as needed.

Formative evaluation occurs during the course of the students’ knowledge and skills training. These evaluations include grade point averages on courses related to the safety option, and advisor feedback on the quality of students’ performance in their research areas. In addition, feedback on the efficiency of program implementation is elicited. Summative evaluations are conducted at the end of the Spring semester of each academic year, and these data are examined before the fall semester. Students and their advisors have informal meetings at the beginning of the subsequent fall semester to identify areas requiring improvement. For students involved in internships or practica, feedback is elicited from the relevant industry supervisors regarding the students’ performance. Feedback is also gained using structured exit surveys.

Summative evaluations are a direct consequence of graduate performance in industry and the regional impact of the Training Program. Graduate performance in industry is assessed using the approaches below. Note that exit surveys of students and Industry supervisors/managers are already conducted by the ISE Department. Our efforts specifically track data gained from students in the Safety Engineering Option.

1. Point-of-exit survey of graduate students' evaluation of the degree to which the program prepared them for industry.
2. Point-of-exit survey of faculty advisors of graduating students to evaluate the degree to which the student was prepared for industry upon graduation.
3. Two-year post-exit survey of students' evaluation of preparedness.
4. With the permission of the student, two-year post-exit survey of supervisors' opinions of the degree to which the employee was prepared for industry.

Regional impact is used as one of the assessment criteria and reflects a global summative evaluation of the program. Information from the assessment is used to revise criteria as needed and to revise the program components or the distribution of emphasis. To evaluate regional impact, a three-fold strategy is being used. First, the numbers of graduating students who acquire employment in the region is tracked using exit and follow-up surveys. The Graduate Program has tracked these data since 1993.

Second, needs assessments of regional businesses are being developed in conjunction with the Chairman of the Graduate Program in Industrial and Systems Engineering. This office has developed assessments in the past to determine needs for senior design projects, and have successfully matched student skills, interests, and research activities with company needs. A similar survey format and analysis method is being used to develop a needs assessment instrument specifically geared toward occupational safety and health needs in Southwest Virginia. Samples of regional businesses will be surveyed in 5-year cycles to identify current needs and trends. The sampling frame will be established after identifying the population of companies who would be potential candidates for assessment, and the critical features that vary between companies. Critical features (i.e., size, skill base, geographic region, etc.) will be used to establish sampling strata in order to select a representative sample in each survey cycle. The first needs assessment will be conducted in the fall of 2001, and these data will be used to develop the outcome measures to determine regional impact.

Third, a regional impact survey is being developed with the assistance of the Center for Survey Research at Virginia Tech. Through a combination of outcomes developed from the needs assessment and other indicators of regional impact identified through joint efforts with the Center for Survey Research, a final "impact" assessment instrument will be developed and administered every 5 years to a stratified sample of businesses in the region. Again, the sampling frame will be determined using strata defined in the needs assessment. The regional impact data will be used to revise and improve the Training Program. All impact survey data will be included in the annual report submitted to the advisory committee 60 days before the annual review session is held.

The regional impact assessment plan is cost-effective because it relies on existing and proven evaluation strategies currently implemented by the Graduate Program in the ISE Department.

### **Training Candidates**

Trainees in our program are candidates for the Master of Science within the Human Factors and Ergonomics program in the Department of Industrial and Systems Engineering. The trainees hold baccalaureate degrees in engineering or science from an accredited college or university. They are admitted competitively based on grade point average, letters of recommendation, and standardized test scores. Once accepted, there is an open competition between the students enrolled in the *Safety Engineering 'track'* for NIOSH trainee grants. The awardees are selected each year based on current GPA, safety experience, and their stated goals for their participation in the program. Students who are in their second year in the program and are ready to conduct a research project are given priority. Students who do not receive NIOSH funding often receive other support from the Department in the form of Graduate Research Assistantships, Graduate Teaching Assistantships, and Graduate Intern Fellowships.

