# Motion-Tracking Technology & Three-Dimensional Displays Provide Leading-Edge Research & Educational Tools to Industrial Engineering Students at Texas A&M University-Commerce

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Abstract

In the fall of 2002, a new Industrial Engineering program was established at Texas A&M University-Commerce (TAMUC). A central component of this new undergraduate program is a reconfigurable, modularized Human Factors & Ergonomics Laboratory (HFEL) that will provide students and faculty access to state-of-the-art graphical displays, audio systems, motion-tracking systems, and ergonomic workstation evaluation tools and technologies. Four laboratory modules have been designed to enable students to study and evaluate a wide variety of workplace and workstation human factors and ergonomics configurations. MotionMonitor[1], by Innovative Sports Training incorporates magnetic sensors, sophisticated software, and motion-tracking systems which are being integrated into the laboratory to enable students to study a variety of human movement parameters within traditional and experimental office, educational and industrial settings. A value-added element of the laboratory is a set of three-dimensional (3D) graphical displays, developed by StereoGraphics[2], that present realistic 3D images to the student without the aid of virtual reality goggles or other external stereo-optical vision devices. This new, unaided 3D presentation technology is expected to allow the student to create and evaluate techniques to enhance training, design, and systems engineering effectiveness. The motion-tracking technology used in the TAMUC Industrial Engineering laboratory, is similar to the equipment used to capture human movements and to generate human-centered data for animation teams, such as in the animated feature film, *Shrek*® by Dreamworks Skg. This technology, based on a system called *Flock of Birds*® by Ascension Technology Corporation, uses magnetic sensors, placed in strategic locations on the human body to capture data points in 3D space for use in various engineering design, simulation, and animation tasks. Candidate uses of this technology include fatigue studies, physical performance evaluations, sports physiology, work methods analyses, and industrial hygiene analyses. This paper provides a detailed overview of the Human Factors Laboratory development effort at TAMUC, with a special emphasis on motion-tracking technologies and the new 3D graphical display technologies that are being integrated into the laboratory.

## Background and Initial Laboratory Preparations

In support of the new Industrial Engineering (IE) program at Texas A&M University-Commerce, new laboratory developments have been energized to include a Human Factors & Ergonomics Laboratory (HFEL). This new laboratory is being designed and integrated from the ground up, to provide undergraduate IE students with state-or-the-art equipment to study and

evaluate human performance factors that are demonstrated and practiced in traditional and non-traditional work activities. Several industries and jobs specific to those industries can be evaluated using the functions available in this new modular laboratory configuration. Four such modules are planned for integration and operation during the Spring 2004 semester. These four modules are:

1) 3D Visual Analysis and Evaluation Module

2) Ergonomic versus Traditional Hand Tool Comparison and Evaluation Module

3) Ergonomic Workstation Design and Evaluation Module

4) Motion-Tracking and Motion-Capture Analysis and Evaluation Module

Within each module, common and unique equipment and furnishings are being tailored and integrated to meet the needs specified for use in each module. Since the laboratory is being created in the same area as a previous electronics laboratory and an adjoining classroom, several infrastructure changes had to be made before new component installations and systems integrations could occur. The first step was to remove pre-existing furnishings and to tear down the wall that separated the electronics laboratory from the classroom environment, leaving half of the floor covered with tile and half covered with relatively new carpeting *and* a six inch concrete gap between the two areas where the wall once stood.

An internal TAMUC facilities contract was generated to begin the tasks of reworking the room. In the first phase of re-construction, steps were taken to repair the floor where the wall had been, to remove some electrical conduit that had been installed inside the wall, to reposition some of the lighting fixtures to re-balance the overall lighting patterns within the room, and to install new carpeting to "match" the pre-existing carpeting. This process consumed several weeks during the late spring 2003 semester and during the early summer months of 2003. Additional facilities improvements were made which included the installation of double glass doors to form an elegant entry point into the new laboratory. Some additional electrical conduit that had been surface-mounted in the original laboratory also had to be re-routed and reinstalled before furnishings could be placed against the walls. With these initial laboratory preparations now competed, the task of identifying laboratory components, systems, furnishings, tooling, and systems configurations now began in earnest.

