# General Engineering

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The Department of General Engineering offers programs of undergraduate and graduate study that provide an approach to system engineering and engineering design that crosses traditional disciplinary lines. The master's degree program accepts students with bachelor's degrees in general, mechanical, civil, and electrical engineering as well as computer science, and the program is structured to emphasize planning and execution of large projects in engineering design and manufacturing. The department now offers a new master's/doctoral Program in System and Entrepreneurial Engineering (SEE).

The backgrounds of faculty members are diverse, but research is generally focused in the areas of integrated engineering design, decision making, communications, scheduling, control, Six Sigma processes, entrepreneurship, and the business side of engineering. Currently this activity is divided into design of engineering systems, including decision making, reliability, and optimization; engineering graphics; geometry and solid modeling; control and robotics; communication networks; manufacturing systems analysis; expert systems and artificial intelligence in the design process; nondestructive testing and evaluation; and biomechanics and rehabilitation engineering.

Doctoral students in computer science, electrical, mechanical, and civil engineering work with or are supervised by General Engineering Department faculty members.

**Research is conducted in specialized laboratories:**

- The Decision Systems Laboratory focuses on the development of decision support systems utilizing both operations research and artificial intelligence techniques.
- In the Manufacturing Systems Laboratory, new modeling, decision making, and control techniques to improve the efficiency of large-scale manufacturing systems are investigated.
- The Illinois Genetic Algorithms Laboratory investigates the theory and application of genetic algorithms-search procedures based on the mechanics of natural selection and natural genetics.
- The Mechatronics Laboratory for the integration of electrical and mechanical systems is under development.
- The Nondestructive Testing and Evaluation Research Laboratory provides acoustic emission, ultrasonics, acousto-ultrasonics, eddy-current, magnetic particle, holography, and real-time microfocus x-ray equipment for nondestructive evaluation and characterization of a variety of materials and structures.
- The Robotics Laboratory features several research-quality robot arms, vision systems, and workstations with state-of-the-art robotics software.
- The SELL lab provides resources to student groups beyond what is otherwise available in the typical university setting. The availability of tools and adequate space allows students to create and develop ideas into working prototypes—goals that would remain only a dream without this type of assistance.

## Faculty and Their Interests

**Carolyn L. Beck**
Control systems, modeling and model reduction for the purposes of control, systems theory

**Francesco Bullo**
Nonlinear controls, autonomous vehicles

**Scott A. Burns**
Engineering design optimization, structural analysis

**James V. Carnahan**
Probabilistic methods, applied statistics, simulation

**Thomas F. Conry**
Tribology, mechanical design, mechanical systems

**Wayne J. Davis**
Hierarchical systems and programming for planning and control, advanced simulation of manufacturing systems

**David E. Goldberg**
Genetic algorithms and evolutionary computation in search, optimization and machine learning, innovation

**W. Brent Hall**
Reliability engineering, conditional reliability and decision making, structural optimization, cold-formed steel design

**Juraj V. Medanic**
Systems theory, control systems, systems analysis

**Manssour H. Moeinzadeh**
Biomechanics, dynamic modeling, experimental mechanics

**Raymond L. Price**
Engineering management, time to market, business and technology strategy

**Henrique L. M. dos Reis**
Nondestructive testing and evaluation, structural analysis and design, composite materials

**Ikhlaq Sidhu**
Technology management, with a focus on the technology areas of networking, image processing, hardware development, software development, and communications

**Mark W. Spong**
Control theory, robotics, mechatronics

**R. S. Sreenivas**
Discrete-event systems, automatic control simulation

**Deborah L. Thurston**
Multiattribute decision making under uncertainty and risk, environmentally conscious design and manufacturing

**Louis Wozniak**
Control theory, systems identification and simulation, speed control, power systems

**Ali Yassine**
Product development models, design theory and methodology, concurrent engineering, project management

# Bioengineering

**Multivariable Modeling and Control of Anesthetic Pharmacodynamics**
C. Beck,* M. Bloom
*National Science Foundation, ECS9720523*

This project concerns the investigation and construction of mathematical models to describe the pharmacodynamic response of patients to various anesthetic agents. Due to the variability of responses of individuals to drugs, families of models, rather than single models, are being considered. To be useful, these models must reflect the time-varying nature of human response to anesthesia, the wide range of variation in human subjects, and the complexity of the underlying mechanisms involved. The eventual goal of this work is the development of robust feedback control designs for the purposes of automated anesthesia delivery. Recent system identification and model validation techniques are being used to construct candidate models, utilizing clinical data recorded by the Department of Anesthesiology at the University of Pittsburgh Medical Center.