Prospective trainees are also actively recruited through our interactive Web page on the Internet, from program brochure mailings, and from active participation of both faculty and students at conferences. Approximately 30-40 applications are received each year for the entire program (Human Factors and Ergonomics Option within ISE). Of these, on the order of 15-20 applicants are accepted and enroll. Of students who enter the Human Factors option, roughly 1/5 to 1/4 pursue the Safety Engineering track. Over the last several years, we have received about 6-8 applications for our two NIOSH traineeships. All students selected have accepted and entered the NIOSH program.

### **Training Facilities and Resources**

Our training facilities include a number of laboratories that are used on a regular basis for safety-related research and instruction. These include:

- Assessment and Cognitive Ergonomics,
- Auditory Systems Laboratory,
- Displays and Controls Laboratory,
- Environmental and Safety Laboratory,
- Industrial Ergonomics Laboratory, and
- Virginia Tech Transportation Institute.

Other facilities include those normally found at a major University and include dedicated, multimedia classroom space, computer laboratories, and faculty and student office space. A brief description of each of our laboratories and their associated equipment is provided below. Additional research support is provided by the Industrial and Systems Engineering Department in the form of office space for all graduate students (each office containing a networked computer with software), supplemental funds for subject fees and travel, and a fully equipped machine and electronics shop with four full-time staff members.

### ***Assessment and Cognitive Ergonomics***

The ACE Lab conducts applied research on human information processing and the design of interfaces. Particular attention is paid to individual differences in cognition that may impact users' interaction with information such as risk communications. Cognitive and cultural human factors perspectives are often used research frameworks. The primary research goals of the ACE Lab are to:

- Determine design features of information displays (risk communications or computer-based interfaces) that enhance attention-capture, comprehension, learning, decision-making, and ultimately, behavior,
- Assess user needs, capabilities, and preferences that can be used to develop design principles for the display of information, and
- Develop efficient, yet robust, quantitative and qualitative measures to capture user-centered information design features.

Current projects include explorations of effective design features for safety signs and labels that will influence risk perception by individuals with non-English primary languages, and that will enhance risk perception of product hazards for general consumers and operators within a work context. Research on user interface design principles for novice and marginalized users (i.e., older users, users with disabilities, ethnic and class minority groups) is also being conducted.

### ***Auditory Systems Laboratory***

In the Auditory Systems Laboratory, methods of human factors, behavioral science, and acoustics are applied to solve problems concerning hearing conservation, auditory information display, driver-display interaction, communications systems, warning systems, product design, and general ergonomics. The facility supports industrial and community investigations as well as controlled laboratory experiments.

Example research services include: in-vehicle auditory display evaluation; attenuation testing of hearing protection devices as per ANSI, ISO, and MIL Standards; evaluation of Active Noise Cancellation devices and communications headsets; hearing protector design; experimentation on auditory displays and warning signals; speech intelligibility studies with headset or sound field electronic communications systems; masking and perceived urgency of signals; assessment of industrial noise, product noise, and community noise using dosimetry, real-time spectral analysis, and FFT analysis; audiometry for research purposes; and, auditory perception and hearing loss experiments. The Laboratory is unique among U.S. academic institutions in that its hearing protector research and test facilities are fully accredited by the National Institute of Standards and Technology, National Voluntary Laboratory Accreditation Program (NVLAP) for Acoustical Testing Services in accordance with ANSI S3.19-1974 and ANSI S12.6-1997 Standards. In 1994, the facility was featured on the Cable News Network (CNN).

Reverberant and anechoic chambers exist for the conduct of psychoacoustic experiments. A versatile test signal system, applicable to hearing protector evaluations and other psychophysical signal detection studies, consists of a computer-controlled Norwegian-Electronics Type 828 unit. Physical measurements can be performed to various standards using miniature microphones in human ears, a KEMAR manikin with Zwislocki couplers, or an acoustical test fixture that meets ISO/DIS 6290. A partial listing of instrumentation includes: a Norwegian-Electronics Hearing Protector Test System; Larson-Davis 3100D Real-Time and FFT Spectrum Analyzer; Rion Octave, Third Octave, and FFT Analyzers; Larson-Davis 800B Precision Sound Level Meter; Quest Noise-Logging Dosimeters and Community Noise Analyzer; Sony Digital Audio Tape recorder; Beltone 2000 high-frequency, masking, speech, and bone conduction audiometer; and a Beltone 114 clinical audiometer. A variety of audio signal reproduction and computer equipment is also available. A digital computer-controlled commercial vehicle driving simulator is used for presenting realistic driving scenarios in experiments involving vehicular display evaluations, with particular emphasis on auditory and tactile displays. The laboratory also supports ANSI Standards development efforts in hearing protection and hearing protector evaluation.

