OCCUPATIONAL SAFETY AND HEALTH TRAINING GRANT

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Final Report

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ABSTRACT

This report describes relevant activities during the period of 7/1/01 through 6/30/06 for the Master of Science (M.S.) program in Industrial and Systems Engineering (ISE). We offer specialized 'tracks' in Safety Engineering, Ergonomics, and Occupational Biomechanics that are part of the Human Factors Engineering and Ergonomics M.S. program (HFEE). Program funds provided by NIOSH were used to support 2 students per year 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 during the project period. 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 courses, and direct the required research conducted by all M.S. students in the program. Safety Engineering, Ergonomics, and Occupational Biomechanics have been, and continue to be, integral parts of the HFEE graduate option within ISE. The number of applicants to our program have been consistent and relatively high during this reporting period, as have the number of students who actually enroll. We have also been successful in recruiting minorities into our training program, and our trainees generally pursue careers related to occupational safety and health. Many of these trainees publish the results of their research, and a number have continued in our doctoral program. NIOSH support for our training program has allowed us to enhance our recruitment efforts, to support additional training, and to assist students in the conduct of essential research that would otherwise be difficult to achieve.

HIGHLIGHTS / 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 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 some area of safety and occupational health (e.g. ergonomics or occupational biomechanics) 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 25 semester hours of relevant coursework; and 3) a required 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 was led by Dr. Maury A. Nussbaum. Dr. Nussbaum joined the Virginia Tech faculty in 1996, initially served as a research advisor, and had primary fiscal and administrative responsibility both for the NIOSH grant during the reporting period. Dr. Tonya Smith-Jackson joined the faculty in 1999, and acted as Co-director on both the grant and graduate option. Dr. Casali continued to provide administrative oversight. Drs. Kari Babski-Reeves and Thurmon Lockhart joined Virginia Tech in 2000, and served as research advisors. Faculty and staff participation was both high and diverse, covering a wide range of topics within safety engineering, human factors, and ergonomics. Additional administrative changes included 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 were also regularized to evaluate and improve the effectiveness of training, and new procedures were generated to evaluate the regional impact of the program.

Training facilities included six laboratories that were used on a regular basis for safety and occupational health-related research and instruction. Dr. Smith-Jackson 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 continued to be active in a range of research projects, sponsored both by governmental and industrial sponsors.

During the project period, 20 students completed the training program, and nine different students were supported using program funds. Sixty-one publications (43 in conferences and 18 in archival journals) were generated by students in the program.

SCIENTIFIC REPORT

Overview

The core rationale for our training program can best be summarized by our department's (ISE: Industrial and Systems Engineering) mission statement, copied below. Our program has been designed to achieve these three goals to the extent possible.

1) To provide a high quality education that will prepare our undergraduate and graduate students for a life-long learning experience in this rapidly changing field, and to prepare these students to be future leaders in the industrial engineering profession, in business, in industry, and in academia.
2) To conduct high quality basic and applied research to advance the frontiers of engineering and to support the industrial and economic growth of the Commonwealth of Virginia and the nation as a whole.
3) To provide service to the profession, industry, and society to contribute to the advancement of civilization and the betterment of all.

Our training program emphasized three aspects of occupational safety and health (OSH). These are safety engineering, occupational ergonomics, and occupational biomechanics, the first being a 'core' discipline, the latter two 'related' disciplines. The program itself is a component within the Human Factors Engineering and Ergonomics (HFEE) graduate option within ISE. A safety engineering emphasis was implemented nearly 30 years ago, under the direction of Dennis Price, and later under Tom Dingus. In the initial years, safety engineering at the MS level was the main emphasis of our program, and was the component that received training support as a NIOSH TPG (which started in 1992). In 2002, the program was expanded to include MS students with training interests in occupational ergonomics and biomechanics, in order to reflect several changes that had occurred in program faculty, student interests, contemporary needs in research and industry, and ongoing research projects. Several additional changes have been implemented based on the constructive input of proposal reviewers, our external and internal advisory boards, and our current and former students. Such changes are summarized below.

Our program interfaced closely with several other current training activities at Virginia Tech. These were primarily through overlapping participation in several centers, including the new NIOSH-funded Center for Innovation in Construction Safety and Health, the Center for Applied Biomechanics, the Center for Gerontology, and with the School of Biomedical Engineering and Sciences. Most students are involved with our student chapter of the Human Factors and Ergonomics Society. As a formal relationship, and as noted above, students in the program were part of the HFEE option within ISE.

Primary purposes and objectives of our TPG are in parallel to those given above as the rationale: to provide a high quality education (at the MS and PhD levels), to conduct high quality research, and to provide service. With respect to funding provided in support of our TPG, this was used primarily to attract and maintain top students, maintain a critical mass of students, support our curriculum, and facilitate meaningful research that was not otherwise funded. Program funds have also allowed us to maintain our program breadth, which in turn also helps attract and support students. Summary information on the trainees past and present are provided below.

Our training activities occurred in three areas. The first is traditional coursework. Specific curricula requirements have been developed to ensure both breadth and depth of exposure, and are described below. The second is a formal research experience. All program participants were required to generate a thesis, and traditionally the majority of these have led to publication either at a conference or in an archival journal. The third is professional development. As described more completely below, this occurred through participation in seminars, tours, and conferences, with a goal of 'rounding out' the students' educational experiences.

