



DEPARTMENT OF  
**INDUSTRIAL ENGINEERING**  
2007 ANNUAL REPORT





The Center for Innovation in Healthcare Logistics was established in 2007 by Interim Department Head and Distinguished Professor Ronald R. Rardin to study the supply chain and material flow aspects of healthcare operations that can be addressed with improved information and logistics systems and processes. More detail on the structure and work of this new research initiative can be found in the “Research” section of this annual report.

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## FROM THE DEPARTMENT HEAD



Dear Colleagues:

The past year has been one of transition and change for the Department of Industrial Engineering at the University of Arkansas. Dr. John English, who served as Department Head since 2001, accepted the position of Dean of Engineering at Kansas State University in Manhattan, KS. New faculty, including myself and Dr. Sarah Root (Ph.D., University of Michigan), have been settling into our new roles in the department, and I also took on the role of Interim Department Head for one year. A successful search for a permanent head has been completed, and Dr. Kim LaScola Needy of the University of Pittsburgh, who is highly regarded throughout the IE community, will step into that position by fall, 2008.

While change poses many challenges in the short run, it also refreshes and invigorates, drawing us toward new frontiers of development and progress. Furthermore, the ongoing changes have not prevented the department from sustaining its recent progress. We continue to maintain a solid undergraduate program, now supported by a common Freshman Engineering year. Our MSIE and PhD programs are growing, as is our professional Master of Science in Operations Management--now the largest master's program at the university.

The current report also documents some of the research initiatives that we have launched or enhanced in 2007. Particularly notable are a new Center for Innovation in Healthcare Logistics initiated in collaboration with several industrial partners, and first steps toward a Reliasoft Risk, Reliability and Maintainability Research Alliance. These initiatives come in addition to the continuing success and IE leadership of the NSF Center for Engineering Logistics and Distribution and the Mack-Blackwell Rural Transportation Center.

I'd like to recognize the faculty, staff, alumni, and students whose support and hard work in all these areas has helped us retain and enhance our standing as one of the emerging leaders among Industrial Engineering departments.

We hope that the past year has brought you much success and that we'll be hearing from you about your department's accomplishments. Please feel free to contact us in the medium of your choice, regarding anything in these pages that attracts your attention. We wish you all the best in your endeavors in the coming year.

Sincerely,

Ronald L. Rardin, Ph.D.  
Distinguished Professor and Interim Department Head

**Ronald L. Rardin,  
Ph.D.,  
Distinguished Professor and  
Interim Department Head**



Dr. Rardin is the inaugural incumbent of the John and Mary Lib White Systems Integration Chair in Industrial Engineering. His research and teaching interests center on large-scale optimization modeling and algorithms, including their application in healthcare delivery, transportation and logistics, and energy planning. Dr. Rardin joined the faculty in early 2007 and directs the new Center for Innovation in Healthcare Logistics in collaboration with Wal-Mart, Blue Cross Blue Shield, the VHA hospital network and other industrial partners.

**Education:**

Ph.D. (Georgia Institute of Technology)

M.P.A. Municipal Administration (University of Kansas)

B.A. Mathematics/Political Science (University of Kansas)

**Nebil Buyurgan,  
Ph.D.,  
Assistant Professor**



Dr. Buyurgan's research interests include Auto-ID technologies; RFID system optimization and data quality assessment; inventory control and management; auctioning methods; distributed control of large-scale systems; modeling and control of discrete event systems; modeling and analysis of flexible manufacturing systems; and automation and integration of advanced manufacturing systems. Dr. Buyurgan teaches courses in manufacturing design, processes and system analysis. He joined the faculty in 2004.

**Education:**

Ph.D. (University of Missouri - Rolla)

M.S.E.M. (University of Missouri - Rolla)

B.S.I.E. (Istanbul Technical University)

## FACULTY

**C. Richard Cassady,  
Ph.D.,  
Professor**



Dr. Cassady holds the John L. Imhoff Chair in Industrial Engineering and serves as Director of Freshman Engineering for the College of Engineering. His primary research interests lie in repairable systems modeling. He also conducts research in the areas of reliability engineering, statistical quality control, transportation/distribution systems modeling and sports applications of operations research. Dr. Cassady teaches courses in reliability and maintainability engineering, operations research, probability and statistics, and statistical quality control. He joined the faculty in 2000.

**Education:**

Ph.D. (Virginia Tech)

M.S.I.S.E. (Virginia Tech)

B.S.I.S.E. (Virginia Tech)

**Justin R. Chimka,  
Ph.D.,  
Assistant Professor**



Dr. Chimka's research interests include categorical data analysis, inventory control, statistical quality control, survival analysis and time series. He teaches courses in applied statistics, generalized linear models, optimization and production. Dr. Chimka joined the faculty in 2002.

**Education:**

Ph.D. (University of Pittsburgh)

M.S.I.E. (University of Pittsburgh)

B.S.I.E. (University of Pittsburgh)





**Earnest W. Fant,  
Ph.D., P.E.,  
Associate Professor**

Dr. Fant's research interests include applications for machine-visioned robotics in automated production/processing and material handling systems and the application of operations research to in-plant logistics systems and warehousing. He teaches courses in robotics, machine vision and material handling/warehousing systems. Dr. Fant joined the faculty in 1988.

**Education:**

Ph.D. (Texas Tech)

M.S.I.E. (Southern Methodist University)

B.S.I.E. (University of Arkansas)



**Carol S. Gattis,  
Ph.D.,  
Adjunct Associate Professor**

Dr. Gattis has been responsible for undergraduate student recruitment and taught courses in statistics, work methods and measurement, and engineering economics. She is currently the Director of Recruitment, Retention, Honors and Diversity for the College of Engineering. Dr. Gattis joined the faculty in 1991.

**Education:**

Ph.D. Engineering (University of Arkansas)

M.S.E.E. (University of Arkansas)

B.S.E.E. (University of Arkansas)



**Steven L. Johnson,  
Ph.D., P.E., CPE.,  
Professor**

Dr. Johnson's research interests have spanned the continuum from occupational ergonomics (e.g., hand tool design, reduction of musculoskeletal disorders, development of computer-based job analysis systems) to in-vehicle information, communication and entertainment systems in commercial trucks and automobiles. His current research involves modeling driver workload, evaluating lane-departure systems and investigating the effect of heavy truck/automobile speed differentials on highway safety, efficiency and economics. He teaches courses in human factors engineering/ergonomics, quality control and design of experiments. Dr. Johnson joined the faculty in 1982.

**Education:**

Ph.D. (SUNY at Buffalo)

M.S. Human Factors (University of Illinois)

B.A. Psychology (University of South Dakota)



**Scott J. Mason,  
Ph.D.,  
Associate Professor and  
Associate Department Head**

Dr. Mason serves as the Chair of Graduate Studies and began serving as Associate Department Head in 2004. His research interests include production planning and control; scheduling; and large-scale system optimization, modeling and algorithms, with emphasis on semiconductor manufacturing and transportation logistics. Dr. Mason teaches courses in industrial engineering design, sequencing and scheduling, and in the modeling and analysis of semiconductor manufacturing. He joined the faculty in 2000.

**Education:**

Ph.D. (Arizona State University)

M.S.E. (The University of Texas)

B.S.M.E. (The University of Texas)



**Dr. Russell D. Meller,  
Ph.D.,  
Professor**

Dr. Meller is Hefley Professor of Logistics and Entrepreneurship and serves as the Director of the Center for Engineering Logistics and Distribution (CELDi) and the Deputy Director of the Center for Innovation in Healthcare Logistics (CIHL). His research interests include facility logistics, facility layout, material handling, supply chain design and operations research applications to healthcare logistics. Dr. Meller teaches courses in facility logistics and material handling. He joined the faculty in 2005.

**Education:**

Ph.D. (University of Michigan)  
M.S.I.O.E. (University of Michigan)  
B.S.I.O.E. (University of Michigan)



**Heather Nachtmann,  
Ph.D.,  
Associate Professor**

Dr. Nachtmann serves as the Director of the Mack-Blackwell Rural Transportation Center. Her research interests include economic decision analysis, cost estimation, intermodal transportation networks and engineering education. Dr. Nachtmann teaches courses in the areas of engineering economy, cost and financial engineering, and operations research. She joined the faculty in 2000.

**Education:**

Ph.D. (University of Pittsburgh)  
M.S.I.E. (University of Pittsburgh)  
B.S.I.E. (University of Pittsburgh)



**Chang S. Nam,  
Ph.D., CHFP,  
Assistant Professor**

Dr. Nam's research interests include haptic virtual environments, brain-computer interface, cognitive and cultural ergonomics, and intelligent human-computer interaction. Dr. Nam teaches courses in human factors and ergonomics. He joined the faculty in 2004.

**Education:**

Ph.D. (Virginia Tech)  
M.S.I.E. (SUNY at Buffalo)  
M.A.B.A. (Sogang University)  
B.S.I.E. (SungKyunKwan University)



**Sandra C. Parker,  
Ph.D.,  
Professor Emeritus**

Dr. Parker teaches courses in operations research, project management and engineering management. She served as the Director and Chair of Studies for our operations management program until her retirement in 2007. She continues to teach in the operations management program.

**Education:**

Ph.D. (University of Arkansas)  
M.S. Anthropology (University of Arkansas)  
B.S. Natural Sciences (University of Arkansas)



**Edward A. Pohl**  
**Ph.D.,**  
**Associate Professor**

Dr. Pohl's research interests include repairable systems, large-scale systems engineering and analysis, probabilistic design, risk and reliability, and engineering optimization. He teaches courses in quality control, engineering statistics, non-linear programming, heuristics, risk modeling, systems engineering and management. He is the current Director and Chair of Studies for the operations management program and has been selected as the next John L. Imhoff Chair in Industrial Engineering. Dr. Pohl joined the faculty in 2004.