### ***Displays and Controls Laboratory***

The Displays and Controls Laboratory (DCL) in the Human Factors Engineering Center is dedicated to research and development work involving visual displays and manual controls systems. The DCL facilities include several rooms that are used for experiments on complex human-system interaction, visual psychophysics and image quality, and manual/voice control, as well as for radiometric measurements, engineering compliance evaluations, software

development, and device fabrication and repair. The DCL also maintains a technical library, which contains over 5,000 scientific, industrial, and government documents on significant developments in displays and controls ergonomics.

The DCL operates a state-of-the-art optical measurement facility for image quality work on visual display devices and components. The facility houses a large-area, three-dimensional translator stage for precision measurements across entire screen areas; steel and granite optical benches to isolate measurement equipment from vibrations; numerous custom radiometers and photometers to assess spatial, temporal, and color properties of light from displays; and high-bandwidth video controller systems to drive virtually any type of CRT, flat panel, and projection display.

The DCL also has a Stanford Research International eye tracker. This device can measure vertical and horizontal eye position (to 15 arc seconds) and accommodation (to 0.1 diopter) at the rate of 200 Hz. The DCL has built an extensive software library for automatic cataloging of saccades and fixations movements, as well as correlated accommodation measures. The DCL also possesses and evaluates numerous manual and voice input device systems. The DCL's work with these devices addresses the advantages and disadvantages of various device styles, their control movement dynamics, and utility in complex-interaction systems.

#### *Environmental and Safety Laboratory*

The Environmental and Safety Laboratory in the Human Factors Engineering Center consists of experimental rooms, a control and observation room, and an environmental chamber. A one-way mirrored window separates one experimental room from the control and observation room. The environmental chamber measures 10 feet wide by 20 feet long and has an interior ceiling height of over 7 feet. The chamber's interior temperature can be controlled within a range from 0° to 44° Centigrade and is capable of a 3° per minute rate of change. Relative humidity can also be controlled within the range of 40 to 95%, plus or minus 0.5%. Lighting in the environmental chamber and throughout the laboratory is continuously variable. Temperature, relative humidity, and lighting are controlled by a microprocessor capable of providing up to 24 step changes in conditions. The time interval for each step can be individually varied. The Laboratory also provides 110, 220, and 440 volt power, closed circuit television equipment, physiological monitoring equipment such as Grass Polygraph instruments, and environmental measuring equipment.

#### *Industrial Ergonomics Laboratory*

The Industrial Ergonomics Laboratory consists of one large (10 x 14 x 3 m) room that can be sub-divided as needed for research, development, and evaluation in the areas of: Engineering anthropometry, classical and functional, and related to workstation and equipment design; Biomechanics of the human body; modeling, strength, motions, and working postures; Human engineering of systems, equipment, tools, workstations, and work tasks; and, Ergonomic design for safety, efficiency, and high performance of manned systems.

Recent projects undertaken in the Industrial Ergonomics Laboratory include: investigation of the biomechanical basis of psychophysically (subjective) determined lifting limits; measurement and prediction of hand and finger force capability; determination of the effects of training on worker behaviors during common nursing tasks involving patient handling; development of guidelines for control of shoulder muscle fatigue through quantification of time-to-fatigue during overhead assembly work; and, empirical evaluation of biomechanical models for prediction of low-back muscle activity. The Industrial Ergonomics Laboratory is particularly well equipped to do research in these areas with:

- Anthropometric devices, such as anthropometers, calipers, tape measures, skinfold measures, and photometric equipment.
- Automatic motion analysis system (6-camera ProReflex™), photographic equipment for still pictures and motion photography, regular and digital cameras, video taping equipment, and specialized exoskeletons to record hand, wrist, and back postures and motion.
- Several devices for measuring forces and torques: 2 Bertec™ force plates; 2 AMTI™ force plates; 2 AMTI™ load cells (3-axis); torsion gauges; isometric, isokinetic, isoinertial test devices. Strength testing is performed using a Biodex™ System 3 Pro.