One particular example of innovation in training occurred in the safety courses. Dr. Smith-Jackson used safety cases and seminar-type discussions to allow students to use problem-based approaches to apply their knowledge and skills. Students were assigned projects that were either self-selected by exploring common issues related to hazards in Industry or projects that were provided by our Industry partners. The pedagogy used to provide hands-on learning through active projects was based on constructivism, which allows students to create meaning based upon their own past experiences, knowledge, and skills, with support from scientific theory and practical industry knowledge. Student teams explored, at all levels, the causes, antecedents, and implications of different hazardous contexts. For example, in 2003, one student team explored the biohazards presented by Virginia Tech's custodial staff. Teams not only collected data, but created an easy-to-use, literacy-compatible training program that could be delivered online and within 30 minutes (to fit a lunch break). Teams met face-to-face with the targeted users and empowered workers to work together to create a usable and effective online training tool.

Program Leadership and Faculty

Dr. Maury A. Nussbaum of the Industrial and Systems Engineering Department directed the Training Program Grant, served as the NIOSH liaison, and managed budgetary issues. Additional budgetary assistance was provided by the Department Business Manager. Along with each student's primary advisor, Dr. Nussbaum served as a point-of-contact for all students funded under this grant, and was 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. Smith-Jackson co-directed both the grant and graduate option, and had 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, continued 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, moved to the Civil Engineering Department at Virginia Tech in the early portion of the project period.

An internal advisory committee has been in place for several years to help guide the operation of the program. This committee consisted of the six core program participants. In addition to the faculty previously noted, the remaining board members included: Dr. Tonya L. Smith-Jackson, a specialist in safety and cognitive ergonomics; and, Ms. Deborah E. Young, a Certified Industrial Hygienist, who provided a real-world tie for our program. The internal advisory committee discussed 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 were discussed by email, moderated by the program director. Continuing feedback regarding the operations of the program and opportunities for improvement were obtained through a new *external* advisory committee and a formal feedback mechanism involving students from the Safety Engineering option (further details below).

Additional support was provided by: Dr. Kari Babski-Reeves, who joined the faculty in 2001, with expertise in upper extremity disorders and risk assessment; Dr. Thurmon Lockhart, another new faculty member (2001) 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. Dr. Williges retired in 2002, and Dr. Babski-Reeves left the University in the Summer of 2006.

Faculty Commitment/Breadth.
The faculty listed below were each committed to the success of the program. With the exception of Ms. Young, who was the Co-Director of Environmental, Health and Safety Services for Virginia Tech, each was a full-time, on-campus faculty member in the Department of Industrial and Systems Engineering at Virginia Tech. This faculty represented a truly unique combination of talents in the areas of occupational safety, ergonomics, and biomechanics.

Faculty Reputation.
The program faculty enjoyed 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 continued to grow in reputation over the past year, with growing corporate participation and rapid student placement. Our Human Factors and Ergonomics program was re-endowed yearly by the United Parcel Service, Inc. This endowment primarily provided student fellowships. A scholarship ($1000) was 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 exemplified the quality of the program as viewed by outside industry and professionals.

Core Faculty	Areas of Expertise
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

Supporting Faculty	Areas of Expertise
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

Mentoring of trainees occurred through both formal and informal mechanisms. Formal mentoring occurred primarily through advising of student MS research. A research project was required of all MS trainees, and program faculty served as major advisors and committee members for trainees. Informal mentoring occurred through several mechanisms. As organized by our student HFES chapter, there were several 'brown bag' seminars led by faculty and students each semester, with recent examples including 'How to write a proposal', 'How to write a thesis/dissertation', 'How to choose a research topic and advisor', and several presentations by senior and former graduate students on their own research. In addition, the core program faculty provided mentoring as needed, pro-actively based on our tracking of student progress, or at a trainee's request.

Collaboration among our faculty was extensive. Over the past five years, the faculty listed above have jointly authored 3 papers in archival journals (with several currently under review or in preparation), 10 conference papers, and had 18 collaborative funded projects (and several pending or in preparation). Of particular note were two recent centers that have been established. One is the Center for Applied Biomechanics, of which Dr. Nussbaum is the director, and in which Drs. Babski-Reeves and Lockhart are members, along with their respective advisees. The other is the Center for Innovation in Construction Safety and Health, which is supported by a five-year grant from NIOSH. Faculty also served as committee members on each others students, which was enforced by our own requirements of no fewer than two HFEE faculty on MS committees.

The program faculty were quite active in a diverse set of research areas. This research support, in turn, provided increased exposure to trainees on a variety of contemporary topics, and much of this funding allowed for student support in addition to that provided by the TPG. The faculty were also quite active in advising students, most of whom continued on to have successful careers in some aspect of occupational safety and health.

Program Description

Our program was designed to provide training in three aspects of OSH: safety engineering, occupational ergonomics, and occupational biomechanics. This training was offered at the MS level. Trainees in the program formed a subset of graduate students within the Human Factors Engineering and Ergonomics (HFEE) graduate option. We typically received funding to support two trainees. The program as a whole, however, had roughly 30 current MS students (many part time) and 3-5 new MS students each year. Of these, roughly half were considered members of the program, based on their academic and research interests (and formal requirements as indicated below). At the MS level, only students pursuing a thesis option were considered potential members.

MS students were required undertake a formal research project (thesis option), as well as complete 31 credit hours beyond the baccalaureate. Of these, at least 25 credit hours (eight courses) were formal coursework. All of our MS students were required to take a set of four courses and a department seminar. A brief description of each of these 'core' courses is given below. In addition, our MS program was structured into 'tracks', to allow students the flexibility to develop specialization within a sub-discipline. The three tracks comprising our program are listed below, and required a minimum of four courses beyond the core. At least two of the elective courses had to be in ISE, at least one of these ISE courses must have been in HFEE, and no more than two elective courses outside ISE could be used for meeting the requirements. Students, however, could deviate from these requirements with approval of the HFEE faculty (typically because of prior exposure to a topic or specialized interests).