## Module Planning and Design

Initial planning for the layout and location of each of the four modules centered on a specific high cost item to be used in the laboratory. The overhead multi-media projector was expected to cost between $4,500 and $5,500 for a single unit and it was anticipated that each of the four modules would likely require independent access to such a projector to display and evaluate the outputs of their respective modules. An elegant solution was defined that allowed one projector to be used independently to support each of the four modules. This was accomplished by hanging the projector overhead, near the center of the 30 foot by 40 foot

laboratory and placing the projector mount onto a pivoting coupling device that would allow the projector to be repositioned with minimal effort (and time) onto another wall where a dedicated projector screen was to be installed. Three such manually-operated projector screens [on the south wall, the east wall and on the west wall] were able to be attached to the ceiling and to lay flush against the corresponding walls. To balance the focal length required for the fourth screen, located on the north end of the laboratory, the screen configuration had to be countersunk into the ceiling. This required a slightly different configuration, such that the screen could be raised and lowered electrically, as needed. With this design innovation, one projector could be used to demonstrate and evaluate products and processed generated by each module without having to look over the shoulder or look to the side to view images specific to a given module. We believe that this will enable participants to improve their research skills and to enhance the effectiveness of each module within the lab. In addition to the visual projection system, two separate sound systems were installed to enable multimedia presentations to integrate sound into the system. One sound system is a typical surround-sound configuration with front channel speakers [L & R], rear channel speakers [L&R], a center channel speaker, and a ceiling mounted sub woofer. This surround-sound system is installed to allow visitors and teams to use a small conference table near the center of the lab as the focal point of the sound (see Figure 1).

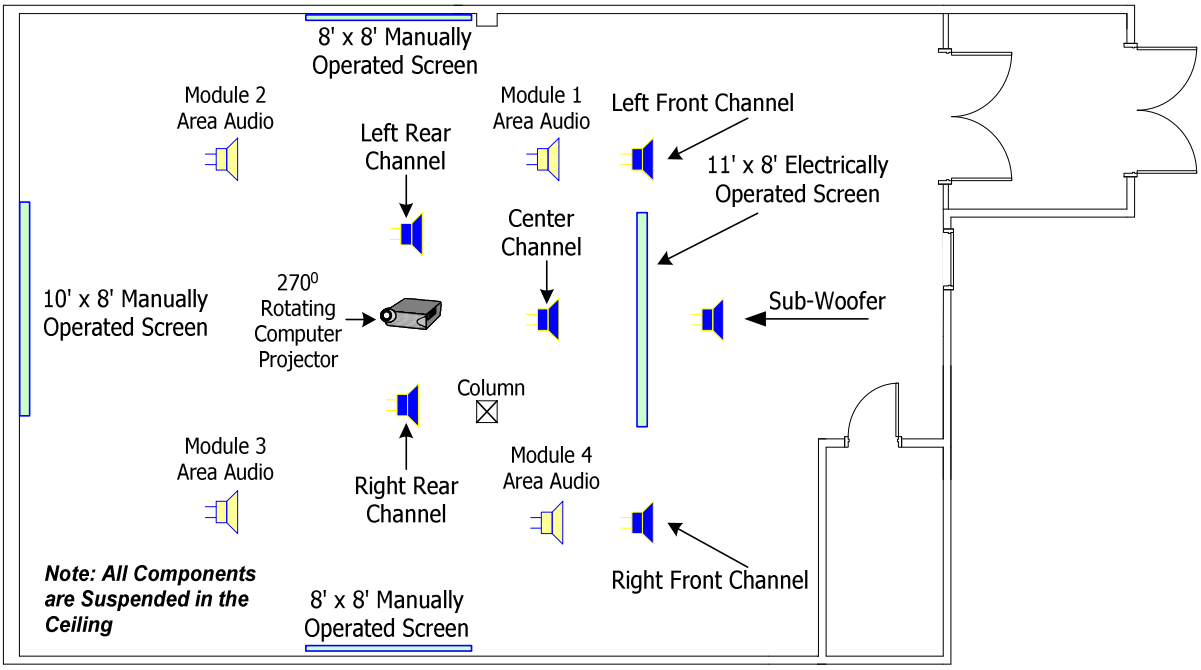


Figure 1. Conceptual Design of Human Factors & Ergonomic Laboratory – Audio System

The audio system also has four independent speakers, centered roughly over each of the four modules in the laboratory, to allow separate sound sources to be used in the laboratory to simulate work environments where conversations, machinery noise, traffic, construction noise, or any combination of sound sources can be simulated. The planned use of this second audio system is to create a more realistic research environment where effects such as noise can be used

during research projects along with existing lighting, temperature, humidity, and other environmental stressors to better replicate conditions found in daily work environments. It may also be used to create more realistic training and educational scenarios for further use and evaluation by students, researchers, customers, and faculty.

Figure 2 shows a conceptual plan of the finished HFEL configuration after furnishings, equipment, and support systems have been installed. Since the laboratory is still in the early development stages, due in-part to delays in procurement activities and in related delivery schedules, the final layout of the laboratory is yet to be defined. [Note: The laboratory is expected to be fully functional by mid-March or early-April 2004, therefore, by the time this paper is presented at the 2004 ASEE Annual Conference and Exposition, much more accurate detail and more realistic laboratory diagrams, including digital photographs, will be available.]