# Biomechanics and Rehabilitation Engineering

**Human Postural Control Modeling**
C. L. Beck,* M. H. Moeinzadeh,* A. Mahboobin
*University of Illinois*

The function of human postural control involves a multisensory feedback process that relies on information from the visual, vestibular, and proprioceptive systems. Previously, such sensory system models were regarded as stationary (time-invariant), but recent analysis indicates that the dynamics of upright balance have nonnegligible, time-varying characteristics. The aim of this research is the development of time-varying postural control models reflecting the interaction of all three sensory systems in the control of upright stance in human posture. The research will lead to a better understanding of balance mechanisms in healthy individuals, resulting in improved diagnosis and treatment for those with balance disorders.



*Denotes principal investigator.

**Ground Reaction Force Analysis of Changing Direction during Walking**
M. H. Moeinzadeh,* D. Xu
*University of Illinois*
*Conducted in the Department of Kinesiology*

Walking is the basic means of locomotion for human beings. Various aspects of walking have been studied by a number of researchers; however, there is limited information on the unique characteristics of changing direction during walking. This study investigates the kinetic walking patterns and properties of the ground reaction forces (GRF) in changing direction. Thirty-three subjects are tested through a walking protocol representative of all of the complex movements of directional walking. Their GRF and body movements are recorded via a force plate and motion analysis systems, respectively. The insight gained in this study will be helpful in the clinical diagnosis of dysfunctional walking.

**Performance Characterization of a Hollow Aluminum Baseball Bat**
M. H. Moeinzadeh,* A. M. Nathan,* J. T. Czapka
*University of Illinois*

A project has begun to study performance of a hollow aluminum baseball bat and the role played by shell modes, which are excited during the ball–bat collision by the local compression of the shell of the bat at the impact point. Energy stored in these modes during the collision is effectively restored to the ball, giving rise to the so-called "trampoline effect." The goal of this study is to develop a quantitative understanding of the trampoline effect using both finite element analysis and modal analysis. Results should provide insight for the design improvement and performance of the baseball bats.

**Rigidity of External Fracture Fixation Devices**
G. J. Pijanowski* (Vet. Biosci.), M. H. Moeinzadeh*
*University of Illinois*

There is growing evidence that the local mechanical environment has an important influence on the process of fracture healing. The configuration of an external skeletal fixator frame is known to affect the stiffness of the frame and thus, the local mechanical environment. The purpose of this work is to develop a computer model of the frame and provide the clinician with information about the mechanical environment of the healing fracture. This will allow the clinician to alter the configuration of the frame to optimize healing.

# Communications Networks

**Bilateral Teleoperation over Unreliable Communication Networks**
M. W. Spong
*Office of Naval Research, N00014-02-01-0011*

This project investigates bilateral teleoperation over unreliable communication networks. This problem is motivated by the increasing use of the Internet as a communication medium in networked control systems. Particular emphasis is placed on the problems of stability and performance in the face of uncertainties introduced by the communication network. A fundamental goal is to make the control layer transparent to such effects so that system designers can focus on higher level issues necessary to create modular, reliable systems. Potential applications include work in hazardous and remote environments, surveillance, search and rescue robots, autonomous vehicles, haptic devices, remote construction, and remote surgery.

**Development of Virtual Prototyping Systems**
R. S. Sreenivas,* W. R. Norris
*Caterpillar Inc.*

The notion of "steering quality" is difficult to quantify in the design of steering systems for earth-moving vehicles. Researchers envision an expert driver operating a simulated vehicle within a virtual environment where the parameters in the design of a steering system can be altered instantaneously. In this paradigm, the process of trial-and-error design becomes a viable option. This project involves the derivation of vehicle models of appropriate complexity and detail that can be simulated in real-time within a virtual environment. To improve the real-time performance of these models, particular attention is focused on artificial neural networks.

**On Deadlock Avoidance, Livelock Avoidance, and Performance Improvements in Discrete Event Systems: A Collection of Open Problems**
R. S. Sreenivas*
*National Science Foundation, ECS-0000938*

Researchers consider a large class of discrete-state systems such as traffic networks, manufacturing systems, computer networks, and distributed/parallel computing. A livelock in such systems is a situation when some process is unable to finish because its clients perpetually create more work for it to do after they have been serviced. This phenomenon is different from that of a deadlock where there is essentially

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no activity as each process is perpetually in a state of waiting, anticipating the release of resources that are held by other processes. The issue of deadlock- and livelock-avoidance is particularly important to the synthesis of protocols, routing, cache and memory management, computer operating systems, manufacturing systems, traffic management, operations management of large organizations, and so forth. This project addresses several open problems in the analysis, synthesis, and performance evaluation of supervisory control policies that guarantee liveness (absence of deadlock and livelock) in Petri net (PN) models of the discrete-state systems described above.