CORE Courses for MS trainees:

Course	Title	Hours	Description
ISE 5024	ISE Seminar	0	Overview of and orientation to the ISE department, graduate student life and issues, rules and policies, library services, honor system, etc.
ISE 5604	Human Information Processing	3	An examination of human information reception, information processing, and skilled performance capabilities and limitations in human-machine systems with an emphasis on models and techniques including psychophysics, signal detection theory, information theory, and decision theory.
ISE 5605	Human Factors System Design	3	Human factors input into manned-system design, development, testing, and evaluation. Emphasis on the systems approach to human-machine interfacing, with discussion and application of specific methodologies and analytical techniques. Display and control design and selection fundamentals with engineering modeling of manual control systems. Each student performs a design project relying on application of systems analysis and design techniques.
ISE 5614	Human Physical Capabilities	3	Focuses on the modeling, analysis, and evaluation of industrial workplaces with emphasis on the physical demands placed on and the capabilities of workers. Topics covered include: physiology, anthropometry, bioinstrumentation, and

			biomechanics. Students learn and apply a range of contemporary analytical and assessment methods.
ISE 5615	Human Factors Research Design	4	Procedures for conducting and analyzing human factors and ergonomics experiments, including fundamentals of research, design alternatives, fitting and testing statistical models, and data interpretation and presentation. Primary focus on linear regression (simple and multiple) and analysis of variance (single and multiple factor).

MS Track Courses:

Safety Engineering	**Occupational Ergonomics**	**Occupational Biomechanics**
ISE 4644 Occupational Safety and Hazard Control	ISE 4624 Work Physiology	ISE 4624 Work Physiology
ISE 4984 Principals of Industrial Hygiene	ISE 5694 Macroergonomics	ISE 5104 Operations Research or ISE 5405 Optimization
ISE 5644 Human Audition and Auditory Display Design	ISE 4644 Occupational Safety	ISE 5424 Simulation
ISE 5674 System Safety or ISE 5684 Industrial Health and Safety	STAT 4504 Applied Multivariate Statistics or 5644 Nonparametrics	ESM 4204 Musculoskeletal Biomechanics and Biologic Control
	HNFE 4984 Exercise & Neuromuscular Performance	ESM 5984 Introduction to Biomedical Engineering
	HNFE 5724 Epidemiology	HNFE 4984 Exercise & Neuromuscular Performance
	EMS 5984 Physiology	HNFE 5814 Skeletal-Muscular Function in Exercise

In addition to these didactic course requirements, each trainee had to meet the following requirements. Each completed a plan of study, in which the set of courses intended to meet the requirements was listed, and which was approved by the student's advisor, committee, option coordinator (Nussbaum), and ISE graduate program director. Both advisors and committee members were selected by the student, with input as needed from any program member. A formal research proposal was required, with a written version distributed to the student's committee followed by a formal oral presentation (proposal defense). Upon acceptance, students commenced their research, with a department-required progress meeting occurring at least once before the final defense. The research was presented in written form (thesis/dissertation) to the committee, again followed by an oral presentation (final defense). Most students were required to show evidence of prior or intended publication of their research at the final defense.

Duration of training for MS trainees was targeted for two years. Many MS students required the second summer or a fifth semester to complete the program. We have had exceptions to these trends, primarily due to: 1) students holding full or part time jobs concurrently; and 2) many MS students delay graduation to take additional coursework.

During their training period, student progress was monitored and evaluated primarily by the advisor, and the student's committee. In addition, the HFEE option coordinator (Nussbaum) communicated at least once per semester with each student, and the option completed a formal review process for each student at the end of each academic year.

All MS students within the program participated directly with research activities. In large part this is due to the research requirements, but this participation is almost always broader for several reasons. First, students became members of laboratories directed by their advisors, and hence were exposed to other work being undertaken there. Second, some defenses were open, providing exposure to work throughout the HFEE option. Third, students often volunteered to either serve as experimental participants or to assist with data collection. Specific student research projects were chosen at the discretion of the student and their advisor. These were typically either new topics developed by the student, or extensions of existing work being done by the faculty advisor. Each student was expected to make a new intellectual contribution (e.g. simply performing work that had been proposed by a faculty advisor in detail would not be considered acceptable).

Students were expected to broaden their educational experience by attending seminars within and outside the university, department, and option. As noted above, there were several offered by faculty and students within HFEE. In addition, our student HFES chapter was quite active (and won the HFES student chapter of the year for 3 consecutive years, before being asked not to apply again for a year), and hosted 2-3 speakers on technical topics each semester. We did not formally enforce any requirements to attend seminars, as we found that students attended these voluntarily (nearly all are standing room only). Nearly all our students attended the annual HFES conferences, either supported by their advisors or using travel supplements provided by our TPG, the university, or the student HFES chapter.

Our program strived to ensure that graduates were equipped to recognize, evaluate, and control industrial hazards. They received 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, and statistical analysis. It is this combination and breadth of interdisciplinary material that we believe keeps our program in demand. The combined Virginia Tech faculty are unusual in ergonomics and human factors programs because of the breadth and interdisciplinary backgrounds they bring.

Virginia Tech had 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 conducted site visits to local industries and engineering laboratories, and hosted formal seminars and 'brown-bag'

lunches by safety researchers and professionals. These interdisciplinary exchanges occurred on a continuing basis and were 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.