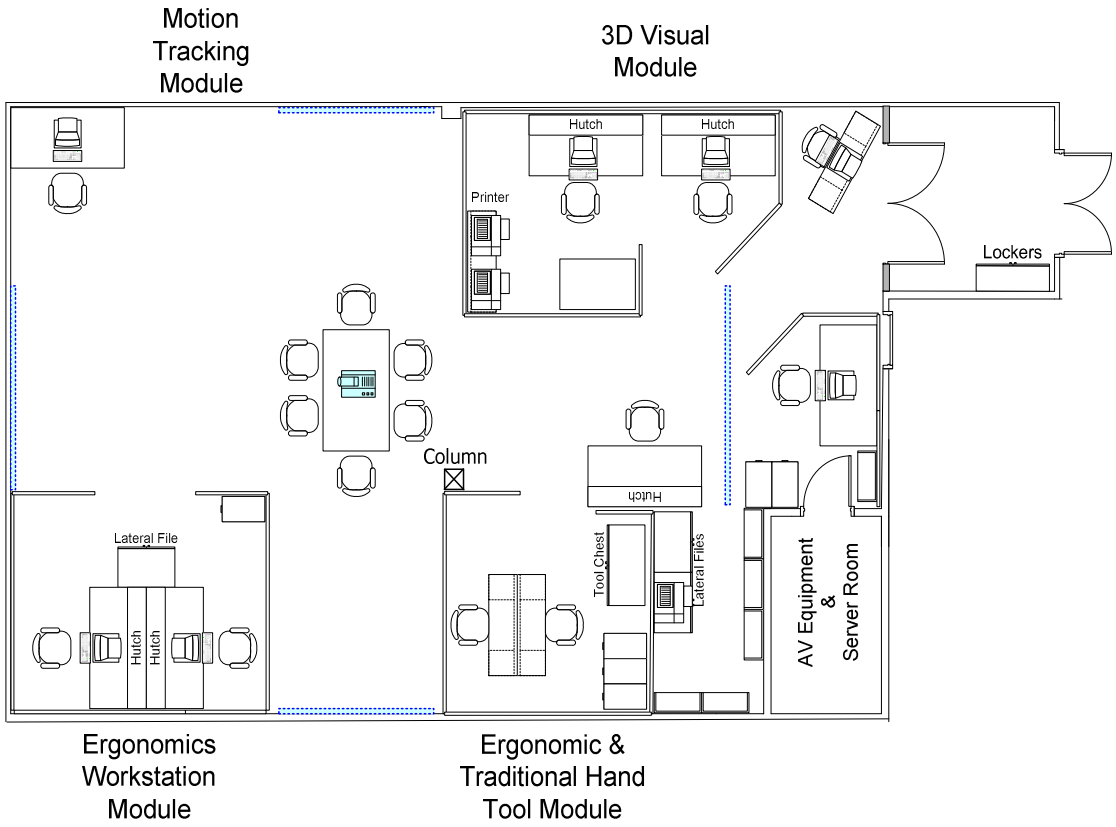


Figure 2. Conceptual Design of Human Factors & Ergonomic Laboratory – Research Modules

The principal purpose behind creating a modular design in the HFEL at Texas A&M University-Commerce is to allow for rapid laboratory reconfigurations: 1) as research interests of faculty change over time, 2) as new customers emerge and require a different mix of furnishings and supporting equipment, 3) as newly-funded research projects require modifications to the laboratory design to support short-term or long-term projects, and 4) to minimize costs to meet the changing needs of research teams at TAMUC. The initial four modules as defined earlier, will support several existing undergraduate courses, specifically IE 403 – Human Factors

Engineering, IE 310 – Systems Simulation, and IE 316 – Production Systems Operations. Other courses may also benefit as the capabilities of the laboratory are more fully defined and explored. Specific uses of the laboratory will be centered on Human-Computer Interaction (HCI) issues in a noise-rich environment. The objective is to introduce students to noise, lighting, and other environmental stressors as they complete engineering tasks on various computer workstations and computerized equipment. Comparative measures obtained during various environmental settings will then be compared to Occupational Safety and Health Administration (OSHA) and other industry standards to reinforce the need for protective equipment usage and safety standards in the workplace. Several individuals have had an input into the initial laboratory configuration, including three student teams, enrolled in the spring 2003 IE 316 course of Production Systems Operations. Some equipment, some tooling, and some infrastructure changes were incorporated as a result of the student's input.