- Equipment to record physical reactions of the human body to external stresses, including: heart rate monitors (beat-by-beat and time-averaged recording); oxygen uptake measurement for both instantaneous and integrated recording; 8 channel telemetered electromyographic (EMG) system (Noraxon) and an additional 32 channels of traditional EMG equipment to measure muscle activity.
- A large assortment of other equipment, such as video cameras, mixers, and displays, personal computers, signal acquisition and processing hardware and software, and human modeling software (e.g. JACK™, 3DSSPP™).

***Virginia Tech Transportation Institute***

The Virginia Tech Transportation Institute is a multi-disciplinary university-level research center with a substantial core program and staff conducting human factors and driving safety research. Professor Tom Dingus, Human Factors Program faculty member, serves as the Institute's Director. Professor John Casali, Human Factors Program faculty member, has had an active research program with the Institute since 1993. Professor Walter Wierwille, Human Factors Program research faculty, is a Senior Transportation Research Fellow with the Institute.

Human Factors research equipment includes a fleet of nine light and heavy vehicles an instrumented section of highway managed by the Institute in cooperation with the Virginia Department of Transportation. These vehicles and facility are unobtrusively instrumented to collect a range of performance measures, including eye glance data, lateral lane position, steering measures, and average vehicle velocity.

## Curriculum

In response to prior feedback provided by program reviewers, and our own internal review, the MS curriculum in Human Factors Engineering and Ergonomics (HFEE) has been substantially modified. Master level students are required to complete five required courses (Table 3), a minimum of four elective courses, and six hours of thesis work. A listing of pre-approved tracks with their associated courses (Table 4) are provided in tables below. Deviations from the suggested tracks are possible with the approval of the HFEE faculty.

TABLE 3. Required (core) courses in the HFEE graduate option.

Course Number	Course Title	Credit Hours
ISE 5604	Human Information Processing	3
ISE 5605	Human Factors System Design I	3
ISE 5614	Human Physical Capabilities	3
ISE 5615	Human Factors Research Design I	4
ISE 5984	Integrated Systems Design	3
ISE 5994	Research Thesis	6
Electives	(See Pre-Approved Tracks Table)	12
	<b>Total Hours</b>	<b>34</b>

### Pre-Approved Tracks (Electives)

A minimum of four courses can be chosen from any one of these pre-approved tracks and used as electives. At least two of the electives must be ISE courses and at least one of these ISE courses must be an HFEE course. No more than two elective courses outside of ISE may be used toward meeting degree requirements.

TABLE 4. Pre-approved tracks, consisting of differing sets of elective courses.