Students in the core and allied programs frequently interacted through the mechanisms described above (meetings, gatherings, etc.) and through coursework. While students in the three programs took elective courses specific to their interests, there was overlap among students in these, and along with the core course requirements the curriculum ensured that all program trainees interacted with each other and with students in other disciplines. Interaction among students was further facilitated through performance of project requirements associated with classes. In these cases, projects were often student selected and usually student groups were typically selected to combine student expertise across multiple areas.

National/Regional Needs

Several points emphasize and justify the need for training in the three areas of OSH noted. First, work-related accidents, injuries, and illnesses continue at high levels across many sectors, and much of our training was focused on contributing to a better understanding of the causes and the development and evaluation of methods for alleviating these. Second, we continued to have substantial student interest in these sub-disciplines, not only from within the US, but from around the world. Third, we believe the breadth of experience we emphasized in our program is necessary to adequately prepare students in OSH areas, and to maximize the likelihood of their success after graduation. Fourth, the need for talented graduates in OSH continues, as indicated by the numerous requests from companies and consulting firms that we received for student applications (roughly 2-3/month). Fifth, we have graduated well over 100 students from our program, and a majority are currently working in areas related to their training. Sixth, our program is the only one in the Commonwealth of Virginia that provides depth and breadth of training in these fields. We also served a regional need, in that we are not located within close proximity to any current ERCs (the nearest being UNC-Chapel Hill). In addition, we are located in a rural area and provided expertise and potential employees that can serve in capacities beyond the specific OSH training they received (e.g. most received more general training in industrial and systems engineering).

Interdisciplinary Interaction

Our program strived to foster interdisciplinary interactions. We cooperated in particular with civil engineering, computer science, statistics, and psychology. This cooperation took 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. Nussbaum has affiliated status with Mechanical Engineering. Dr. Smith-Jackson has a joint appointment in Psychology.

Several faculty are affiliates with the VT Center for Gerontology (Lockhart, Nussbaum, and Smith-Jackson) and are members of the School of Biomedical Engineering and Sciences (Babski-Reeves, Lockhart, and Nussbaum). Many students took Dr. Scott Geller's course on safety management principles in the Department of Psychology, and students also attended local seminars taught by health professionals. Allowing students to freely select several 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.

External Advisory Committee

A program advisory committee (Table below) was 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 worked with the faculty to establish criteria to define measurable outcomes and evaluate program quality. This information was applied to curriculum development along with performance indicators from summative evaluations conducted by students, faculty, and industry that was submitted to the advisory committee.

External advisory committee members.

Member	Affiliation	Specialty Area or Title	Location
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

Summary of Program Evaluation Efforts:

First, both the Faculty and the Advisory Committees established criteria reflecting successful preparation for occupational safety and health careers. We held an advisory committee meeting on October 27th, 2000 to set the program criteria that would be used to guide program implementation beginning in 2001. Four of the 5 advisory committee members attended, all of whom were safety and/or industrial hygiene professionals within industry. Faculty also attended this meeting. Several important criteria were identified as attributes of students who are prepared and likely to be successful in health and safety careers. The attributes were as follows:

a. Capable of addressing real-world safety and industrial hygiene problems (applied knowledge).
b. Knowledgeable of the safety and industrial hygiene domain.
c. Cognizant of the need to join and be active in professional societies such as the American Society of Safety Engineers and the American Industrial Hygiene Association.
d. Able to demonstrate applied knowledge.
e. Able to demonstrate experience gained from hands-on learning (learning outside of the classroom).

Due to their highly demanding schedules, Advisory Committee members voiced support for collaborating and providing feedback using electronic means and phone consultations as needed throughout the rest of the training program time line. This remains a sentiment of the advisory committee. Additional feedback items from Advisory Committee members have been accumulated and have been used to improve courses and other aspects of the training program. For example, Advisory Committee members emphasized the need to involve a Certified Industrial Hygienist. Deborah Young, M.S., an adjunct faculty member who teaches the Industrial Hygiene course, achieved certification in IH in 2002. Members also suggested that more generalists were needed in the safety and health profession, and students needed to have project management experience. To address this recommendation, we have ensured that the occupational ergonomics and biomechanics track requirements include flexibility to allow students to gain additional knowledge, skills, and abilities outside of their specialties. Substantial flexibility has also been incorporated in our new PhD curriculum. Members also expressed strong concerns about the mismatch between 'academic culture' and 'industry culture', and elimination of this perceived mismatch continues to be a facet of our program that is closely monitored by advisory board members. They suggested that students should get more exposure to industry before completing their degrees. In response to this concern, we partnered with Industry to develop semester projects offered in some of our courses that require site visits and close working relationships with specific individuals in Industry (e.g., ISE 5684, ISE 5674).

The criteria that were provided (above list) were used to develop an evaluation survey that was administered two times during the implementation of our training program. These metrics were then used to revise the program as needed. Two program surveys were administered. The first program survey was administered in August of 2002. There were 11 respondents. The second program survey was administered in May of 2005, and there were 26 respondents. The results from each program survey are shown below with means and standard deviations summarized for each item.

Demographic Data

Academic Level of Respondents:

	2002	2005
MS	54%	30%
PhD	27%	31%
Alumni	11%	35%
Other (MS student that matriculated to PhD)	0%	4%

Academic Plan of Respondents:

	2002	2005
Declared or graduated from the safety track:	45%	35%
Declared or graduated from the ergonomics track:	9%	8%
Will declare the safety track:	N/A	4%
Will declare the ergonomics track	N/A	8%
Have not declared either track, but have taken safety and/or ergonomics courses:	45%	38%

Number funded by the NIOSH Training Grant:

2002: N/A 2005: 15% were funded

Responses to Likert Items (means, standard deviations).
Response alternatives were –

1 (SD: strongly disagree)
2 (D: disagree)
3 (N: neutral)
4 (A: agree)
5 (SA: strongly agree)
NA (not applicable)

Means (SDs) in italics and bold are from the 2002 program survey.