# Control Systems

**From Power Laws to Power Grids: A Mathematical and Computational Foundation for Complex Interactive Networks**
R. Bagrodia, C. Beck, J. Doyle,* J. Carlson, K. Chandy, M. Cross, M. Gerla, S. Lall, B. Lesieutre, J. Marsden, F. Paganini, L. Petzold, G. Verhese
*Electric Power Research Institute; Army Research Office, DAAG55-98-R-RA08*

The goal of this research consortium is to enhance the understanding of network behavior, including phenomena such as power outages and large cascading power failures, as well as to provide significantly improved capabilities for reducing the frequency and severity of such events. An increasing awareness of the importance of understanding and designing for robustness in complex networks, coupled with concurrent advances in theoretical and software-based tools, has dramatically improved the prospects for gaining insights into these types of systems. All the research investigators involved in this consortium have made fundamental contributions at the heart of these recent developments. Professor Beck, specifically, is involved in the development of modeling and model reduction theory, and related computational tools, for networked and interconnected power systems configurations with an emphasis on maintaining robustness in systems stability and performance.

**Modeling and Model Reduction for Complex Engineering Systems**
C. Beck*
*National Science Foundation, ECS 00-961999*

The focus of this research is on the development of systematic modeling and model reduction methods for the purpose of facilitating control design, analysis, and simulation of complex engineering systems. This development is based on the consideration of practical engineering systems; power networks and bioengineering systems comprise the main focus for the applications work. In general, the systems to be considered in this research may be time-varying, parameter-varying, distributed or multidimensional, and/or nonlinear in behavior. The main modeling framework considered is that typically used in robust control. The development of algorithms and computational tools to implement the proposed modeling techniques is one of the goals of this project.

**Algorithmic and Differential Geometric Trajectory Planning**
F. Bullo*
*University of Illinois*

Motion planning and trajectory optimization are key technological problems in the development of dexterous and autonomous machines, including robotic manipulators and autonomous vehicles. The first step is to introduce and characterize kinematically controllable systems. For these systems, the problem of planning fast, collision-free trajectories can be decoupled into the computationally simpler problems of path planning followed by time-optimal time scaling. Second, researchers present a power series approach to trajectory planning. Two-point boundary-value problems corresponding to trajectory planning are solved locally via an inverse theorem for power series representations. Investigations include both the regular and singular cases corresponding to linearly and nonlinearly controllable systems.

**Constructing a Physical Emulator for Automated Manufacturing Systems**
W. J. Davis*
*Campus Research Board*

A physical emulator for an advanced manufacturing system is being designed for both research and education needs. The emulator consists of a large mimic board where detailed state information is electronically displayed. The included processes are emulated by microprocessors that drive the electronic displays and accept control inputs from and provide sensory feedback to other microprocessors. A new course addressing the distributed intelligent control of complex systems is being developed around the emulator. The emulator will also interface with the World Wide Web to permit researchers to test new algorithms for the distributed online intelligent control of such systems.


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**Modeling and Analysis of Large-Scale, Discrete-Event Systems**
W. J. Davis*
*University of Illinois*

A new hierarchical framework for the intelligent control of large-scale, discrete-event systems has been formulated. The conceptualized hierarchy defines a coordinated object that can be employed recursively to describe the desired hierarchy. In order to distribute planning and control, an intelligent controller is included within each coordinated object. The essential mechanisms to coordinate the distributed planning and control are now being explored. New object-oriented simulation tools are also being developed to model the interaction among the coordinated objects.

**Specialized Simulation Models for Production Planning**
W. J. Davis*
*U.S. Army, DAAA08-97-M-0647*

A new object-oriented simulation approach is being developed for the production planning problem. The approach will permit the product structure diagram and specialized policies for managing the inventory for each product to be considered. Finally, the simulation approach defines a generalized queue for all staged and dispatched orders that can be interfaced to any intelligent control algorithm for managing the production. Eventually, the modeling will be expanded to consider the purchasing of materials from external vendors, material and capacity requirements planning, and real-time production scheduling.

**Flexible and Survivable Embedded Systems**
L. Sha, V. Adve, M. W. Spong
*National Science Foundation, CCR-0209202*

This project is to investigate the design of flexible, reliable, and survivable networked embedded systems. An important need in networked embedded systems is the ability to perform online upgrades because embedded systems have long life cycles and because the downtime of a large distributed control system is often expensive and impractical. The challenge is exacerbated by the real-time requirements and the high reliability, availability, and security requirements of such systems, since their failures may cause physical harm to equipment or personnel. Furthermore, system stability must be maintained in spite of insider attacks masquerading as upgrades.