**Education:**

Ph.D. (University of Arizona)

M.S. Reliability Engineering (University of Arizona)

M.S. Systems Engineering (Air Force Institute of Technology)

M.S. Engineering Management (University of Dayton)

B.S.E.E. (Boston University)



**Sarah E. Root,**  
**Ph.D.,**  
**Assistant Professor**

Dr. Root's research interests are in defining, modeling, and solving applied large-scale optimization problems. She is particularly interested in the application of optimization tools to problems encountered in healthcare and logistics. She teaches courses in operations research and service systems engineering. Dr. Root joined the faculty in 2007.

**Education:**

Ph.D. (University of Michigan)

B.S.I.E. (University of Pittsburgh)



**Manuel D. Rossetti,**  
**Ph.D., PE.,**  
**Associate Professor**

Dr. Rossetti serves as the Chair of Undergraduate Studies. His research is focused on the design, analysis and optimization of transportation, inventory, healthcare and manufacturing systems, using stochastic modeling, computer simulation, information systems and heuristic modeling techniques. He teaches courses in the areas of probability modeling, discrete event simulation, object-oriented and database systems, transportation/logistics modeling, and inventory modeling. Dr. Rossetti joined the faculty in 1999.

**Education:**

Ph.D. (The Ohio State University)

M.S.I.S.E. (The Ohio State University)

B.S.I.E. (University of Cincinnati)



**John A. White,**  
**Ph.D., PE.,**  
**Chancellor & Distinguished**  
**Professor**

In addition to being the Chancellor of the University of Arkansas, Dr. White is both a distinguished alumnus and faculty member of the Industrial Engineering Department. He is a member of the National Academy of Engineers and a recipient of the Frank and Lillian Gilbreth Industrial Engineering Award, the highest award conferred by the Institute of Industrial Engineers (IIE). Dr. White teaches engineering economics.

**Education:**

Ph.D. (The Ohio State University)

M.S.I.S.E. (Virginia Tech)

B.S.I.E. (University of Arkansas)

Dr. White also holds honorary degrees from the Katholieke Universiteit of Leuven in Belgium and George Washington University.

# RESEARCH

The faculty of the Industrial Engineering Department at the University of Arkansas is engaged in a wide variety of research endeavors. This section of our annual report features a sampling of faculty research initiatives in the areas of healthcare delivery and transportation & logistics. Also highlighted is the newly formed Reliasoft Risk, Reliability, and Maintainability Research Alliance, a corporate partnership designed to foster research and student involvement in the areas of risk analysis and reliability/maintainability engineering.

## Healthcare Delivery

Healthcare in the United States is a paradox of breath-taking advances in medical research, paired with treatment that is delivered with inconsistent quality, safety, efficiency and access, even as delivery costs continue to escalate uncontrollably. These healthcare delivery shortfalls are neither acceptable nor sustainable, and they present many exciting opportunities for contributions by industrial engineers.

While dramatic improvement is needed in nearly every aspect of healthcare delivery, the restructuring of healthcare supply chain and logistic systems represents an opportunity to recover very significant costs and achieve new efficiencies that will lead to a more transparent, cost-accountable healthcare industry for America. After wages and benefits costs, the procurement, manufacture, distribution, storage, and clinical utilization of healthcare materials comprises the healthcare industry's greatest expense. It is conservatively estimated that some \$11 billion per year in uncaptured cost savings are currently embedded in the healthcare industry's supply chain and delivery systems alone. Of equal importance is the fact that addressing supply chain and logistic mechanisms can have a direct effect on improving the safety and quality of patient care by reducing confusion that takes provider time away from patients and leads to dangerous errors.

## Center for Innovation in Healthcare Logistics



Drawing on its rich expertise in supply chain and logistics engineering, the University of Arkansas, led by its Department of Industrial Engineering, launched in 2007 a major collaboration with a number of industrial and healthcare partners to address some of the critical challenges in healthcare supply chain and delivery systems. The new Center for Innovation in

Healthcare Logistics, or CIHL (pronounced "kyle"), will lead a nationwide effort to identify and foster systemic adoption of ground-breaking healthcare supply chain and logistic innovations that cost-effectively put the right materials in the hands of caregivers when and where they are needed. The Center's goal is to recover significant costs and achieve new efficiencies, while enhancing safety, quality and equity of patient care.

Recognizing that hospitals and other large clinics have often been slow to adopt the collaborative, IT-intensive solutions that have revolutionized supply chain operations in many other industries, CIHL will target supply chain and material flow aspects of healthcare operations that can be addressed with better information and with improved logistics systems and processes.

CIHL was made possible by the interest and support of a variety of industrial and healthcare partners. Building on a pioneering commitment by Wal-Mart, the strategic partners who sustain and set directions for the Center now include three regional Blue Cross Blue Shield organizations, and the VHA volunteer hospital supply chain network. Procter and Gamble and IBM are also affiliated with the Center, as are leading organizations in healthcare logistics such as the Association for Healthcare Resource & Materials Management (AHRMM) and the Strategic Marketplace Initiative



(SMI), a partnership of healthcare supply chain executives. CIHL is also working with a growing number of healthcare provider networks where innovations will ultimately be implemented.



Drs. Ronald Rardin (left) and Russell D. Meller (right) inaugurate the new CIHL headquarters.

The Center has grown to have sustaining support for approximately 5 years at over \$600K annually, and a headquarters office has been provided by the College of Engineering. CIHL employs a team of outstanding faculty and graduate students from the College of Engineering and the Walton College

of Business, including approximately 10 faculty members, 7 graduate students, and a Program Assistant. Ronald L. Rardin, John and Mary Lib White Distinguished Professor of industrial engineering, is Director of the Center, and Russell D. Meller, Hefley Professor of industrial engineering, is Deputy Director.

## CIHL Approach and Initial Projects

CIHL approaches the task of shaping and fostering adoption of innovations in healthcare logistic by

- Highlighting and replicating proven best practices that already benefit some patients and providers;
- Seeking opportunities to adapt logistics and supply chain solutions from other industries to the healthcare arena; and
- Conducting Center research to bridge gaps and overcome roadblocks to progress.

Prior work on healthcare logistics innovations has too often produced “one-of,” single-site successes that go unadopted and in many instances,

unsustained even at the original site. To avoid this trap, CIHL projects seek broader solutions that can be replicated and scaled, making them adaptable to multiple settings. Training and decision-making aids are also planned to help make the business and healthcare cases for preferred solutions and to facilitate their systemic adoption.

Following this vision of industry-wide impact, the fall 2007 partners’ meeting agreed to initiate CIHL efforts with 3 projects.

- Unit and Dose Packaging Systems Analysis (PI Dr. Russ Meller, CoPI’s Drs. Scott Mason and Sarah Root) focuses on improving efficiency and reducing errors in repackaging pharmaceuticals as they pass from bulk quantities, produced by manufacturers to the unit or course-of-treatment dosages, needed by patients. Opportunities include exploiting economies of scale through centralized and third-party processing.



This small-scale medication repackaging device is used in single hospitals to create unit doses from bulk-packaged medicines for distribution to patients. It illustrates the “cottage industry,” human-operator-heavy feel prevalent in today’s healthcare delivery system. More automation and centralization can improve both the efficiency and accuracy of such processes.



As illustrated by this “pump army,” hospitals maintain large stocks of expensive portable clinical equipment. Better management can reduce procurement and maintenance costs for such equipment, and more importantly, prevent long searches by clinical personnel for an available device through the application of information technology that tracks and manages device availability.

- Receiving to Patient Hospital Supply Chain Digitalization (PI Dr. Ron Rardin, CoPI's Drs. Nebil Buyurgan and Craig Thompson) addresses supply chains inside hospitals and large clinics that are often fragmented, manual and *ad hoc*, and that make relatively little use of technology to track and manage stocks of materials and equipment. Central targets are processes for managing portable clinical equipment, as well as the tracking and control of inventories of high-value implantable devices.
- Identifying Opportunities for Cost & Quality Improvements in Healthcare Logistics (PI Dr. Heather Nachtmann, CoPI Dr. Ed Pohl with involvement from AHRMM) updates and expands often referenced, but out-of-date, assessments of the cost savings and quality improvements available in different parts of healthcare supply chains. The goal is both to guide future CIHL project selection and to offer independent documentation of the size of the healthcare logistics opportunity that can empower materials managers in assembling the needed investment resources for adopting preferred solutions.

Results and deliverables from these projects are expected by the end of 2008.

## Transportation and Logistics

The University of Arkansas has a longstanding tradition of conducting advanced research and educational programs in the area of transportation & logistics. Through participation in the Center for Engineering Logistics and Distribution (CELDi) our department has received millions of dollars for industry-funded research on a wide range of issues related to logistics engineering and transportation. The department also receives substantial funding for logistics and transportation research from the Mack-Blackwell Rural Transportation Center (MBTC).

### Center for Engineering Logistics and Distribution

CELDi is a multi-university, multi-disciplinary National Science Foundation sponsored Industry/University Cooperative Research Center (I/UCRC), headed by Dr. Russell D. Meller of our faculty. The center was created to provide integrated solutions to logistics problems through research related to modeling, analysis and intelligent-systems technologies. In the last year, the center added Virginia Tech and the University of Missouri to its list of academic partners. These universities join existing CELDi members: the University of Arkansas, the University of Louisville, Oklahoma State University, the University of Oklahoma, Lehigh University, Texas Tech University and Clemson University.