Statement	SD	D	N	A	SA	N/A	Mean (SD)
1. My understanding of safety engineering is sufficient to support success in an organizational setting.	**0** *0*	**8%** *0*	**27%** *18%*	**54%** *73%*	**11%** *9%*	**0** *0*	**3.69 (.79)** *3.91 (.54)*
2. My understanding of safety engineering is sufficient to support my own research.	**0** *0*	**0** *18%*	**11%** *18%*	**54%** *45%*	**27%** *18%*	**8%** *0*	**4.17 (.64)** *3.64 (1.03)*
3. My understanding of WMSDs is sufficient to support success in an organizational setting.	**0** *0*	**8%** *0*	**11%** *36%*	**58%** *46%*	**19%** *18%*	**4%** *0*	**3.92 (.81)** *3.82 (.75)*
4. My understanding of WMSDs is sufficient to support my own research.	**0** *0*	**11%** *10%*	**19%** *36%*	**35%** *36%*	**23%** *18%*	**11%** *0*	**3.78(1.00)** *3.64 (.92)*
5. The safety program (includes advising, teaching, and research support) has been effective in preparing me for Industry.	**0** *0*	**11%** ***0***	**27%** ***9***	**50%** *64*	**8%** *27*	**4%** *0*	**3.56 (.82)** *4.18 (.60)*
6. The safety program (includes advising, teaching, and research support) has been effective in preparing me for research.	**0** *0*	**8%** *18%*	**11%** *36%*	**50%** *36%*	**23%** *9%*	**8%** *0*	**3.96 (.86)** *3.36 (.92)*
7. The advising support I have received for safety-related research (including WMSDs) has been adequate.	**0** *9%*	**8%** *0%*	**20%** *27%*	**40%** *45%*	**16%** *18%*	**16%** 0	**3.76 (.89)** *3.64 (1.12)*
8. The financial support I have received for safety-related research (including WMSDs) is/was adequate.	**8%** *9%*	**15%** *9%*	**11%** *64%*	**15%** *0*	**27%** *18%*	**23%** *0*	**3.50 (1.43)** *3.09 (1.14)*
9. There are sufficient opportunities to learn outside the classroom.	**4%** *9%*	**11%** *18%*	**23%** *27%*	**35%** *36%*	**17%** *10%*	**8%** 0	**3.58 (1.10)** *3.18 (1.17)*
10.The design of the safety program meets my expectations.	**0** *0*	**19%** *18%*	**31%** *27%*	**42%** *45%*	**4%** *10%*	**4%** *0*	**3.32(.85)** *3.45 (.93)*
11.The courses I have taken in the safety program are challenging.	**0** *0*	**23%** *9%*	**27%** *18%*	**50%** *64%*	**0** *9%*	**0** *0*	**3.27 (.83)** *3.73 (.79)*
12. I am comfortable providing feedback to faculty regarding the quality of the program.	**4%** *0%*	**19%** *9%*	**4%** *10%*	**38%** *36%*	31% *45%*	**4%** *0*	**3.76 (1.23)** *4.18 (.98)*
13. I plan to pursue a field related to safety engineering.	**8%** *0*	**15%** *10%*	**42%** *18%*	**23%** *45%*	**8%** *27%*	**4%** *0*	**3.08 (1.04)** *3.91 (.94)*
14. I plan to pursue a field related to WMSDs.	11%	31%	23%	19%	11%	4%	2.88(1.24) *3.00 (1.00)*
15. The resources available to me in the safety program (lab space, computers, etc.) are sufficient	**4%** *0%*	**19%** *18%*	**23%** *45%*	**27%** *36%*	**11%** *0*	**15%** *0*	3.27 (1.12)

for the purposes of learning and research.							*3.18 (.75)*
16. The safety program is effective.	**0**	**4%**	**38%**	**50%**	**4%**	**4%**	**3.56 (.65)**
	0	*0*	*27%*	*55%*	*18%*	*0*	*3.91 (.70)*

Results of Content Analysis of 2002 and 2005 verbal responses to the question: *Please let us know how we can improve the NIOSH Safety Training Program.*

Qualitative Code	Frequency	Brief Description
More lab resources needed	2002: 2 2005: 1	More access to journals, software, and measurement equipment.
More lab space needed	2002: 1 2005: 2	Difficult to share labs to run experiments; crowded labs make scheduling difficult.
Course content should be expanded	2002: 3 2005: 2	Need more content on computational modeling (WMSD), OSHA regulations, information to support certification, psychology, organizational safety information.
Need more courses offered for graduate students.	2002: 0 2005: 3	Need more graduate-level course and would like to have 5674 offered more than every other year.
Need to offer more practical experience	2002: 2 2005: 3	Need more hands-on activities to support learning. Need more on industry practice; less theory. Need more industry tours, visits.
Need more funding for safety and health research.	2002: 3 2005: 4	More funding is needed to support students with interests in occupational safety and health.

The evaluation data above have been used to redesign the program (as described earlier). Advisory committee members reviewed the aforementioned results along with the course lists, descriptions, and sample topics from students' thesis research. Members then provided feedback to improve the program and align it with specific needs within Industry. Advisory members have recommended that we focus more on providing internships or coops to ensure students are ready for "industry culture". Other recommendations included the need to ensure that students have sufficient exposure to industrial hygiene, gain management skills, and acquire knowledge through exposure (for example, plant visits).