**Collaborative Research: Teleautonomy in Networked Control Systems**
M. W. Spong, C. Abdallah (Univ. of N. M.)
*NASA; National Science Foundation, IIS-0233314*

This project addresses both the problems of remote assembly with minimal human intervention and direct teleoperation. The present research seeks to integrate robotic control algorithms with communication networking research, along with issues associated with projecting and magnifying human capabilities to facilitate assembly in space structures. The technical issues include bilateral teleoperation, the reliability of the communication links, and the coordination of complex assembly tasks.

**Layered Architectures for Complex Networked Systems**
M. W. Spong, P. R. Kumar, F. Bullo, C. Hadjicostis
*National Science Foundation, ECS-0122412*

Future embedded real-time control systems will increasingly be wireless, distributed, large-scale, and inherently hybrid, combining discrete or digital components with continuous time nonlinear dynamics. The complexity of such networked systems presents new challenges that lie at the confluence of communication, computing, and control. In this project, we investigate the design and analysis of layered control and communication architectures for treating complexity, delays, reliability, planning, and other issues. Our goal is to develop the right abstractions that are application independent and enable the convergence of sensing and actuation with communication and computing.

**Passivity Based Control of Networked Control Systems**
M. W. Spong*
*Romeo Ortega; CNRS-Supelec; France CNRS; National Science Foundation, INT-0128656*

This project is to investigate passivity based architectures for bilateral teleoperation. We have shown that the standard scattering transformation applied to position and integral of force results in a passive communication link between master and slave. We use this approach to overcome the problem of position drift and in the important case that the communication delay is not constant. One example occurs when the Internet is used for teleoperation; in this case, when the delay is varying, position cannot be obtained by simply integrating the (delayed) velocity. This work will have important applications for telemedicine, remote inspection, and remote construction.

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**Determining Hydrogenerating System Stability and Performance**
L. Wozniak*
*University of Illinois*

Hydrogenerator governors are designed with predetermined rotational inertias and conduit dimensions for maximum acceptable off-speeds (speed deviations from reference). However, this parameter selection may not be favorable for stable operation and satisfactory small signal level performance when governing isolated loads. Poorly governed plants operating in interconnected systems degrade the overall stability. This work develops a graphical method to determine expected performance and stability characteristics based on inertia and conduit sizing decisions. It is directed toward mechanical and civil engineers involved in the design and associated economics of plant layouts.

**Efficiency-based Optimal Control of Kaplan Hydrogenerators**
L. Wozniak, P. Schniter*
*University of Illinois*

This research investigates an optimal strategy for controlling the speed response of Kaplan hydrogenerating systems to decreases in load. Typically, primary control gates restrict and redirect water through the turbine to stabilize and transfer the system to operating point demand. The adjustable turbine blade angle is used to return to maximum operating efficiency at the new load level. The overspeed reduction is limited by the ability of the conduit to withstand the overpressure caused by the flow restriction at the turbine. A control scheme using gates and blades simultaneously and independently is developed.

**A Graphic Approach to Hydrogenerator Governor Tuning**
L. Wozniak*
*University of Illinois*

A number of published works deal with governor tuning for speed control of hydrogenerators. This work is based on the hypothesis that some system parameters are not known at the design stage. A graph is developed that can be used to predict optimum proportional and integral gains based on four parameters: the time constants of the water column and the rotor inertia and the self-regulation constants of the turbine and the loading grid. The pole cancellation method of design is used and the results are posed in an easy-to-use format not requiring the solution of systems of equations.

# Design Theory and Methodology

**Reliability Models of Test-based Design**
W. B. Hall*
*University of Illinois*

Reliability models of structural design are being developed to use information from load testing. The type of system tested and its scale (element, component, or system), number of tests, and kind of information obtained are examples of factors that influence the model to be used. Applications include probabilistic evaluation of test results, such as sample tests and proof load tests, and unbiased decision criteria for test-based design, such as requirements on safety factors and resistance factors. Potential code procedures can be assessed for the possible effects on the structural reliability of systems designed and built.

**Axioms for Overcoming Resistance to Decision-based Design**
D. L. Thurston*
*National Science Foundation, DMI-9908406*

Although decision-based design has tremendous potential for improving the engineering design process, several real and misconceived limitations hamper its progress. The goal of this project is to develop a set of new decision-based design axioms for overcoming these limitations. To overcome the real limitations, the axioms will provide a basis for effectively employing information contained in a utility function during design synthesis and analysis. To overcome the misconceived limitations, the axioms will provide rules and conditions specific to engineering design for formulating and using information from utility analysis throughout each stage of the design process.

**Design for Machinability**
D. L. Thurston*
*Hayes-Lemmerz (through Center for Machine-Tool Systems Research)*

Machining operations affect cost, cycle time, surface finish, tolerance, weight, quality, and the environment. Specialists evaluate designs for machinability to minimize cost or maximize quality, but tradeoff decisions are difficult. The proposed solution is to formulate a mathematical model of the cause-and-effect relationships between design decisions and overall product performance. Controllable decision variables include material, geometry, cast-in versus machined features, machining process


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selection, fixturing, cutting fluids, feed rate, and speed. The objective is to identify the set of design and machining decisions that achieves the best possible combination of product attributes.