Faculty members of the Department of Industrial Engineering at the University of Arkansas bring their expertise to the partnership in the areas of material handling systems, logistics network optimization, simulation of logistics systems, analysis of spare-parts logistics systems and logistics systems performance measurement. The more than 30 member organizations of CELDi drive the research endeavors of the center. During 2007, our faculty obtained over \$750,000 in research funding from CELDi and its member organizations. More information can be found at the center's web site: [www.celdi.ineg.uark.edu](http://www.celdi.ineg.uark.edu).

### Mack-Blackwell Rural Transportation Center

In 2007, Dr. Heather Nachtmann of our faculty was appointed director of the Mack-Blackwell Rural Transportation Center (MBTC). MBTC is a U.S. Department of Transportation funded interdisciplinary research center,

headquartered in the Department of Civil Engineering at the University of Arkansas. By contributing to better road, waterway, rail and airway systems in rural areas, MBTC helps to move people and goods to their destinations more efficiently and economically. MBTC has become a national center for excellence in transportation infrastructure design and maintenance, in traffic/logistics planning and management, in transportation policy and in the effects of transportation on social and economic conditions. The center was recently selected as a National Transportation Security Center of Excellence. Institutions that make up the NTSCOE are funded by the federal government to conduct research that will improve the security of America's transportation systems. MBTC sponsors interdisciplinary research in all modes of transportation at the University of Arkansas and other institutions. All research funding is matched dollar-for-dollar by federal, state or industry sources. MBTC-sponsored projects are required to involve graduate and/or undergraduate students, thus giving many students from our department the opportunity to gain research experience. More information may be found at the center's web site [www.mackblackwell.org](http://www.mackblackwell.org).

The department's 2007 in-force research awards, together with industry and state matching funds, exceeded \$600,000. The research described below is one MBTC project undertaken by our faculty and graduate students last year.

### A Nationwide High-Speed Rail Network for Freight Distribution

Russell D. Meller, Ph.D. and Jen Pazour, a graduate student in Industrial Engineering at the University of Arkansas, think they know a way to address the problem of rapidly growing congestion on America's highways. Highway congestion today results in an estimated cost of \$7.8B in lost productivity annually and is expected to grow. To alleviate congestion issues, it has often been recommended that the United States should build more high-speed passenger rail capacity. However, since passenger traffic shares highways with freight traffic, the researchers examined an alternate approach to alleviating congestion; namely, removing freight traffic from our highways through the development of a national high-speed network for freight distribution. Meller and Pazour were assisted in their work by Letitia Pohl, another graduate student in the Department, and Kevin





Model of a 20,000-mile nationwide high-speed rail network, developed by researchers Meller et al as part of a study on new approaches to relieving highway congestion and expediting freight distribution across the United States.



The 19-mile Chinese Maglev line serving Shanghai Airport has been fully operational since 2002.

Gue of Auburn University under the auspices of a Mack-Blackwell Rural Transportation Center research project.

In addition to reducing highway congestion, a high-speed rail network, utilizing technologies such as magnetic levitation (i.e., Maglev), would also afford benefits in terms of fuel-efficiency and lower emissions -- both highly important objectives, given the unprecedented cost of fuel and the importance placed on environmental and "green" initiatives. Maglev trains are levitated above rails via magnetic fields for nearly frictionless travel and are currently being employed in China, Germany and Japan. The Yamanashi Maglev Test Line in Japan runs 42.8 km between Sakaigawa and Akiyama, achieving a top speed of 500 kph, while the Shanghai Airport line has been fully operational since 2002 with 99.9% uptime. With a decided speed advantage over traditional highway-based freight distribution, such a network would be commercially attractive, especially for "truckload" distribution, even on a network that is significantly smaller than the current interstate highway system.

The specific objective of Meller *et al's* research was to explore the maximum impact of instituting a high-speed rail network for freight distribution. This research utilized the results of technology-feasibility tests and addressed the problem of designing such a network, as well as analyzing its maximum impact on the current highway system. The model created by the researchers showed that with sufficient capacity and associated investment, a high-speed network for freight distribution will have a significant impact on freight transit times and on highway congestion, with the potential to address many of the challenges facing transportation today. For example, a 20,000-mile network (approximately half the length of the present U.S. interstate highway system) that utilizes current Maglev technology and proposed 6-minute headways would make it advantageous for a majority of the freight traffic to utilize the high-speed network. And although such a network would require a significant investment of \$760B - \$2.8T (using current cost estimates of \$38M - \$140M per mile), this investment would lead to an estimated 38% reduction in overall freight transit times. Perhaps more importantly to the public, it would also precipitate a net 78% decrease in annual total truck highway miles driven.

## ReliaSoft Risk, Reliability and Maintainability Alliance

ReliaSoft Corporation donated over \$700,000 in cash and software to the University of Arkansas in 2007 to form and support the ReliaSoft Risk, Reliability, and Maintainability Research Alliance (R<sup>3</sup>MRA). The purpose of this research alliance is to provide integrated solutions to complex risk, reliability, and maintainability problems for commercial, military and government applications through modeling, simulation, and analysis.

Drs. Edward A. Pohl (Director), C. Richard Cassady (Associate Director), and Justin Chimka, all of the U of A Department of Industrial Engineering, are the current academic associates of the ReliaSoft Research Alliance. The alliance is designed to facilitate interaction between industry and academia and to serve as a conduit for sharing research problems and solutions among members. Industry members of the alliance bring relevant problems and some level of financial resources to the alliance, while the academic members of the alliance facilitate the partnership and leveraging of resources among university researchers. The objective is to bring systematic research efforts to bear on problems of interest to all alliance members. The vision for this research alliance is to develop an internationally recognized center of excellence in the area of Risk, Reliability and Maintainability, modeled on the Industry/University Cooperative Research Centers (I/UCRC) that are sponsored by the National Science Foundation.

The rationale for a research alliance that is focused on questions of risk, reliability and maintainability can be summarized as follows:

- Reliability and maintainability are critical elements for all engineering systems. Because of rapid advances in technology the level of complexity of engineering systems has been growing exponentially. As complexity increases, the tools and techniques necessary to ensure reliability and maintainability must continue to increase.
- Since the events of September 11, 2001, risk analysis has acquired new importance in the field of engineering systems design. As a result, the design paradigm of all systems must be expanded to include considerations of risk and vulnerability.

- The technical workforce is graying and the “baby boom” generation is fast approaching retirement age. In addition to a growing shortage of engineers in general, risk, reliability and maintainability engineers will soon be in particularly short supply, given that most new entrants to the profession came to it during the establishment of the space program in the 60’s and the military buildup of the 70’s and 80’s. Therefore, another goal of this alliance is to define and provide educational solutions in risk, reliability and maintainability as a service to industry.

The initial donation of software by ReliaSoft is intended to provide engineering students with state-of-the-art tools to help identify potential risks and calculate the severity of disruptions within a manufacturing or transportation environment. The cash portion of the donation will be used to purchase computing equipment to create the collaborative research and learning center in the areas of risk, reliability and maintainability, described above. In addition, the grant will be used to “seed” graduate and undergraduate research in the alliance’s focus areas.



ReliaSoft Corporation Chief Executive Officer, Pantelis Vassiliou (center) and Vice President, Doug Ogden (far right), present a larger than life check, representing their company's significant funding of the new Risk, Reliability and Maintainability Research Alliance. Accepting the donation for the U of A are (left to right), Dr. Russell D. Meller, COE Dean Ashok Saxena and R<sup>3</sup>MRA Director Dr. Ed Pohl.

# PUBLICATIONS

The faculty of the Department of Industrial Engineering at the University of Arkansas published one book, contributed chapters to 5 textbooks or handbooks, saw the publication of 23 refereed journal articles and made 30 contributions to refereed conference proceedings and other refereed publications during 2007.

The following is a list of these publications. Faculty members' names are shown in bold face type.

## Textbooks

Konz, S. and **S.L. Johnson**. *Work Design: Occupational Ergonomics*. Scottsdale, AZ: Holcomb-Hathaway, 2007.

## Chapters in Textbooks or Handbooks

**Johnson, S.L.** *Work Design: Occupational Ergonomics – Instructors Manual*. Scottsdale, AZ: Holcomb-Hathaway, 2007.

**Pohl, E.** "System Effectiveness." *Systems Decision Making for Systems Engineering and Management: Fall 2007 Edition*, New York, NY, 2007.

**Pohl, E.** and **H. Nachtmann**. "Life Cycle Costing." *Systems Decision Making for Systems Engineering and Management: Fall 2007 Edition*, New York, NY, 2007.

**Pohl, E.**, T. Yeung, and **C.R. Cassady**. "Maintainability and Supportability in Logistics." *Logistics Engineering Handbook*, Boca Raton, FL, 2007.

**Rardin, R.**, Langer, M., and A. Tuncel. "Optimal Planning for Radiation Therapy." *Optimization in Medicine and Biology*, Oxford, UK, 2007.

## Refereed Journal Articles

**Buyurgan, N.**, M.A. Ertem and **J.R. Chimka**. "Read Rate Analysis of RFID Systems for Business Applications." *International Journal of RFID Technology and Applications*, Vol. 1, No. 2, 147-163, 2007.

**Buyurgan, N.**, L. Meyyappan, C. Saygin, and C.H. Dagli. "Real-Time Routing Selection for Automated Guided Vehicles in a Flexible Manufacturing System." *Journal of Manufacturing Technology Management*, Vol. 18, No. 2, 169-181, 2007.

**Cassady, C.R.**, T.G. Yeung, and **E.A. Pohl**. "Allocating and Deploying Maintenance Resources for a Set of Multi-State Systems." *Military Operations Research*, Vol. 12, No. 1, 19-34, 2007.