Training Candidates

Trainees in our program were candidates for the Master of Science and Doctor of Science within the Human Factors Engineering and Ergonomics (HFEE) graduate option in the Department of Industrial and Systems Engineering. The trainees all held baccalaureate degrees in engineering or science from an accredited college or university. They were admitted competitively based on grade point average, letters of recommendation, personal statements, work experience, and standardized test scores. Once accepted, there was an open competition between the students for NIOSH trainee grants. The awardees were selected each year based on current GPA, program experience, and their stated goals for their participation in the program. Students who were in their second year in the program and were ready to conduct a research project

were given priority. Students who did not receive NIOSH funding usually received other support from the Department in the form of Graduate Research Assistantships, Graduate Teaching Assistantships, and Graduate Fellowships.

Prospective trainees were also actively recruited through our interactive web page on the internet, from program brochure mailings, and from active participation of both faculty and students in conferences. We drew students from around the US, and with major sources of international applicants from China, Korea, and India. Approximately 30-40 applications were received each year for the entire program (HFEE Option within ISE). Of these, on the order of 20-30 applicants were accepted and about 10 enrolled. Of students who enter the HFEE option, roughly half pursued research in some aspect of occupational safety, ergonomics, or biomechanics. Over the last several years, we have had 4-6 candidates per year for our two NIOSH traineeships. All students selected have accepted and entered the program.

Each year, students from around the U.S. were invited to a recruitment event held on campus. Departmental funds were used to offset the travel expenses involved, typically up to $500 each. The event included an introduction to the university, department, and HFEE option. Faculty were present to introduce themselves and their research and to provide laboratory tours. Student representatives from the local HFES chapter participated as well. Additional recruiting occurred through faculty affiliations with other departments at Virginia Tech, and through advertising at conferences (especially the annual HFES).

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 and Biomechanics Laboratory, and
- Locomotion Research Laboratory.

Other facilities include those normally found at a major University and include dedicated, multimedia classroom space, computer laboratories, and faculty and student office space. 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.

PUBLICATIONS RESULTING FROM TRAINEES

The following list contains only publications that were generated by trainees in the program (current or prior reporting period). Trainees are indicated by underlining, and those supported by TPG funds are **bolded**.

Conference Papers:

1. **Astin AD**, Nussbaum MA: [2001] Review of workload assessment tools, with special emphasis on subjective methodologies. In: Advances in Occupational Ergonomics and Safety 4: Proc of the International Occupational Ergonomics and Safety Conference, (eds. AC Bittner Jr, PC Champney, SJ Morrissey), IOS Press, pp 11-17
2. Babski-Reeves K, **Tran G**: [2004] Assessment of recovery rates during light exercise using micro-climate cooling products. 2004 National Athletic Trainers Association Annual Meeting and Clinical Symposium, Baltimore, Maryland, June 16-20
3. Babski-Reeves K, **Tran G**: [2004] EMG evaluation of a bed assistive device. 48th Annual Human Factors and Ergonomics Conference, New Orleans, Louisiana. September 20-24
4. Babski-Reeves K, McCauley-Bell P, **Bertmaring I**: [2006] Thermographic assessment of the anterior deltoid during overhead static exertions. Industrial Engineering Research Conference, Orlando, Florida, May 20-24
5. Barker L, Babski-Reeves K, **Hughes L**: [2006] Efficacy of using thermography to assess shoulder loads during overhead intermittent work. 50th Annual Human Factors and Ergonomics Conference, San Francisco, California, October 16-20
6. Brown S, Smith-Jackson TL: [2002] Behavior When Using Child's Meal Toys: An Observational Study. Proc of the 16th Annual International Society for Occupational Ergonomics and Safety Conference
7. Davis T, Lockhart TE: [2002] Relationship between age and anxiety on the biomechanics of slips and fall. Proc of 14th Annual International Society of Occupational Ergonomics and Safety, Toronto, Canada, Session 5-3:1-5, June 9
8. Davis T, Lockhart TE: [2003] The Effects of Age on Stress and The Biomechanics of Slips and Falls. 47th Annual Human Factors and Ergonomics Conference, Denver, Colorado, 1131-1135, October 13-18
9. Davis T, Lockhart TE: [2005] The Effects of Age on Stress and the Biomechanics of Slips and Falls. Proc of the 16th Annual International Occupational Ergonomics and Safety Conference, Las Vegas, Nevada, 574-576, June
10. Ghosh A, Lockhart T: [2005] Effects of Multi-Modal Warning Systems on Perceived Urgency of Elderly Drivers. Proc of the 16th Annual International Occupational Ergonomics and Safety Conference, Las Vegas, Nevada, 371-375, June
11. **Hughes L**, Babski-Reeves K: [2003] Evaluation of an Electrogoniometer for Wrist Position Measurements. 47th Annual Human Factors and Ergonomics Conference, Denver, Colorado, October 13-18