Module One – 3D Visual Analysis and Evaluation Module

Each of the four HFEL modules can be described by their basic function as indicated earlier; however, specific sets of equipment, tooling, and sometimes furnishings are required to fully define each module. The 3D Visual Analysis and Evaluation Module uses an 18-inch SynthaGram Monitor and a 42-inch SynthaGram Monitor, created by StereoGraphics Corporation[2], to provide realistic three-dimensional displays to users without the use of supplemental visual augmentation equipment such as: Virtual Reality (VR) goggles, 3D glasses or other mechanical devices. The ability to view 3D settings without the aid of supplemental equipment provides the user with a more realistic view of the synthetic world, thus making complex tasks easier to understand and to master. It is anticipated that the 3D Visual Analysis and Evaluation Module will be a major element in the near-term research and educational program at TAMUC. The 3D Visual Analysis and Evaluation Module is expected to serve as one of the two primary modules within of the HFEL.

Module Two – Ergonomic versus Traditional Hand Tool Comparison and Evaluation Module

The least complex of the four modules is designed to allow students to evaluate traditional hand tools versus ergonomic hand tools that have been created for common tasks in an operational environment. These tool comparisons will include selected wrenches, pliers, wire cutters, screwdrivers, socket sets, and hammers. The objective of this module will be to evaluate and test claims made by selected *ergonomic tool manufacturers* regarding *their enhanced ergonomic designs* and to determine whether these designs are: 1) meant to reduce injuries to workers, 2) designed to improve productivity, or 3) merely an attempt to increase corporate profits, without substantially improving worker safety and/or productivity, since marketing terms using ergonomic terminology are sometimes used to inflate product prices without regard to true benefits to the worker.

Module Three – Ergonomic Workstation Design and Evaluation Module

Workstation and workplace design is an area that has received a lot of emphasis over the past several years, yet adequate adjustability and elegant re-configurability of workstations is a

design objective that continues to elude many furniture and equipment manufacturers. Repetitive stress injuries (RSI), carpal tunnel syndrome (CTS), musculoskeletal disorders (MSD), cumulative trauma disorders (CTD), and overuse disorders (OD) are all terms used by Kroemer, et.al.[3] to described a class of injures to workers that can be reduced, if not completely eliminated, by effectively designing and using support equipment, furnishings, and if necessary, by modifying the work processes themselves. Module three will allow the TAMUC research teams to develop and test workstation components and furnishings to improve functionality while reducing the factors that lead to MSD/RSI symptoms. A major payback to this form of research can be a significant reduction in workman's compensation claims and improved productivity from injury-free workers.


Figure 3. Sample MotionMonitor Output Analysis Using Motion-Tracking System

Module Four – Motion-Tracking and Motion-Capture Analysis and Evaluation Module

A cornerstone of the Human Factors & Ergonomics Laboratory at Texas A&M University-Commerce will be a motion-tracking module that requires a slightly different configuration, due to the system's sensitivity to metallic surfaces and other metallic infrastructure components. Wooden furnishings are primarily being integrated into Module Four in lieu of the more traditional-styled cubicle furniture and metal/wood-veneer furnishings found in most university laboratory settings. The MotionMonitor[1] system by Innovative Sports Training (IST) is designed to capture and analyze multiple elements of body position and forces acting on the body in various work configurations. Figure 3 provides a sample output for an adult human walking Gait Analysis at 100 Frames per Stride. This and numerous other outputs

are available to capture true motion variables to permit detailed analyses of factors that may improve efficiency or reduce stress on the individual in various situations. As stated by Moira F. Tracy[4] in the Chapter entitled *Biomechanical methods in posture analysis*, "Unfortunately, biomechanics cannot on its own answer questions of the type: 'What force can be applied safely and without fatigue *x* times a minute for *y* hours, given *n* rest pauses of *m* minutes are provided?'" This limitation may be due in part to the inability to collect sufficiently accurate, repeatable data using traditional observational and questionnaire techniques. The technologies used to create the MotionMonitor system may help improve the effectiveness of workplace fatigue characteristics much better than in older, less accurate techniques. This same motion tracking capability has been used successfully in sports medicine and athletic performance analyses as well as ergonomic research and various other research and industrial settings.

## Summary

The Industrial Engineering faculty, students, and college administration personnel at Texas A&M University-Commerce are excited about the new IE program and have reinforced this enthusiasm through significant commitments to program initiatives such as the HFEL development effort documented in this paper. Given the baseline capabilities cited herein, the TAMUC Human Factors & Ergonomics Laboratory is well positioned to conduct a wide range of educational and research initiatives. With the advent of new technologies and new research methodologies, we further believe that our new laboratory is well designed and well positioned to quickly and effortlessly integrate these new technologies into the laboratory as they develop.

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## Biography

ANDREW E. JACKSON, Ph.D. is a Professor of Industrial Engineering at Texas A&M University-Commerce where he teaches a variety of Industrial Engineering courses, including: Engineering Economics, Human Factors Engineering, Production Systems Engineering, Discrete Event Simulation, and Engineering Management. His research interests focus on Human Factors and Ergonomics in Large-Scale Systems.