**Environmentally Conscious Design and Manufacturing**
D. L. Thurston,* J. V. Carnahan
*National Science Foundation, DMI 95-28629*

This project develops a rigorous new method for integrating quantitative decision analysis over the entire range of product design, manufacture, use, and disposal. Specifically, the methodology combines statistical manufacturing process control with life-cycle analysis and concurrent multiobjective design optimization. Pollution and its removal cost are treated as product defects. This project significantly expands on previous work to develop design tools that can be used by any industry. Procedures for classes of manufacturing processes and their resultant waste streams are specified. The best combination of strategies is identified, including specification of the product design, materials, manufacturing process design, and manufacturing process control settings.

**Integrating Customer Preferences into Green Design and Manufacturing**
D. L. Thurston*
*Motorola (through Center for Machine-Tool Systems Research)*

"Green" products must compete in the marketplace against many rivals. If consumers do not purchase them, they do not succeed in their goal of environmental protection. Preferences for "environmentally friendly" products have been difficult to assess, since customers' stated willingness to pay often differs from their actual purchasing practices. This project incorporates information about customer preferences into environmentally conscious design and manufacturing. It expands upon mathematical models of the concurrent design process and addresses issues of cost, manufacturing cycle time, product quality (measured in terms of defect rate), product size and weight, volatile organic compound (VOC) production, recycling, disassembly, and other environmental impacts.

# Environmental Design and Manufacturing

**Business-Led Environmental Management: Environmental and Economic Implications**
M. Khanna,* D. L. Thurston
*U.S. Environmental Protection Agency, G8J30188*

"Pollution Prevention Pays" is an appealing concept. However, there are limits. If pollution prevention always did pay, then market forces would drive all firms to their least polluting potential. The problem is to determine what drives some and not other firms to undertake self-regulated environmental management and the extent to which it can be relied upon to achieve environmental protection. The goal of this project is to develop a theoretical econometric framework to analyze the determinants of business-led environmental management and derive conditions under which business-led (as opposed to mandatory regulations) can achieve cost-effective environmental protection.

# Genetic and Evolutionary Computation

**Caterpillar Genetic Algorithm-based Cooling System Design Optimizer**
D. E. Goldberg*
*Caterpillar Inc.*

This project interfaces a simple genetic algorithm to Caterpillar cooling system models and performance indices to develop an optimization procedure for cooling system design. The result will be a pilot code suitable for practical use by Caterpillar Inc.

**Competent and Efficient Genetic Algorithms**
D. E. Goldberg*
*National Science Foundation, DMII-9908252*

This project investigates the development of competent selectorecombinative genetic algorithms that solve hard problems quickly, reliably, and accurately and methods for speeding up competent GAs further through methods of parallelization, time utilization, evaluation relaxation, and hybridization (with other search and optimization methods).

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**Competent Probabilistic Model Building Genetic Algorithms**
D. E. Goldberg,* M. Pelikan
*U.S. Air Force Office of Scientific Research, F49620-00-0163*

This project investigates genetic algorithms and other selectionist schemes that explicitly build probabilistic models of the best points in the sample stream. In particular, Harik's extended compact genetic algorithm (ecGA) and Pelikan's Bayesian optimization algorithm (BOA) are analyzed, tested, enhanced, and applied to practical problems. Extensions for hierarchically organized problems and codings other than *k*-ary strings are considered. Practical problems in electromagnetics and protein folding are tackled to demonstrate the power of these methods.

**Efficient Genetic Algorithms**
D. E. Goldberg*
*Illinois Genetic Algorithms Laboratory*

This project seeks to obtain fast, accurate solutions in genetic algorithms by spatial efficiencies, temporal efficiencies, sampling efficiencies and evaluation relaxations, and systematic hybridization. The results of this project are important to the growing number of real-world applications of genetic and evolutionary computation.

**Piecewise Development of Design Theory for Genetic Programming**
D. E. Goldberg*
*Illinois Genetic Algorithms Laboratory*

Work at the University of Illinois has resulted in the development of a piecewise theory of simple genetic algorithms that seeks to understand building block existence and definition, building block supply, building block difficulty, building block decision making, building block growth and timing, and building block mixing. This theory has been instrumental in analyzing solution quality (or its lack thereof) in existing simple selectorecombinative GAs and designing more effective crossover and ancillary operators. This project seeks to replicate the success of these efforts in the domain of genetic programming. Steps taken in the bit-string GA domain are retraced and enhanced as necessary for the understanding of the more complex situation of GP.