12. **Hughes L**, Babski-Reeves K: [2005] Effects of time pressure and mental workload on WMSD risk. Proc of the 13th Annual Institute of Industrial Engineering Research Conference, Atlanta, Georgia, May 14-18
13. **Hughes L**, Babski-Reeves K: [2005] Time pressure and mental workload effects on key strike force and perceived workload during typing. Proc of the 49th Annual Human Factors and Ergonomics Conference, Orlando, Florida, September 26-30
14. **Johnson H**, Nussbaum MA: [2001] Analysis of a self-regulating method for determining acceptable finger force limits. Proc of the Human Factors and Ergonomics Society Annual Conference, Minneapolis, Minnesota,1031-1035
15. Khuvasanont T, Lockhart TE: [2002] Age-related ankle strength and the effects on the slip-induced falls. Proc of 14th Annual International Society of Occupational Ergonomics and Safety, Toronto, Canada, Session 5-4:1-5, June 9
16. Kim H, Nam CS, Smith-Jackson TL, Scales W: [2005] Culture-centered design guidelines for web-based tutorials. In: Proc of CybErgo 2005: The Fourth International Cyberspace Conference in Ergonomics, (eds. A Thatcher, T James, A. Todd), International Ergonomics Associate Press
17. Kim S, Hurley H, Nussbaum M, **Hughes L**, Babski-Reeves K: [2006] Residential wall panel designers' knowledge and attitudes toward ergonomics. 50th Annual Human Factors and Ergonomics Conference, San Francisco, California, October 16-20
18. Kim S, Lockhart TE: [2002] Effects of age-related changes in hamstring activation rate and heel contact velocity on the biomechanics of slips and falls. Proc of 14th Annual International Society of Occupational Ergonomics and Safety, Toronto, Canada, Session 5-2:1-5, June 9
19. Kim S, Lockhart TE: [2003] Age-Related Changes in Hamstring Activation Rate and Its effects on Initiation of Slip While Walking over a Slippery Floor Surface. Proc of 15th Triennial Congress of the International Ergonomics Association, Seoul, Korea, August 24-29
20. Kim S, Lockhart TE: [2005] Prediction of Fallers and Non-fallers. Proc of the 16th Annual International Occupational Ergonomics and Safety Conference, Las Vegas, Nevada, 550-554, June
21. Kim S, Lockhart TE: [2006] Gait Asymmetry: Factors Influencing Slip Severity and Tendency among Older Adults. Proc of the Human Factors and Ergonomics Society, 50th Annual Meeting, San Francisco, California, October 16-20
22. Liu J, Lockhart TE: [2003] Differences in Localization and Dynamic Simulation Methods in Joint Moments Determination during Normal Walking. Proc of 15th Triennial Congress of the International Ergonomics Association, Seoul, Korea, August 24-29
23. Liu J, Lockhart TE: [2004] Role of ankle joint in successful reactive-recovery: A 3D joint moment analysis. 48th Annual Human Factors and Ergonomics Conference, New Orleans, Louisiana. September 20-24
24. Liu J, Lockhart TE: [2005] Aging Effect on Joint Moment Response Time during Successful Reactive-Recovery from Unexpected Slips. Proc of the 16th Annual International Occupational Ergonomics and Safety Conference, Las Vegas, Nevada, 563-567, June

25. Liu J, Lockhart TE: [2006] Aging Effect on Initial Postural Responses of Unperturbed Foot to Unexpected Slips. Proc of the Human Factors and Ergonomics Society, 49th Annual Meeting, New Orleans, Louisiana, October 16-20
26. Liu J, Lockhart TE: [2006] Age-related Upper Limb Response Strategies to Unexpected Slips. 16th World Congress of the IEA, Maastricht, the Netherlands
27. Liu J, Lockhart TE, Granata KP: [2005] Reaction Moment At The L5/S1 Joint During Unexpected Step Perturbation While Load Carrying. Proc of the 16th Annual International Occupational Ergonomics and Safety Conference, Las Vegas, Nevada, 123-127, June
28. Lockhart TE, Atsumi B, Raj P, Ghosh A: [2005] Assessment of Age Related Effects on Daytime and Nighttime Visual Acuity. Proc of the 16th Annual International Occupational Ergonomics and Safety Conference, Las Vegas, Nevada, 571-581, June
29. Nam CS, Kim H, Smith-Jackson TL, Scales W: [2005] Culture and Cognition: Implications for Cognitive Design of Learning Resources. Proc of the Human Factors and Ergonomics Society, 49th Annual Meeting, Santa Monica, California, 1444 – 1448
30. Nam CS, Kim HN, Smith-Jackson TL, Nussbaum MA: [2003] Development of a guidelines tools for mobile phone interfaces. Proc of the 47th Annual Human Factors and Ergonomics Conference. Denver, Colorado, 792-796, October 13 – 17
31. Parijat P, Lockhart TE, Granata KP, Liu J, Park K: [2005] Effects of Load Carrying on Trunk Dynamics During Unexpected Slip and Recovery. Proc of the 16th Annual International Occupational Ergonomics and Safety Conference, Las Vegas, Nevada, 568-571, June
32. Singh N, Nussbaum MA: [2006] Influence of visual and somatosensory inputs on the frequency distribution of sway during quiet standing. Proc of the American Society of Biomechanics Annual Conference. Blacksburg, Virginia, September 6-9 (CD only, not paginated)
33. Singh N, Nussbaum MA, Lin D, Madigan ML: [2005] Effect of localized neuromuscular fatigue induced at different joints on postural control and recovery. Proc of the 49th Annual Human Factors and Ergonomics Conference. Orlando, Florida, 1306-1310, September 26-30
34. Sood D, Hager K, Nussbaum MA: [2002] The effects of differing overhead heights on shoulder fatigue during a repetitive intermittent task. Proc of the 46th Annual Human Factors and Ergonomics Conference. Baltimore, Maryland, 1081-1085
35. Sood D, Nussbaum MA, Babski-Reeves KL: [2004] Effects of work conditioning and adjustment period on psychophysical estimates in manual torquing tasks. Proc of the 48th Annual Human Factors and Ergonomics Conference. New Orleans, Louisiana, 1388-1392, September 20-24
36. **Spaulding J M**, Lockhart T E: [2002] The effects of age and fear of falling on muscle activity patterns of the lower extremities during normal and adjusted human gait. Proc of 14th Annual International Society of Occupational Ergonomics and Safety, Toronto, Canada, Session 5-1:1-6, June 9
37. **Spaulding J M**, Lockhart T E: [2003] The Effects of Age on Gait Parameters During Adjustment. 47th Annual Human Factors and Ergonomics Conference, Denver, Colorado, 1136-1140, October 13-18