<b>Cognitive Ergonomics</b>	<b>Human-Computer Interaction</b>
*ISE 5634 Training Systems *ISE 5694 Macroergonomics *ISE/CS 5714 Usability Engineering *ISE 5794 Independent Study/Special Topics STAT 4504 Applied Multivariate Statistics  PSYC 5344 Cognitive Psychology	*ISE 5634 Training Systems *ISE 5714 Usability Engineering *ISE 6604 Visual Displays *ISE 6614 Human Computer Systems CS 4624 Multimedia, Hypertext, and Information Access CS 5734 Computer-Supported Cooperative Work CS 5724 Models and Theories of Human Computer Interaction
<b>Macroergonomics</b>	<b>Methods</b>
*ISE 5694 Macroergonomics *ISE 5606 Human Factors Systems Design II *ISE 5634 Training systems  CS 5734 Computer-Supported Cooperative Work PSYC 5125 Organizational Psychology STAT 4505 Applied Multivariate Statistics ENGR 5104 Applied Systems Engineering	*ISE 5616 Human Factors Research Design II ISE 5424 Simulation EDRE 6614 Qualitative Methods in Educational Research PSYC 5134 Advanced Psychometric Theory SOC 6204 Survey Research Methods STAT 4504 Applied Multivariate Statistics STAT 5644 Nonparametrics
<b>Occupational Biomechanics</b>	<b>Sensory and Perception</b>
*ISE 4624 Work Physiology ISE 5405 Optimization ISE 5424 Simulation ECPE 5724 Neural and Fuzzy Systems STAT 4504 Applied Multivariate Statistics ESM 4204 Musculoskeletal Biomechanics and Biologic Control HNFE 4844 Exercise & Performance	*ISE 5644 Human Audition *ISE 6604 Human Factors in Visual Display *ISE 5606 Human Factors Systems Design II PSYC 5144 Sensory Processes PSYC 4074 Sensation and Perception CS 5754 Virtual Environments
<b>SAFETY ENGINEERING</b>	<b>Telecommunications</b>
*ISE 4984 Principals of Industrial Hygiene *ISE 5644 Human Audition and Auditory Display Design *ISE 5674 System Safety *ISE 5684 Industrial Health and Safety	*ISE 5714 Usability Engineering *ISE 5606 Human Factors Research Design II  EDCI 5604 Distance Learning CS 5516 Computer and Network Architecture CS 5734 Computer-Supported Cooperative Work ACIS 5514 Management of Information Systems ACIS 5594 Web-based Applications and Electronic Communications
<b>Transportation</b>	<b>Work-Related Musculoskeletal Disorders</b>
*ISE 5606 Human Factors Systems Design II *ISE 6604 Human Factors in Visual Displays *ISE 5644 Human Audition and Auditory Display Design *ISE 5674 System Safety *ISE 5714 Usability Engineering *ISE 6614 Human Computer Systems  ISE/CEE 5944 Human Factors in Transportation	*ISE 4624 Work Physiology *ISE 5974/6624 Independent Study/Special Topic *ISE 4644 Occupational Safety  STAT 4504 Applied Multivariate Statistics STAT 5644 Nonparametrics ESM 4204 Musculoskeletal Biomechanics and Biologic Control HNFE 5724 Epidemiology

\* Denotes an HFEE course

## Trainees

During the project period, 10 students were enrolled in and seven students completed the Safety Engineering graduate option, while seven different students were supported using program funds. More detailed information on each of these students is provided in the table below. Nine publications were generated by students supported under the grant, with an additional two under current review (see subsequent section for a list of these publications).

TABLE 5. Students enrolled in or completing the Safety Engineering Graduate Option during the program period. Numbers in parenthesis indicate semesters of funding under program grant.

Name	Thesis Title	Entered Program	Degree Awarded	Degree Received	Current Status / Employer
Mitchell Woods (2)	TBD	8/00	TBD	N/A	Current M.S. Student
Hope Johnson (3)	Strength and subjective limits for repetitive manual insertion tasks	8/99	8/01	M.S.	Consumer Product Safety Commission, Bethesda, MD
Jimmy Vu (1)	TBD	8/99	TBD	N/A	Current M.S. Student
Suzanne Stevens (4)	Effects of intervention on booster seat purchase: a field study	8/98	5/00	M. S.	Ph.D. Student, ISE, Virginia Tech
Angela DiDomenico Astin (4)	Finger force capability: measurement and prediction using anthropometric and myoelectric measures	8/97	12/99	M. S.	Ph.D. Student, ISE, Virginia Tech
Stephanie Dawes Binder	Benefits and costs of ultraviolet headlights for safety improvement	8/97	TBD	N/A	Human Factors Engineer, NCR, Rockville, MD
Myra Blanco	Effects of in-vehicle information systems (IVIS) tasks on the information processing demands of a commercial vehicle operations (CVO) driver	8/97	12/99	M. S.	Ph.D. Student, ISE, Virginia Tech
Lisa Cooper Shreiner	An investigation of the effectiveness of a strobe light as an imminent rear warning signal	8/97	11/00	M.S.	Human Factors Research Engineer, General Motors, Warren, MI
Margaret Kirst Lanza	Effects of tool weight on fatigue and performance during short cycle overhead work operations	8/97	12/99	M. S.	Performance Development Engineer, Bosch, Charleston, SC
John Shutko	Commercial vehicle driver response to in-vehicle warnings at imminent crash circumstances	8/95	7/99	M. S.	Human Factors Engineer, Xerox

## **Conclusions**

Our program occupies a niche that is somewhat unique, but clearly valuable to the safety training community. It is oriented strongly towards engineering aspects of safety, while also being influenced by its place within the larger ergonomics and human factors engineering graduate option. Students are exposed to a wide variety of health and safety issues, including such topics as system safety, industrial hygiene, traditional physical ergonomics, engineering design, and human factors research methods.