**Simulating the Evolution of Signaling Networks within Cells**
D. E. Goldberg,* J. E. Mittenthal*
*Campus Research Board*

This project simulates the evolution of intracellular signaling networks in which signaling proteins are modeled as a set of domains; pairs of domains with high affinity can mediate interactions between proteins; point mutations can delete domains; and domains can be transferred between proteins. The simulation will test the hypothesis that a number of generic characteristics of signaling networks arise through the selection for a greater number of pathways.

**Structural Design Using a Hybrid Genetic Algorithm**
D. Goldberg,* S. Burns,* P. Parthasarathy
*National Science Foundation, DMI-9908252, CMS-9912559; AFOSR Grant No. F49620-00-0163*

The project involves a hybrid genetic algorithm (GA) for locating multiple, fully-stressed designs of portal frame structures. The hybrid GA is composed of a real-coded GA as the global searcher and the stress-ratio method and Broyden-Fletcher-Goldfarb-Shanno method as local searchers. A niching method has been developed to address the issue of multiple optima while using hybrid GAs. The method has been used to solve a variety of frame structures. Future research involves solving bigger problems and also improving the niching method so that the number of function evaluations required for solving the problem is minimized.

## Integrated Mechanical and Structural Design

**Integrated Design and Construction Planning of Steel Frame Structures**
S. Burns,* L. Liu,* A. Nandula, D. King
*National Science Foundation, CMS 9912559*

This research will seek to develop a structural steel frame design simulation system to improve communication among designer, fabricator, and erector. From the designer's point of view, this software will serve to provide immediate feedback of estimated total project cost as the design evolves, permitting "what-if" scenarios to be conducted quickly and efficiently. One of the key features of the software will be its ability to suggest design alternatives that lower total project cost or otherwise


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improve on the design, considering complex interactions between material costs, labor costs, and structural behavior.

**Multiobjective Seismic Design of Steel Frame Buildings**
S. Burns,* Y. Wen,* M. Liu
*National Science Foundation, CMS 9912559*

The goal of this project is to develop a new approach for structural seismic design that provides a distribution of seismic design alternatives, each of which has relative merit with respect to the others in terms of initial material cost and usage, expected lifetime seismic damage cost, design and construction complexity, and a system redundancy index. This gives the decision maker a direct sense of tradeoffs associated with the various objectives, and the ability to select a compromise design that best meets the goals of all parties involved in the project.

**Optimal Structural Standardization**
W. B. Hall*
*University of Illinois*

For economic reasons, many structural members are produced in fixed sizes rather than in a continuous supply of structural shapes. This presents an interesting optimization problem, namely, how to design an assortment of profiles or sizes to best satisfy a structural demand. One solution approach is to minimize the material waste from overdesign that occurs when standardized sizes are selected rather than "made-to-order" cross sections. Related problems include the modeling of economy of scale and the optimal consolidation of production materials.

**Reliability Allocation in Structural and Mechanical Systems**
W. B. Hall*
*University of Illinois*

Strategies for allocation of reliability to components of a system are being investigated. In general, a uniform allocation of reliability to individual components will not efficiently achieve system reliability goals, whereas optimized schemes show potential for cost savings and improved consistency in reliability control. Promising strategies depend on the type of system, the costs of component reliabilities, and other factors. Current structural design codes, which seek to control reliability at the component level, appear to be inconsistent at the system level. Practical methods to improve reliability allocation in design are being sought.

**On the Physical Realizability of Singular Structural Systems**
E. N. Kuznetsov*
*University of Illinois*

The physical and numerical realizability of singular geometric configurations depends on the type of singularity—generic versus nongeneric. Many theoretically predicted and thoroughly studied singular configurations (systems with simultaneous statical and kinematic indeterminacy, unprestressable first-order mechanisms, all higher-order mechanisms, singular positions of finite mechanisms, and kinematically mobile closed polyhedral surfaces) are, in fact, nongeneric. Hence, they are physically unrealizable and noncomputable (except for exact or symbolic calculation). Thus, in spite of their sometimes remarkable theoretical features, these systems are just purely formal constructs. An attempt at their implementation would produce a generic prototype with "essentially" different properties, including structural response.

**Singular Configurations of Structural Systems**
E. N. Kuznetsov*
*University of Illinois*

Singular configurations exist only in underconstrained structural systems, including systems with infinitesimal mobility. This work addresses a critical, yet so far unexplored, aspect of singular configurations—their realizability. It has been found that the only generic, physically realizable type of a singular configuration is a system with first-order infinitesimal mobility, and even this cannot be constructed without inducing prestress of finite magnitude. All other singular configurations (unprestressable first-order mechanisms, higher-order mechanisms, and singular configurations of finite mechanisms) are unrealizable. Moreover, except for exact or symbolic calculation, they are also noncomputable, which explains numerous failed attempts at their analysis.