**Cassady, C.R.**, E. Cakici, J. Jia, **S.J. Mason**, L.M. Pohl, and A.J. Lachowsky. "Cellar Tank Piping Network Analysis at E. & J. Gallo Winery." *Journal of Wine Research*, Vol. 17, No. 3, 145-160, 2007.

**Cassady, C.R.**, S. Salman, **E.A. Pohl**, S.W. Ormon. "Evaluating the Impact of Cannibalization on Fleet Performance." *Quality and Reliability Engineering International*, Vol. 23, No. 4, 445-447, 2007.

**Cassady, C.R.** and N. Sortrakul. "Genetic Algorithms for Total Weighted Expected Tardiness Integrated Preventive Maintenance Planning and Production Scheduling for a Single Machine." *Journal of Quality in Maintenance Engineering*, Vol. 13, No. 1, 49-61, 2007.

**Cassady, C.R.**, T. Yeung, and **E.A. Pohl**. "Multi-State Selective Maintenance Decisions." *Journal of Military Operations Research*, Vol. 12, No. 1, 19-34, 2007.

**Chimka, J.R.** and **H. Nachtmann**. "Operational Readiness as a Function of Maintenance Personnel Skill Level." *Air Force Journal of Logistics*, Vol. 31, No. 3, 45-51, 2007.



**Chimka, J.R.**, T. Reed-Rhoads and K. Barker. "Proportional Hazards Models of Graduation." *Journal of College Student Retention*, Vol. 9, No 2, 221-232, 2007.

**Chimka, J.R.** and P.V. Cabrera-Arispe. "Type II Errors of Demerits Control Charts." *Quality Engineering*, Vol. 19, No. 3, 207-214, 2007.

**Mason, S.J.**, R. Swaminathan, M.E. Pfund, J.W. Fowler, and A. Keha. "Impact of Permutation Enforcement When Minimizing Total Weighted Tardiness in Dynamic Flowshops with Uncertain Processing Times." *Computers & Operations Research*, Vol. 34, No. 10, 3005-3068, 2007.

**Mason, S.J.**, E. Cakici. "Parallel Machine Scheduling Subject to Auxiliary Resource Constraints." *Production Planning & Control*, Vol. 18, No. 3, 217-225, 2007.

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**Nam, C.S.** and T.L. Smith-Jackson. "Web-Based Learning Environment: A Theory-Based Design Process for Development and Evaluation." *Journal of Information Technology Education*, Vol. 6, 23-43, 2007.

**Nam, C.S.** and D. Chung. "An Analysis of the Variables Predicting Instant Messenger Use." *New Media and Society*, Vol. 9, No. 2, 212-234, 2007.

**Rardin, R.**, S. Witz, L. Schwarz, J. Pekny, B. Caldwell, S. Chand, B. Cleveland, E. Lukesh, J. McGlothlin, D. McKinnis, H. Moskowitz, K. Musselman, J. Novak, B. Peine, R. Ramanujam, R. Uzsoy, J. Wang, P. Whitten, R. Widdows, Y. Yih, and A. Kak. "The Regenstrief Center for Healthcare Engineering: Designing, Implementing, and Sustaining Interdisciplinary Solutions to Transform Healthcare-Delivery Systems." *International Journal of Healthcare Technology and Management*, 399-416, 2007.

**Rardin, R.**, Uzsoy, R., J. Clement, J. Pekny, S. Orcun, and J. Asmundsson. "Supply Chain Optimization and Protocol Environment (SCOPE) for Rapid Prototyping and Analysis of Complex Supply Chains." *Production Planning and Control*, Vol. 18, No. 5, 388-406, 2007.

**Rardin, R.**, X. Qu, J.A. Williams, and D. Willis. "Matching Healthcare Provider Capacity to Demand in Advance Access Scheduling Systems." *European Journal of Operational Research*, Vol. 183, No. 2, 812-826, December 2007.

**Root, S.**, A. Cohn, A. Wang, and D. Mohr. "Integration of the Load Matching and Routing Problem with Equipment Balancing for Small Package Carriers." *Transportation Science*, Vol. 41, No. 2, 238-252, May 2007.

**Root, S.**, P. Hughes-Cromwick, and C. Roehrig. "Consumer-Driven Healthcare: Information, Incentives, Enrollment, and Implications for National Health Expenditures." *Business Economics*, Vol. 42, No. 2, 43-58, April 2007.

**Rossetti, M.D.** and M.H. Al-Rifai'. "An Efficient Heuristic Optimization Algorithm for a Two-Echelon (R, Q) Inventory System." *International Journal of Production Economics*, Vol. 109, No. 1-2, September 2007.

## Refereed Conference Proceedings and other Refereed Publications

**Buyurgan, N.**, J.R. English, L. Yu, and **M.D. Rossetti**. "A Statistical Process Control Approach to Cycle Counting." *International Conference on Flexible Automation and Intelligent Manufacturing*, Philadelphia, PA, June 2007.

**Buyurgan, N.**, A. Mendoza, and J.R. English. "Availability of Powered Roller Conveyors." *International Conference on Flexible Automation and Intelligent Manufacturing*, Philadelphia, PA, June 2007.

**Buyurgan, N.**, **M.D. Rossetti**, S. Gumrukcu, and J.R. English. "Inventory Accuracy Improvement via Cycle Counting in a Two-Echelon Supply Chain." *Proceedings of the 2007 IIE Annual Conference*, Nashville, TN, May 2007.

**Buyurgan, N.**, A. Mendoza, and J.R. English. "Predicting Reliability of Powered Roller Conveyors via Artificial Neural Networks." *Proceedings of the 2007 IIE Annual Conference*, Nashville, TN, May 2007.

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**Cassady, C.R.** "Introduction to Repairable Systems Modeling." *Tutorial Notes of the 2007 Reliability and Maintainability Symposium*, Orlando, FL, January 2007.

**Cassady, C.R.**, and Y. Xiang. "Time to Failure Behavior under a Stochastic Deterioration Model." *Proceedings of the Annual Reliability and Maintainability Symposium*, Orlando, FL, January 2007.

**Cassady, C.R.**, and Y. Xiang. "Comparing Scheduled and Condition-Based Maintenance Policies for Single-Unit Systems Operated in Markovian Environments." *Proceedings of the 2007 IIE Annual Conference*, Nashville, TN, May 2007.

**Cassady, C.R.**, K. Schneider, and L.M. Maillart. "The Re-Use of Single-Use Medical Devices." *Proceedings of the 2007 IIE Annual Conference*, Nashville, TN, May 2007.

**Johnson, S. L.** "Analysis of Heavy Truck and Automobile Speed Distributions for Uniform and Differential Speed Limit Configurations on Interstate Highways." *Transportation Research Board (TRB) Annual Meeting*, Washington, D.C., January 2007.

**Mason, S.J.**, M.E. Kurz, M.E. Pfund, J.W. Fowler, L.M. Pohl. "Multi-Objective Semiconductor Manufacturing Scheduling: A Random Keys Implementation of NSGA-II." *Proceedings of the 2007 IEEE Symposium on Computational Intelligence in Scheduling (CI-Sched 2007)*, Oahu, HI, April 2007.

**Mason, S.J.**, Y. Unlu. "Optimizing Tank Selection and Operations Scheduling at a Large Winery." *Proceedings of the 2007 IIE Annual Conference*, Nashville, TN, May 2007.

**Meller, R.D.**, L.M. Pohl, and K.R. Gue. "An Evaluation of Two New Warehouse Aisle Designs for Dual-Command Travel." *Proceedings of the 2007 IIE Annual Conference*, Nashville, TN, May 2007.

**Meller, R.D.** and P.J. Parikh. "Modeling Pick-Face Blocking in an Order-Picking System." *Proceedings of the 2007 IIE Annual Conference*, Nashville, TN, May 2007.

**Mason, S.J.** and W. Li. "Comparison of Simulation-Based Schedule Generation Methodologies for Semiconductor Manufacturing." *Proceedings of the 2007 IIE Annual Conference*, Nashville, TN, May 2007.

**Mason, S.J.** and J. Jampani. "Complex Job Shop Multiple Orders per Job Scheduling." *Proceedings of the 3rd Multidisciplinary International Conference on Scheduling*, Paris, France, August 2007.

**Nam, C.S.**, H. Shimizu, J. Murayama, M. Sato, and H. Sato. "Learning Tool Aided by Haptics for Intermolecular Understanding." *NICOGRAPH International Conference*, Toyota, Japan, 2007.

**Nam, C.S.**, Y.S. Ryu, and T.L. Smith-Jackson. "Web-Based Instruction for High School Students: Exploration of Individual and Cultural Learning Styles." *Proceedings of the IASTED International Conference on Web-based Education*, 391-394, Chamonix, France, 2007.

**Nam, C.S.** and J. Soeffner. "Co-Presence in Shared Virtual Environments: Avatars Beyond the Opposition of Presence and Representation." *Human-Computer Interaction, Part I, HCII 2007, Lecture Notes in Computer Science*, Series 4550, 949-958, 2007.

**Nam, C.S.**, D. Chung, and B.D. deBuys. "Influence of Avatar Creation on Attitude, Empathy, Presence, and Para-Social Interaction." *Human-Computer Interaction, Part I, HCII 2007, Lecture Notes in Computer Science*, Series 4550, 711-720, 2007.

**Nam, C.S.**, A. David, B. Piuze, and D. Chung. "Guidelines for the Development and Improvement of Universal Access Systems for Blind Students." *Universal Access in HCI, Part I, HCII 2007, Lecture Notes in Computer Science*, Series 4554, 603-612, 2007.

**Nam, C.S.**, S. Konomi, T. Saito, T. Shimada, Y. Harada, and K. Sezaki. "Designing for Usability and Safety in RFID-Based Intelligent Commuting Environments." *International Conference on Machine Learning and Cybernetics*, 2106-2111, Hong Kong, 2007.