38. **Spaulding J M**, Lockhart T E, Van Goubergen D, Park MY: [2003] Effects of Age on Adjustment of Gait Parameters and Muscle Activity. Proc of 15th Triennial Congress of the International Ergonomics Association, Seoul, Korea, August 24-29
39. Thomas CT, Nam CS, Smith-Jackson TL: [2003] The significance of behavior type on Web information retrieval and academic success. Proc of the 2003 American Society for Engineering Education Annual Meeting and Exposition
40. **Tran G**, Babski-Reeves K: [2005] Evaluation of a self assistive device on self-perceived recovery measures for patients in post operative care. Proc of the 49th Annual Human Factors and Ergonomics Conference, Orlando, Florida, September 36-30
41. **Tran G**, Babski-Reeves KL: [2005] Electromyography Evaluation of a Bed Assistive Device for Patients in Postoperative Care. Proc of the 13th Annual Institute of Industrial Engineering Research Conference, Atlanta, Georgia, May 14-18
42. Yoon HY, Park MY, Kim SW, Lockhart T E: [2004] Effects of the whole-body COM velocity on RCOF. 48th Annual Human Factors and Ergonomics Conference, New Orleans, Louisiana. September 20-24
43. Zhang HB, Nussbaum MA: [2006] Identification of the effects of localized muscle fatigue on postural sway through wavelet analysis. Proc of the Virginia Academy of Sciences. Blacksburg, Virginia. May 25 (abstract only)

Papers in Archival Journal:

1. Babski-Reeves K, Tran G: [2006] Efficacy of a self-assistive device for patients in postoperative care. Assistive Technology 1:191-197
2. Babski-Reeves K, Stanfield J, **Hughes L**: [2005] Assessment of video display workstation set up on risk factors associated with the development of low back and neck discomfort. International Journal of Industrial Ergonomics 35:593-604
3. **DiDomenico A**, Nussbaum MA: [2003] Measurement and prediction of single and multi-digit finger strength. Ergonomics 46:1531-1548
4. **Hughes L**, Babski-Reeves K, Smith-Jackson, T. Effects of psychosocial and individual factors on physiological risk factors for upper extremity musculoskeletal disorders while typing. Accepted for publication in Ergonomics (August 2006)
5. **Johnson H**, Nussbaum MA: [2003] Strength and subjective limits for repetitive manual insertion tasks. American Industrial Hygiene Association Journal 64:763-770
6. Kim SW, Lockhart TE: [2005] Relationship between walking velocity and slip-induced fall accidents. Safety Science 43: 425-436
7. Liu J, Lockhart TE: [2006] Comparison of 3D joint moments using local and global inverse dynamics approaches among three different age groups. Gait and Posture 23:480-485
8. Liu J, Lockhart TE, Jones M, Martin T: [2006] Local Dynamic Stability Assessment of Motion Impaired Elderly using Electronic Textile Pants. IEEE Transactions in Automation Science and Engineering, in press
9. Lockhart TE, **Spaulding J**, Park SH: [2006] Age-related slip avoidance strategy while walking over a known slippery floor surface. Gait & Posture, in press

10. Lockhart TE, Kim SW: [2006] Relationship Between Hamstring Activation Rate and Heel Contact Velocity: Factors Influencing Age-Related Slip-Induced Falls. Gait and Posture 24:23-34
11. Lockhart TE, Atsumi B, Ghosh A, Mekaroonreung H, **Spaulding J**: [2006] Effects of planar and non-planar driver-side mirrors on age-related discomfort-glare responses. Safety Science 44:187-195
12. Nam CS, Smith-Jackson TL, **Thomas C**: [2004] Effects of individual differences and task environments on users' interactions with web resource seeking. Computers in Education 15:79-92
13. Nussbaum MA, **Johnson H**: [2002] Determination and evaluation of acceptable force limits in single digit tasks. Human Factors 44:545-556
14. Nussbaum MA, Clark L, Kirst M, Rice K: [2001] Fatigue and endurance limits during intermittent overhead work. American Industrial Hygiene Association Journal 62:446-456
15. Perez MA, Nussbaum MA: [2002] Lower torso muscle activation patterns for high-magnitude static exertions: gender differences and the effects of twisting. Spine 27:1326-1335
16. Smith-Jackson TL, Nussbaum MA, Mooney AM: [2003] Accessible cell phone design: development and application of a needs analysis framework. Disability and Rehabilitation 25:549-560
17. Sood D, Nussbaum MA, Hager K. Fatigue during prolonged intermittent overhead work: reliability of measures and effects of working height. Accepted for publication in Ergonomics (05/15/06)
18. **Woods M**, Babski-Reeves K: [2005] Effects of negatively sloped keyboard wedges on risk factors for upper extremity WMSDs and user performance. Ergonomics 48:1793-1808

Conclusions

Our program occupied a niche that is somewhat unique, but clearly valuable to the safety and occupational health training community. It was 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 were 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 was successful in terms of graduating a consistent number of well-qualified safety students (2-4 per year). Two of these students were supported each year using funds from our training grant. As can been seen above, however, the effects of this grant went well beyond the direct influence on student tuitions and stipends. The grant was a key aspect in the maintenance and continual improvement of the safety engineering curriculum, and facilitated 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, Occupational Ergonomics, and Occupational Biomechanics at Virginia Tech.