## Nondestructive Evaluation and Testing

**Broken Rail Monitoring System Using an Array of Acoustic Sensors**
H. L. M. dos Reis,* J. P. John
*American Association of Railroads*

Broken rail is a major problem for the railroad industry because of the large capital investment as well as the

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potential financial burden caused by the threat to public safety and the environment. It has been known that the careful placement of the human ear near the railroad rail allows the detection of a train several miles away. Here, the train itself is the source, the human ear is the receiving transducer, and the rail serves as an effective wave-guide through which the noise propagates. The purpose of this research is to investigate the feasibility of using a distributed array of acoustic emission transducers to monitor the health of railroad rails. First, using a track that is currently without traffic, tests will be carried out to investigate the dispersion characteristics of the rail and to assess how far the transducers can be separated and still provide an effective monitoring system. If successful, the rails can also be used as wave guides for waves launched ahead of a train, allowing for inspection of two or three miles of rail ahead of the train.

**Instantaneous Evaluation and Characterization of Fresh Concrete**
H. L. M. dos Reis*
*University of Illinois*

Concrete is unusual among construction materials in that it is manufactured as used and cannot be tested for acceptance in advance. Acceptance is commonly based on strength tests at an advanced age. Clearly, a need exists to assess the quality of concrete much earlier, ideally before it is placed. It is generally agreed that the most important parameter for determining the quality of concrete is the water-cement ratio. The objective of this study is to investigate a procedure for the instantaneous determination of water-cement ratio to allow a go/no-go decision on an actual batch prior to discharge.

**Manufacturing Process Control of Subminiature Components**
H. L. M. dos Reis,* A. Sethi
*CAMCAR Textron*

Below certain sizes, the conventional methods of processing raw materials, manufacturing parts, gauging, and performance tests do not work satisfactorily. The purpose of this research project is to develop innovative process control methodologies that can be used as quality assurance in the manufacture of subminiature component parts.

**Noise Abatement in Asphalt Concrete Pavements**
H. L. M. dos Reis,* S. H. Carpenter
*FAA Center of Excellence for Airport Pavement Research*

Based upon the nondestructive estimation of the viscous and thermal characteristic lengths using an impulse-echo approach, the acoustic properties of pavement surface layers made of various asphalt concrete mixtures will be evaluated. These properties include the characteristic impedance, the surface acoustic impedance, and the absorption and spherical reflection coefficients at the pavement surface. The experimental results are expected to explain field observations, which consistently indicate the superior noise-abating properties of open-graded (porous) asphalt-concrete pavements. This research should lead to the development of a unified transportation noise model that accounts for all modes of transportation and incorporates factors related to meteorology, topology, and acoustic material properties. Facilities that may be analyzed include railroad, airport, highway, and urban facilities in both open and confined fields.

**Nondestructive Evaluation of Dimension Stone**
H. L. M. dos Reis*
*University of Illinois*

Energy related processes in dimension stones are numerous and may collectively describe the mechanical and physical features of stone, such as its viscoelastic and microstructural properties. Using principles of statistical energy analysis (SEA), diffuse-wave-fields, and analogies to solid media of architectural-acoustic theories on reverberant enclosures, this project will study the energy evolution processes within a given stone component or system by means of an impulse-generated stress-wave field. This is a method to estimate, nondestructively, the required features of stone.

**Nondestructive Evaluation of Particleboard**
H. L. M. dos Reis*
*University of Illinois*

Presently, the most commonly used tests to assess the structural integrity of particleboard are the boil swell and the cyclic soak tests. Although these tests predict how well the particleboard will perform, with the exception of visual examination, there are at present no nondestructive evaluation (NDE) techniques for its structural integrity. The purpose of this study is to investigate the applicability of the acousto-ultrasonic technique to assess the functional structural integrity of particleboard. During the pressing operation, wood-based composite materials are


*Denotes principal investigator.

compressed in thickness beyond the gross density of the wood species and remain compressed because of resin bonding.

**Nondestructive Evaluation of Wood Decay**
H. L. M. dos Reis*
*University of Illinois*

A nondestructive technique to evaluate the strength of wood in early stages of decay is being investigated. Although the "pick test" is commonly used to detect wood decay in the field, it has not been known how advanced decay must be before it can be detected by this means. Because much of the wood's strength is lost in the early stages of decay, a high-sensitivity testing procedure is desirable. The importance of this research can be appreciated by noting that for each real estate transaction, only a termite inspection is required even though the wood frame structure may have reached moderate or advanced stages of decay.