**Nam, C.S.**, J. Murayama, H. Shimizu, and M. Sato. "An Educational Environment for Chemical Contents with Haptic Interaction." *International Conference of Cyberworlds*, Hannover, Germany, October 2007.

**Pohl, E.A.** and **C.R. Cassady**. "Repairable Systems Modeling." *The 2007 Applied Reliability Symposium*, Frankfurt am Main, Germany, April 2007.

**Pohl, E.A.** and D.L. Dietrich. "Introduction to Environmental Stress Screening." *Tutorial Notes of the 2007 Applied Reliability Symposium*, San Diego, CA, June 2007.

**Pohl, E.A.**, Y. Liu, J.R. English. "Application of Gene Expression Programming in the Reliability of K-out-of-N Systems with Identical Components." *Proceedings of the International Conference on Intelligent Computing*, D. Huage, and L. Houtte, M. Loogs (eds.), 217-224, Qing Dao, China, August 2007.

**Rardin, R.**, Z. Yu, J. Oberbeck, and F. Holland. "Modeling Regional CO2 Control Energy Production with Cap and Trade Regulation." *IEEE Power Engineering Systems*, Tampa, FL, June 2007.

**Rossetti, M.D.** and Nangia, S. "An Object-Oriented Framework for Simulating Full Truckload Transportation Networks." Accepted for publication in *The Proceedings of the 2007 Winter Simulation Conference*, S.G. Henderson, B. Miller, M.H. Hsieh, J. Shortle, J.D. Tew, and R.R. Barton, eds., Piscataway, New Jersey: Institute of Electrical and Electronic Engineers, 2007.

**Rossetti, M.D.** and V. Desai. "Evaluating Clustering Methods for Multi-Echelon (r, Q) Policy Setting." *Proceedings of the 2007 IIE Annual Conference*, Nashville, TN, May 2007.

**Rossetti, M.D.** and M. Al-Rifai. "Evaluating Performance Measure Approximations for a Two-Echelon (R, Q) Inventory System via Simulation." *Proceedings of the 2007 IIE Annual Conference*, Nashville, TN, May 2007.



# GRANTS

During 2007, the following research grants were in force for the faculty. Project PIs are indicated in bold face type.

**Buyurgan, Nebil**, Air Force Office of Scientific Research, \$72,173, "AutoID Technologies in Intransit and Total Asset Visibility," 2006-2008

**Buyurgan, Nebil**, State of Arkansas Undergraduate Research Fellowship Program, \$2,650, "Robustness of Statistical Process Control," 2007

**Buyurgan, Nebil**, and Justin Chimka, National Science Foundation, \$149,709, "Integrated Auto-ID Technology for Multidisciplinary Undergraduate Studies (I-ATMUS)," 2007-2009

**Cassady, Richard** and Edward Pohl, National Science Foundation/CELDi, \$20,000, "Research Experiences for Teachers," 2005-2008

**Cassady, Richard**, Edward Pohl, N.Z. Gebrael and J. Kharoufeh, Air Force Office of Scientific Research, \$148,727, "Adaptive Maintenance in a Sense-and-Respond Logistics Environment," 2006-2008

**Chimka, Justin**, Air Force Office of Scientific Research, \$79,238, "Improved Outbreak Detection for Bio Terror Response Logistics," 2006-2008

**Chimka, Justin** and Edward Pohl, Wal-Mart Stores/CELDi, \$45,000, "Bin Locating System," 2007-2008

**Fant, Earnest**, Red River Army Depot/CELDi, \$50,000, "Economic and Technical Feasibilities of Implementing Robotics in an Automotive Repair Environment," 2002-2008

**Fant, Earnest**, Red River Army Depot/CELDi, \$49,869, "Assessing Change Indicators in Activity, Equipment and Inventory for Automated Storage Facility," 2002-2008

**Johnson, Steven**, American Transportation Research Institute, \$49,000, "Investigation of Safety and Economic Impact of Speed Differentials Between Heavy Trucks and Automobiles," 2006-2008

**Johnson, Steven**, Mack-Blackwell Transportation Center, "Field Evaluation of Lane Departure Systems: Operational Effectiveness, Effect on Driver Behaviors and Managerial Use of Data to Assure Driver Acceptance," \$51,360, 2005-2008

**Johnson, Steven** and Chang Nam, Mack-Blackwell Transportation Center, \$41,471, "Development of a Human Performance Simulation Model to Evaluate In-Vehicle Information and Control Systems," 2004-2007

**Mason, Scott**, Sam's Club/CELDi, \$45,000, "Improving Retail Logistics through an Examination of Merchandise Flow," 2007-2008

**Mason, Scott**, National Science Foundation/CELDi, \$25,000, "Collaborative Research: A TIE Research Program on e-Design for Design of Supply Chain," 2007-2009

**Mason, Scott**, State of Arkansas, \$4,320, "SURF: Focused Research in Public School Transportation," 2007

**Mason, Scott** and Nebil Buyurgan, Air Force Office of Scientific Research, \$97,153, "Scheduling and Coordination of Disaster Relief and Deployment Operations," 2006-2008

**Mason, Scott**, Russell Meller, and Edward Pohl, Mack-Blackwell Transportation Center, \$49,501, "Routing Models for Rural Transportation Networks with Time-Varying Constraints," 2006-2008

**Mason, Scott** and Heather Nachtmann, Air Force Office of Scientific Research, \$140,151, "Integrated Distribution Planning and Forecasting for Medical Logistics," 2006-2008

**Meller, Russell**, Mack-Blackwell Transportation Center, \$81,678, "A Nationwide High-Speed Rail Network for Freight Distribution," 2006-2008

**Meller, Russell**, National Science Foundation, \$647,016, "CELDi Center Administration," 2002-2009

**Meller, Russell**, National Science Foundation, \$238,797, "Designing Distribution Centers for a Service Economy," 2006-2009

**Meller, Russell**, National Science Foundation, \$221,973, "A Sequence-pair and MIP-Based Facility Layout Algorithm," 2006-2009

**Meller, Russell**, National Science Foundation, \$23,920, "An Engineering Virtual Organization for Discrete-Event Logistics Systems," 2007-2009

**Nachtmann, Heather**, State of Arkansas, \$40,000, "Ancillary Benefits of the Ouachita River Navigation System," 2005-2007

**Nachtmann, Heather**, Port of Greater Cincinnati Development Authority, \$8,998, "Economic Evaluation of the Impact of Waterways on the Port of Cincinnati," 2006-2007

**Nachtmann, Heather**, Richard Cassady, and Edward Pohl, Mack-Blackwell Transportation Center, \$28,925, "Homeland Security for Rural Transportation Networks," 2007-2008

**Nachtmann, Heather**, Chang Nam, Justin Chimka, and Nebil Buyurgan, Air Force Office of Scientific Research, \$390,567, "Cognitive Decision Support in a Sense and Respond Logistics Environment," 2005-2007

**Nachtmann, Heather**, Edward Pohl, and Richard Cassady, Mack-Blackwell Transportation Center, \$48,922, "Homeland Security for Rural Transportation Networks," 2006-2007

**Nam, Chang**, Air Force Office of Scientific Research, \$120,924, "Experimental Evidence on Team Coordination and Collaboration within a Distributed Medical Logistics Network," 2006-2008

**Nam, Chang**, and Tonya Smith-Jackson, National Science Foundation, \$570,028, "I FEEL SCIENCE: Innovative Flexible Experimental Environment for Learning in SCIENCE," 2007 - 2010

**Nam, Chang** and Joon J. Song, Mack-Blackwell Transportation Center/Arkansas State Highway & Transportation Department, \$160,004, "A Model-Based Risk Map for Roadway Traffic Crashes," 2006-2007

**Pohl, Edward**, Air Force Research Laboratories/CELDi, \$133,560, "Decision Support for Logistics Response to Chemical, Biological, or Radiological Attacks," 2006-2008

**Pohl, Edward**, National Science Foundation/CELDi, \$35,925, "Information Product Quality in a Network Centric Environment," 2004-2008

**Pohl, Edward**, Mack-Blackwell Transportation Center, \$35,845, "Modeling, Assessing and Managing Risk in Transportation Systems," 2004-2007

**Pohl, Edward** and Richard Cassady, National Science Foundation/CELDi, \$20,000, "Research Experiences for Teachers," 2005-2008

**Pohl, Edward** and Russell Meller, Air Force Office of Scientific Research, \$178,442 "A Human Centered Approach to Sense and Respond Logistics," 2006-2008

**Rardin, Ronald**, Russell Meller, Scott Mason, Sarah Root, Nebil Buyurgan, Manuel Rossetti, Heather Nachtmann, and Edward Pohl, Corporate Sponsors of the Center for Innovation in Healthcare Logistics, \$2,250,000, (All projects), 2007-2012

**Rossetti, Manuel**, National Science Foundation, \$50,000, “CELDi/CHMR TIE Project: Examining Inventory Allocation in the Health Care Value Chain,” 2004-2008

**Rossetti, Manuel**, National Science Foundation through CELDi, \$50,000, “Radio Frequency Identification and Productivity Improvements in Military Supply Chains,” 2004-2008

**Rossetti, Manuel** and Nebil Buyurgan, Wal-Mart, Inc./CELDi, \$50,000, “Improving Inventory Record Accuracy within Retail Store Operations,” 2005-2007

**Rossetti, Manuel**, Nebil Buyurgan, Richard Cassady, and Edward Pohl, Air Force Office of Scientific Research through CELDi, \$303,830, “Modeling and Simulation-Based Framework for Sense and Respond Logistics Concepts,” 2005-2007

**Rossetti, Manuel**, Fred Limp, and Edward Pohl, U.S. Department of Transportation, \$36,408, “Integration of Geographical Information Systems (GIS) and Logistics Planning Methods for Arkansas Rural Transportation Emergency Planning,” 2006-2007

**Rosetti, Manuel** and Heather Nachtmann, Mack-Blackwell Transportation Center, \$69,568, “WebShipCost ñ A Geographical Information System for Waterway Utilization,” 2003-2007

**Rossetti, Manuel** and Edward Pohl, Air Force Office of Scientific Research, \$119,577, “Developing and Evaluating Operationally Robust Forecasting Techniques in Military Logistics,” 2006-2008

**Rossetti, Manuel** and Edward Pohl, National Science Foundations, \$40,000, “An Intermittent Demand Forecasting Tool,” 2007



# PROFESSIONAL SERVICE AND RECOGNITION

Dr. Russell D. Meller took the award for best paper in the Facility Logistics Track at the 2007 Industrial Engineering Research Conference. The award for the paper, entitled “An Evaluation of Two New Warehouse Aisle Designs for Dual-Command Travel,” was presented at the May 2007, Institute of Industrial Engineers Awards Banquet in Nashville, TN. Co-authors were Letitia M. Pohl and Dr. Kevin Gue.