The program has been successful in terms of graduating a consistent number of well-qualified safety students (2-4 per year). Two to three of these students are supported each year using funds from our training grant. As can be seen above, however, the effects of this grant go well beyond the direct influence on student tuitions and stipends. The grant is a key aspect in the maintenance and continual improvement of the safety engineering curriculum, and facilitates numerous other activities both intra- and extra-curricular. Examples include our active ASSE chapter, close involvement with local ASSE professional chapters, the Safety Certificate, and continued high enrollments in our safety-related courses both by graduate and undergraduate students.

The program has undergone some substantial revisions during the prior project period. Among these, the major ones have been a change in leadership and administration, a change in the required curriculum, and several losses and new hires among the core and supporting faculty. A continual evolution will likely occur, as we strive to both improve and grow Safety Engineering at Virginia Tech.

## PUBLICATIONS RESULTING FROM GRANT

The following list contains only publications that were generated by students specifically supported using Training Grant funds. Trainees are indicated by underlining.

### Conference Papers:

1. Astin, A.D. and Nussbaum, M.A. (1999) Finger forces and predictability using various hand couplings. *Proceedings of the Human Factors and Ergonomics Society*, Houston, TX , Paper #154, pp. 698-702.
2. Astin, A.D. and Nussbaum, M.A. (2000) The use of standardized forearm EMG measures to predict single and multi-digit forces. *Proceedings of the XIVth Triennial Congress of the International Ergonomics Association and 44<sup>th</sup> Annual Meeting of the Human Factors and Ergonomics Society*, San Diego, CA, pp. 4-559 – 4-562.
3. DiDomenico, A. and Nussbaum, M.A. (2000) Prediction of single and multi-digit forces from standardized forearm EMG measures. *Proceedings of the 19<sup>th</sup> Southern Biomedical Engineering Conference*, Blacksburg, VA, p. 31.
4. DiDomenico, A., Nussbaum, M.A. and Kroemer, K.H.E. (1998) Measurement and prediction of finger forces. *Advances in Occupational Ergonomics and Safety 2: Proceedings of the International Occupational Ergonomics and Safety Conference*, Ypsilanti, MI, Kumar, S. (eds), IOS Press, Amsterdam, pp. 386-389.
5. Johnson, H. and Nussbaum, M.A. (2001) Analysis of a self-regulating method for determining acceptable finger force limits. *Proceedings of the Human Factors and Ergonomics Society 45th Annual Meeting* (in-press). Santa Monica, CA: Human Factors and Ergonomics Society.
6. Stevens, S.L. and Dingus, T.A. (2001) Effects of information on risk perception regarding the use of booster seats. *Proceedings of the Human Factors and Ergonomics Society 45th Annual Meeting* (in-press). Santa Monica, CA: Human Factors and Ergonomics Society.
7. Stevens, S.L. (2000) Effects of information on the purchase of booster seats. *Proceedings of the 2000 Road Safety: Research, Policing and Education Conference*. Brisbane, Australia.
8. Stevens, S.L. (2000) Effective interventions to facilitate booster seat purchase and usage. *Proceedings of the 2000 International Child Passenger Safety Technical Conference*. Arlington, Texas.

### Journal Papers:

1. Astin, A.D. and Nussbaum, M.A. (2001) Finger force capability: measurement and prediction using anthropometric measures. Submitted to *Human Factors*.

2. Nussbaum, M.A. and Johnson, H. (2001) Determination and evaluation of acceptable force limits in single digit tasks. Submitted to *Human Factors*.