Dr. C.S. Nam’s paper, “Effects of Cultural Difference and Task Complexity on Team Interaction Process,” was awarded the distinction of best paper at the annual meeting of the Ergonomics Society of Korea.

The following is a record of our faculty’s service activity to national professional organizations and journals during 2007.

## **Buyurgan, N.**

- Chair, Society of Manufacturing Engineers, SME Senior Chapter 199
- Editorial Board, Journal of Materials and Manufacturing Processes
- Program Committee, Identity Solutions Symposium and Workshop
- Program Committee and Publication Chair First Annual RFID Eurasia Conference and Exhibitions

## **Cassady, C.R.**

- Member, Management Committee, RAMS
- Associate Editor, Journal of Risk and Reliability

## **Chimka, J.R.**

- Immediate Past Director, Quality Control and Reliability Engineering Division, Institute of Industrial Engineering

## **Mason, S.J.**

- Technical Vice President, Technical Networking, Institute of Industrial Engineers
- Member, Editorial Board, Applied Cost Modeling, Wright Williams & Kelly
- Program Co-Chair, 2008 Industrial Engineering Research Conference (IERC), Institute of Industrial Engineers
- Member, 2007 International Technology Roadmap for Semiconductors, Semiconductor Industry of America
- Co-Editor, 2008 Winter Simulation Conference Proceedings
- Associate Editor, IEEE Transactions on Electronics Packaging Manufacturing



**Meller, R.D.**

- Director, Center for Engineering Logistics and Distribution (an NSF/UCRC)
- Immediate Past President, College-Industry Council on Material Handling Education
- Chair, Facility Logistics Special Interest Group, Transportation Science and Logistics Society, INFORMS
- Editorial Board Member, Journal of Manufacturing Systems
- Member, 2008 IMHRC Planning Committee
- Member, 2007 IERC Program Committee (Facility Logistics Track)

**Nachtmann, H.**

- Area Editor, The Engineering Economist
- Immediate Past Director, Institute of Industrial Engineering - Engineering Economy Division
- Member, Wellington Award Selection Committee, Institute of Industrial Engineering - Engineering Economy Division
- Member of the Planning Committee, Transportation Research Board ñ UTC Spotlight Conference
- Member of Advisory Board, Identity Solutions Symposium

**Nam, C. S.**

- Member, Program Board, International Conference on Human-Computer Interaction
- Member, International Program Committee, The IASTED International Conference on Human-Computer Interaction (IASTED-HCI)
- Member, International Program Committee, The IASTED International Conference on Education and Technology (IASTED-ICET)
- Newsletter Editor, Cognitive Ergonomics and Decision Making (CEDM) Technical Group, Human Factors and Ergonomics Society
- Newsletter Editor, Virtual Environments (VE) Technical Group, Human Factors and Ergonomics Society

**Pohl, E.A.**

- Associate Editor, Journal of Military Operations Research
- Associate Editor, IEEE Transactions on Reliability
- Associate Editor, Journal of Risk and Reliability
- President, Military Applications Society of INFORMS
- Member, Management Committee, Program Committee, Annual Reliability and Maintainability Symposium
- NSF Panelist, EFRI Program, 2007

**Rardin, R.L.**

- Associate Editor, Operations Research
- Guest Associate Editor, IIE Transactions: Special Issue on Healthcare Engineering
- Fellow, Institute of Industrial Engineers

**Rossetti, M.D.**

- Co-Editor, 2009 Winter Simulation Conference Proceedings
- Associate Editor, International Journal of Modeling and Simulation
- NSF Panelist, SBIR Program, Information Technology Applications, 2006 – present
- Panelist, Research Grants Council, Hong Kong

# UNDERGRADUATE STUDIES

In the fall of 2007, 120 students were enrolled in our undergraduate program. While this number would appear to be lower than those of recent years, it is actually an artifact of the newly-constituted Freshman Engineering Program, headed by Dr. Richard Cassady of our department. The program provides a common academic foundation in engineering to all incoming freshmen before allowing them to major in a specific engineering discipline. Our undergraduate program, as most others in the College of Engineering, was therefore unable to claim an incoming freshman class. In its first year of operation the Freshman Engineering Program boasted 343 students. An update on the program is included in this section.

## 2007 Highlights

During the 2006-2007 academic year 44 BSIE degrees were granted. Members of the class of 2007 were hired by nationally recognized companies such as J.B. Hunt Transport, Lockheed-Martin, Raytheon, Wal-Mart, and Welch's. A number of students chose to remain at the University of Arkansas for graduate studies in Industrial Engineering and Business Administration. Other graduates are furthering their education at institutions, such as Georgia Tech, Cornell, and UA Medical School in Little Rock.

Awards and honors earned by undergraduates include the following:

Senior Josh Liu (advisor: Dr. Heather Nachtmann) was awarded a SURF grant for his honors thesis topic, "The Contributions of the Nobel Laureates in Economics." Two other advisees of Dr. Nachtmann, senior Seth Borin and senior Adam Keeley were also recipients of Honors College research grants.



Senior Jared Townsley (advisor: Dr. Edward Pohl) received a SURF grant for his honors thesis topic, "Multi-cultural Organizational Simulation of a Terrorism Network."

A team comprised of Seniors Frederick Denny, Meredith Griffin, Alex Natividad and Kelly Sullivan (team advisor: Dr. Russell Meller) took 3rd Place at the 2007-2008 Material Handling Student Design Competition which was sponsored by the College Industry Council on Material Handling Education and Modern Materials Handling magazine.

Senior Wen-Feng Li (advisor: Dr. Scott Mason) presented his research at the 2007 Industrial Engineering Research Conference in Nashville, TN.

Sophomore Coby Durham (advisor: Dr. Richard Cassady) presented his research at the First International Conference on Mathematical Modeling in Sport, held in Manchester, England, under the auspices of the Institute for Mathematics and its Applications.

Senior Abe Lachowsky (advisors: Drs. Scott Mason and Richard Cassady) co-authored an article that was published in the *Journal of Wine Research*.



Interim Department Head, Dr. Ronald Rardin (third from left) presents the IIE Gold Chapter Award to Chapter President Coby Durham. Flanking them are Dr. Justin Chimka (left) and Immediate Past President of the chapter, Wenfeng Li (right).

Seniors Laura Jordan and Roger Snelgrove received scholarships from the Institute of Industrial Engineers.

The Hytrol Challenge Award for Material Handling went to seniors Brent Carter and Sean O'Meara.

Crystal Wilson garnered the ABF Freight Systems Outstanding Freshman Award.

Cooper Power, FM Plastics, Sam's Club, Simmons Foods and UPS were some of the local companies that served as clients for our senior design course in 2007. This course draws on all prior courses in exposing the students to an integrated capstone design experience. The students work in teams to identify and solve real-life industrial engineering problems for their respective client organizations.

The department has an active student chapter of the Institute of Industrial Engineers (advisor: Dr. Justin Chimka). The chapter received the Gold Award in the 2007 IIE national chapter recognition competition.

The College of Engineering's Alpha Pi Mu chapter received second place in the national 2007-2008 Outstanding Chapter Competition. Kevin Oden and Stephanie Garman shared the presidency during the 2007-2008 academic year. Dr. Heather Nachtman serves as the Alpha Pi Mu faculty advisor.

## Program Overview

The goal of the Industrial Engineering Undergraduate Program at the University of Arkansas is to prepare men and women for professional careers and graduate studies in Industrial Engineering. We provide a foundation in mathematics, science, the humanities and social sciences, engineering science, and engineering design in order to produce Industrial Engineers with the intellectual, technical, and professional competence to develop, implement and manage industrial engineering solutions to complex industrial, governmental and societal problems.

Our program includes opportunities for study abroad, an optional cooperative work program and an honors program for qualified students. The study abroad program is administered through the Office of Study Abroad and International Exchange. The John L. Imhoff Global Studies

Endowment supports academic scholarships that help defray expenses incurred by industrial engineering students engaged in for-credit overseas study and/or an overseas work experience (internship or cooperative work program).

The aim of the University's cooperative education program is to provide interested students with opportunities to complement their engineering education with degree-related work experience. The work experience provides participants with opportunities to apply what they have learned in the classroom and to interact with experienced industrial engineers. Participants also gain insights into the industrial engineering profession that help them define their educational and career goals. In recent years, students from our department have participated in cooperative work experiences at Ayrshire, Boeing, Hallmark, International Paper, Lockheed Martin, Pratt & Whitney, Trane, Union Pacific, Wal-Mart, and other major employers.

The Industrial Engineering Honors Experience is designed for industrial engineering students that are also enrolled in the University of Arkansas Honors College. The program gives honors students the opportunity to pursue unique coursework and research experiences. The program requires a minimum of 12 hours of honors engineering courses, an undergraduate research experience and a written thesis.

Dr. Manuel Rossetti serves as the Chair of Undergraduate Studies. More information concerning the undergraduate program may be found at [www.ineg.uark.edu/1443.php](http://www.ineg.uark.edu/1443.php).

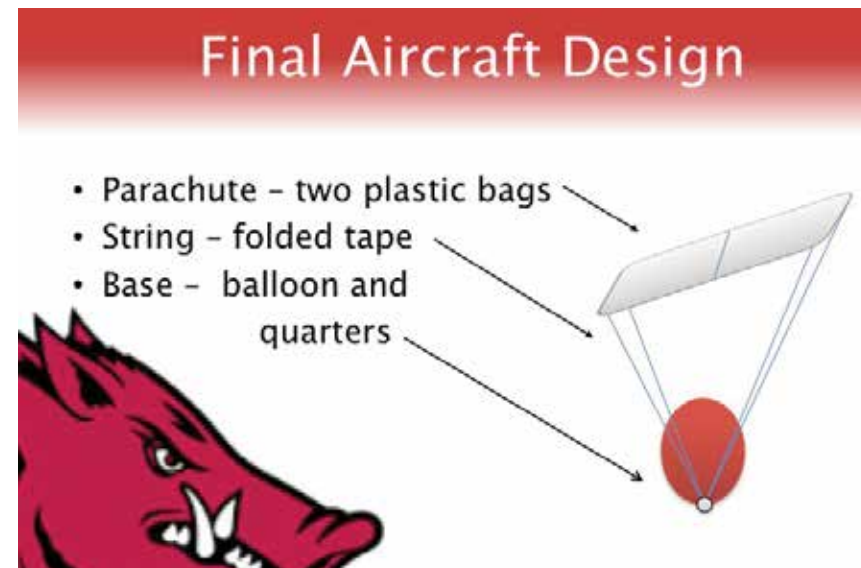
## Freshman Engineering Program Update

The Freshman Engineering Program completed its first year of operation in 2007 with Industrial Engineering Associate Professor C. Richard Cassady at its helm. The program was developed as a means of helping new students who were just entering the College of Engineering to obtain a firm grounding in general engineering concepts and to lay a shared foundation for their future development in the engineering discipline of their choice. Students in the Freshman Engineering Program take a common set of courses for one year. Upon successfully completing this program, they then move on to a discipline-specific undergraduate program within the College of Engineering.

Major accomplishments of the Freshman Engineering Program's inaugural year included:

- The development of an initial budget for the program
- The renovation of 5500 sq ft of Engineering Hall into the new meeting space, an Enhanced Learning Center classroom, a fifty-seat computer lab, and a study lounge
- The planning and execution of Summer Orientation for Freshman Engineering students
- The formation and operation of the Freshman Engineering instructional team which includes the Freshman Engineering Instructor, five College of Engineering faculty volunteers, and seven graduate teaching assistants
- The development and offering of GNEG 1111: for Freshman Engineering students

As a part of their introductory coursework, this year's freshmen were challenged to find effective solutions to one of several design problems posed by the faculty. Projects with intriguing names such as "A Mousetrap-Powered Vehicle" and "Slow Dropping Aircraft" were then assigned to teams comprised of 3 to 4 students each. Strict constraints were imposed on resources that could be used for constructing each project. Up to ten teams competed within each project category for awards for best design, performance, and summary presentation. Faculty and staff judges were recruited to rate each team's project according to its merits.



One Freshman Design Team's solution to the Slow Dropping Aircraft design exercise.



# GRADUATE STUDIES



The Graduate course offerings of the Industrial Engineering Department, as well as research opportunities for graduate students, continue to grow and diversify. A sampling of the published work of our graduate students, highlighted in this section, illustrates the range of research interests they are pursuing under the guidance of our faculty. Also featured below is our professional graduate program in Operations Management.

## 2007 Highlights

Our graduate program was ranked 27<sup>th</sup> in the US News and World Report rankings of graduate manufacturing and industrial engineering programs, having moved up two places.

During the 2006-2007 academic year, 380 students were enrolled in our graduate programs (35 Ph.D. students and 22 Master's students, as well as 323 students enrolled in the Operations Management graduate program). The students who entered our graduate program in the fall of 2007 had the following average GRE scores: Verbal 466 and Quantitative 725.

Approximately 95% of all on-campus graduate students received some sort of financial assistance from the department through graduate research assistantships.

Our graduate students gained recognition, awards and honors in 2007 and published or presented their research in several major venues:

Doctoral student Jennifer Pazour (advisor: Dr. Russell D. Meller) gained the distinction of "Student of the Year" from the Mack-Blackwell Rural Transportation Center for her role in researching a high-speed rail solution to freight distribution. Ms. Pazour's research for MBTC focused on reducing the amount of freight traffic on the current highway system through the deployment of a national high-speed rail system. She presented this research at the INFORMS National Conference in November 2007 and will be presenting updated results as an invited speaker at the Maglev 08 Conference in December 2008. Ms. Pazour also won the Rack Manufacturers Institute Honor Scholarship (\$4,000) from the

Material Handling Education Foundation, the South Dakota Beef Bucks Academic Scholarship and the E.J. Sierleja Memorial Fellowship from the Institute of Industrial Engineers.

Ph.D. Student Jagadish Jampani co-authored “Complex Job Shop Multiple Orders per Job Scheduling” with advisor Dr. Scott Mason. The paper was presented at the 3rd Multidisciplinary International Conference on Scheduling in Paris, France. He was also co-author on a paper accepted for publication in the *Annals of Operations Research*.

Doctoral student Eray Cakici (advisor: Dr. Scott Mason) co-authored two articles. The first, “Parallel Machine Scheduling Subject to Auxiliary Resource Constraints,” published in *Production Planning & Control* and “Cellar Tank Piping Network Analysis at E. & J. Gallo Winery,” appeared in the *Journal of Wine Research*. Doctoral student Letitia Pohl (advisor: Dr. Russell D. Meller) was also co-author on the latter paper and presented her research at both the 2007 Industrial Engineering conference in Nashville, TN and at the INFORMS annual meeting in Seattle, WA. In addition, Ms. Pohl was awarded the Modern Materials Handling Magazine Honor Scholarship (\$2,500) from the Material Handling Education Foundation.

Ph.D. student Alp Ertem (advisor: Dr. Nebil Buyurgan) co-authored “Read Rate Analysis of RFID Systems for Business Applications,” which appeared in the *International Journal of RFID Technology and Applications*. He presented his research at both the 2007 Industrial Engineering conference in Nashville, TN and at the INFORMS annual meeting in Seattle, WA. Doctoral students, Jennifer Ferguson (advisor: Dr. Scott Mason) and Zeynep Kirkizoglu (advisor: Dr. Russell D. Meller) also presented their research at the same INFORMS meeting.

Yisha Xiang, a Ph.D. student working with advisor Dr. Richard Cassady, was co-author of two papers: “Time to Failure Behavior under a Stochastic Deterioration Model,” presented at the Annual Reliability and Maintainability Symposium in Orlando, FL and “Comparing Scheduled and Condition-Based Maintenance Policies for Single-Unit Systems Operated in Markovian Environments,” presented at the 2007 IIE Annual Conference in Nashville, TN.

Doctoral student Kellie Schneider (advisor: Dr. Richard Cassady) co-authored “The Re-Use of Single-Use Medical Devices,” a paper she presented at the 2007 Industrial Engineering Research Conference in Nashville, TN.

## Course of Study Options

For students pursuing graduate studies in the field of industrial engineering we offer several options in terms of degrees, areas of specialization, and full-time or part-time studies.

Graduate degrees for on-campus students are offered in three areas:

- **Master of Science in Industrial Engineering (M.S.I.E.)**
- **Master of Science in Operations Research (M.S.O.R.)**
- **Doctor of Philosophy in Engineering (Ph.D.)**

In addition to the traditional degree options, the Industrial Engineering Department also offers the following non-traditional degree programs:

- **Master of Science in Engineering (M.S.E.)**
- **Master of Science in Operations Management (M.S.O.M.)**

Our faculty's wide range of expertise provides opportunities for study in a variety of areas:

**Economic Analysis**

**Manufacturing Systems**

**Engineering Logistics and Distribution**

**Operations Research**

**Ergonomics/Human Factors**

**Production Control and Materials Management**

**Facilities Design**

**Quality Assurance**

**Healthcare Logistics**

**Reliability Engineering**

**Homeland Security**

**Safety Engineering**

**Human-Computer Interaction**

**Simulation Modeling & Analysis**

**Logistics and Distribution System Design**

**Work Measurement**

Dr. Scott Mason serves as the Chair of Graduate Studies. More information concerning admission requirements and degree programs can be found at [www.ineg.uark.edu/1441.php](http://www.ineg.uark.edu/1441.php).

## Operations Management Master's Program

Dr. Edward Pohl succeeded Dr. Sandra Parker as Director and Chair of Studies of our Master of Science degree program in Operations Management in 2007. Under Dr. Pohl's direction, the MSOM program continues to experience rapid growth with both the number of students active in the program and total enrollments growing by more than 25% over the previous calendar year. Since its inception in 1974, this program has awarded over 4000 degrees, and with over 320 students enrolled, it remains the largest graduate program of the University of Arkansas.

The Operations Management program is designed for the working student who typically holds a professional or management position in an organizational setting, whether business, military, non-profit, or governmental. Program content focuses squarely on the concepts, methods, and tools that are essential to the successful management of both work processes and people in a wide spectrum of organizations. The curriculum grows out of an Industrial Engineering perspective on management and equips graduates to carry out their managerial responsibilities more efficiently and effectively. The curriculum is presented both by Industrial Engineering faculty and by academically qualified

professionals with extensive management and industry experience in the subjects they teach.

Coursework emphasizes the acquisition of practical knowledge in areas such as project planning, quality management, economic decision-making, supply chain management, human behavior analysis, and operations research, as well as many other areas of importance to today's manager. The independent study component of the program emphasizes action or applied research, rather than the formal research that is typical of most traditional graduate programs. Students are able to select from over 20 courses to make up the ten required to complete the degree. Several specific paths through the course material are offered providing concentrations in Industrial Management, Business Management, Human Resources Management, or Health & Safety Management.

Students come to us from three primary sources: the business world, the armed services, and undergraduate academic programs. The corporate affiliations of our current students include numerous Fortune 500 companies such as Wal-Mart, Tyson Foods, J.B. Hunt Transport, FedEx, Lockheed-Martin, and Pratt & Whitney.

In addition to evening classes, held on the U of A Fayetteville campus, live instruction is provided at five other graduate residence centers: Naval Support Activity Mid-South in Millington, TN; Little Rock Air Force Base in Jacksonville, AR; the Air Force Special Operations base at Hurlburt Field, FL; SAU Tech in Camden, AR; and ANC University Center in Blytheville, AR. While all program sites offer live classes, for added flexibility a number of courses are available in distance learning formats. Operations Management is an accelerated, non-thesis degree program consisting of 30 graduate hours and is delivered in five eight-week terms per year. Students who meet the admission standards can enter the program in any term and from any major, provided that program prerequisites are met within the first 12 hours of study.

More information concerning the Operations Management Program can be found at [www.opnsmgmt.uark.edu](http://www.opnsmgmt.uark.edu).



Operations Management faculty members from graduate residence centers in several states attend a conference on the UA campus for training and exchange of ideas and methods.

# RESEARCH/ TEACHING LABORATORIES

Our research and teaching facilities continue to expand through the addition of new laboratories, as well as through procurement of additional equipment and enhancement of existing equipment in all our laboratories.

## David D. and Nancy J. Foust Computation Laboratory

The David D. and Nancy J. Foust Computation Laboratory is a state-of-the-art interactive teaching facility made possible by a generous donation by Mr. and Mrs. Foust in 2002. Students have 24-hour access to 37 workstations, all equipped with the latest software designed for Industrial Engineering projects. The lab is equipped with a large plasma-screen display along with projection equipment to facilitate instruction, software demonstrations, and design presentations. There is also space within the lab for students to use when working on and storing their design projects.

## Ergonomics Laboratory

The Ergonomics Laboratory supports both research and teaching in the field of ergonomics. The laboratory houses equipment used to measure the physical, physiological and psychological dimensions of human performance. The laboratory is used by both graduate and undergraduate students as part of the industrial engineering curriculum. In addition, both graduate and undergraduate students use the laboratory to conduct their thesis research.

A STISM driving simulator and an iViewX eye motion monitoring system were recently acquired for the laboratory. This equipment provides the opportunity to conduct research on a variety of topics related to improving the safety of both automobile and heavy truck driving. Currently, Dr. Steven Johnson and his research team are using the driving simulator to research in-vehicle information systems. The iViewX eye motion monitoring system has a variety of research applications such as the evaluation of driver distraction and workload when using different in-vehicle navigation configurations.

## Human-Computer Interaction Laboratory

Dr. Chang Nam established the Human-Computer Interaction (HCI) Laboratory for the purpose of studying how individuals interact with complex information systems. The HCI lab is being used for both basic and applied research. Established research areas include new approaches to cognitive ergonomics, adaptive and intelligent human-computer interaction, brain-computer interface (BCI), multimodal user interfaces, and ubiquitous computing. The lab is used for instructional purposes in courses on the subjects of human information processing and human computer interaction, as well as, in an advanced human factors course.



Graduate research assistants Steve Johnson and Yueqing Li set up an EEG cap on a participant in preparation for a Brain-Computer Interface (BCI) experiment in the Human-Computer Interaction Laboratory.



## Larry and Gwen Stephens Undergraduate Research Laboratory

The Larry and Gwen Stephens Undergraduate Research Laboratory is a research facility made possible by a generous donation by Mr. and Mrs. Stephens in 2006 and designed to support the research projects of undergraduate students in the Industrial Engineering department. This initiative stems from the University's commitment to promote research at all academic levels.

The lab houses 12 undergraduate student researchers supported by their faculty advisors. Students engaged in research are assigned desk space in the lab for up to three regular semesters and issued wireless laptops to aid in their investigations. Most of the student researchers attend classes together and have collaborated on class projects, which lends the lab a collegial atmosphere in which ideas and methods can be shared, tested and refined.



Dr. Earnest Fant (farthest from camera) demonstrates capabilities of the Hytrol Conveyor System to students in the Material Handling Laboratory.

## Manufacturing Automation Laboratory

The Manufacturing Automation Laboratory houses three new Adept robotic arms (a six-axis articulating arm, a two-axis linear module and a four-axis SCARA with a four-camera machine vision system), an IBM SCARA robotic arm/machine vision work cell with conveyor, and a new Southworth lift table. This equipment is used for both instructional and research purposes. Recently, Dr. Earnest Fant combined the two-axis linear module with the six-axis articulating arm such that the latter could be carried in an inverted position to any location within a range of 1200mm to 1800mm. Both robots use the same controller and programming, but different power supplies. An electric-hydraulic scissor table can lift projects within the reach of the six-axis articulating arm as the arm lowers itself to the project below. Machine vision can also be incorporated into the new work cell. The new Adept SCARA robotic arm with an Automated Temperature Measurement system and touch screen panel computer for system control has been modified so that other research and instructional projects can be performed by students.

## Material Handling Laboratory

The Material Handling Laboratory is a state-of-the-art facility housing more than \$500,000 worth of material handling and storage equipment. The laboratory serves as an excellent resource for supporting undergraduate and graduate level instruction, masters and doctoral thesis research, as well as externally funded research. The laboratory houses a full-scale Hytrol conveyor system that consists of linear and circular components, integrated with barcode technology. A horizontal storage carousel serves as an automated storage and retrieval system (ASRS) for the conveyor system. Material handling and storage machinery is controlled using cutting edge programmable logic controllers (PLC) that allow students to simulate and develop digital and analog control models. The lab provides students with a variety of hands-on experiences in conjunction with several manufacturing related courses offered by the department.

## RFID Laboratory

In February 2007, the RFID laboratory was expanded and a next-generation collaborative learning environment for both on-campus and off-campus students was developed. User-friendly, web-based applications which provide access to off-site students were built by a research team led by Drs. Nebil Buyurgan and Justin Chimka. A motorized hardware system was assembled in order to provide RFID technology testing setups in the laboratory. An agent-based architecture was used to build the hardware and software framework to make experiment setups more flexible. The software infrastructure was constructed with a view to enabling interaction among the diverse devices in this environment.

In addition to the hardware and software tools available, the website of the RFID lab offers online teaching modules for AutoID technologies and their applications in areas such as supply chain, logistics, material handling, production planning, and automated manufacturing. The expanded laboratory serves as an excellent resource for supporting undergraduate and graduate level instruction; M.S. and Ph.D. level research; as well as externally funded research.

The first Industrial Engineering RFID laboratory at the University of Arkansas was established by Dr. Nebil Buyurgan in January 2005, within the Materials Handling Laboratory. Several types of state of the art antennae, high-performance multi-protocol readers, software and an RFID tag printer were installed for students to use with previously available material handling and storage equipment. Since its inception the laboratory has provided students with a variety of hands-on experiences in conjunction with several courses, offered by the industrial engineering department.



2007 AAIE Liaison Committee members hear Dr. Nebil Buyurgan's (back to camera) plans for his new RFID Lab space. Left to right, Dr. Brett Peters, Jessica Hall, Curtis Sawyer, Jr., Andrea Sandage, Gary Whicker and Dr. Ken Musselman.

# ADVISORY BOARD

The Arkansas Academy of Industrial Engineering (AAIE)\* organizes a liaison committee that serves in the capacity of an advisory board to the department. The committee is comprised of accomplished professionals from business and industry who bring both an applied perspective and an independent assessment to the industrial engineering program at the University of Arkansas.

The members of the 2007 Liaison Committee are:

- **Jessica Hall, Sales Representative, Daiichi Sankyo Co., Ltd.**
- **Ken Musselman, Ph.D., President IIE**
- **Brett Peters, Ph.D., Professor and Head, Industrial and Systems Engineering, Texas A & M University**
- **Andrea Sandage, Past President, AAIE Board; Supply Chain Specialist, Hawker Beechcraft Corporation**
- **Curtis Sawyer, Jr., AAIE President; Director, Supply Chain Implementation, Conagra Foods**
- **Gary Whicker, Senior Vice President Engineering Services, JB Hunt Transport, Inc.**

The AAIE was founded in 1986 to recognize the achievements of University of Arkansas Industrial Engineering graduates and to provide continuing guidance and support to the Department of Industrial Engineering. The Academy also provides its members with the opportunity to nurture the organization that played an important role in their professional growth and development. These members provide tremendous financial resources that endow many scholarships for the student body within the department.



Members of the AAIE Liaison Committee with Interim Industrial Engineering Department Head, Dr. Ronald Rardin. Back Row (left to right) Dr. Rardin, Jessica Hall, and Dr. Brett Peters. Front Row (left to right) Andrea Sandage, Gary Whicker, Curtis Sawyer, Jr. and Dr. Ken Musselman.

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