**Online Monitoring of Incipient Die/Punch Failure**
H. L. M. dos Reis,* J. Gutzmer
*CAMCAR Textron*

The objective of this work is to develop a methodology for online monitoring of incipient die/punch failure in cold-heading processes in order to assure parts within specified tolerances. Current work consists of developing transducers and AI signal processing software (neural nets) to make the monitoring process more adaptive, less operator dependent, and therefore more reliable.

**Prototype Instrument for Damage Evaluation and Characterization of Truck Tires**
H. L. M. dos Reis,* J. Borgerson
*University of Illinois*

Underinflated or run-flat radial truck tires can be subjected to steel cord fatigue damage caused by overflexing of the tire. Weakened cords may break with potential catastrophic consequences, such as loss of life. The purpose of this project is to develop a prototype instrument capable of 100% online inspection of new or retreaded tires. The instrument should provide easily interpreted results (color-coded scans) to reduce the possibility of operator error.

# Nonlinear Controls

**Perturbation Methods for Lagrangian and Nonlinear Control Systems**
F. Bullo*
*University of Illinois*

This project investigates averaging theory and oscillatory control for nonlinear mechanical systems. A key result is a series expansion that describes the evolution of a system starting at rest and subject to a time-varying external force. The technical treatment relies on the homogeneity properties of affine connections models for mechanical systems; an interesting link between averaging and controllability theory relates the key concepts of averaged potential and of symmetric product. The results provide a rigorous means of investigating controllability properties, locomotion gaits, vibrational stabilization, and motion control algorithms for a large class of underactuated mechanical systems.

**Invariance Control of Nonlinear Systems**
M. W. Spong*
*University of Illinois; Alexander von Humboldt Foundation*

The goal of invariance control of nonlinear systems is to render a given state space region positively invariant by use of hybrid switching control. Invariance control has been used for stabilization of nonlinear peaking systems, for rollover stabilization of vehicles, and for collision avoidance in aircraft flight control.

# Product Development

**SQD and Six Sigma Plus Methods**
H. E. Cook,* J. L. Freeman, D. R. Herington, L. A. Wissmann
*Caterpillar Inc.; University of Illinois*

Strategic Quality Deployment (SQD) is a structured methodology for guiding the design of new products. It integrates marketing research, quality management, value engineering, and design of experiments into a single formation. The research is targeting applications in support of the development and introduction of new products. Design of experiments, Taguchi methods, QFD, long- and short-term statistical process control, target costing, and value engineering are important elements in the quality management process known as Six Sigma. The objective of this research is to integrate these tools into a single formalism for total quality management.

*Denotes principal investigator.

**Strategic Quality Deployment**
H. E. Cook,* J. L. Freeman, D. R. Herington, C. Suarez, L. A. Wissmann
*Caterpillar Inc.; University of Illinois*

Strategic Quality Deployment (SQD) is a structured methodology for guiding the design of new products. It integrates marketing research, quality management, value engineering, and design of experiments into a single methodology. The research is being applied to the planning of new product introductions and the development of business plans.

# Robotics

**Locomotion of Smooth and Hybrid Mechanical Systems**
F. Bullo*
*University of Illinois*

An area of increasing interest is modeling and control of locomotion systems, that is, autonomous vehicles or mechanical and grasping devices that interact with the environment via contacts and collisions. Examples are hopping and walking robots, robots that progress by swinging arms, and devices that switch between clamped, sliding, and rolling regimes. The engineering goal is to analyze and design systems that accomplish various tasks efficiently and robustly. This motivation leads to a number of problems that arise in the interaction of discontinuities, locomotion, and stability. Topics of interest include stabilization via multiple Lyapunov functions, motion planning across different regimes, and numerical integrators for mechanical systems subject to impacts, nonholonomic constraints, and forces.

**Passivity Based Control of Bipedal Locomotion**
M. W. Spong*
*University of Illinois*

This project aims to develop nonlinear feedback control algorithms that exploit the notion of passive walking in bipedal locomotion. Principles of total energy shaping, potential energy shaping, and hybrid switching control are used to remove the sensitivity of passive limit cycles to variations in ground slope, initial conditions, and disturbances as well as to increase the basin of attraction of the limit cycles.

# Tribology

**Freight Car, Truck Rotational Friction Effect on Rail Car Dynamics and Wheel/Rail Friction and Wear**
T. F. Conry,* D. J. Laboda
*Association of American Railroads*

The focus of this research is to develop strategies to keep the static friction torque across the center plate and side bearings within some acceptable range that avoids excessive hunting of the rail-car trucks and avoids excessively high lateral forces between the rail and the wheels. As wheel loads continue to increase and train speeds increase, the frictional behavior of the center plate and side bearings will strongly influence the dynamic behavior of rail cars. The dynamic performance requirements over a range of rail car loads and speeds will be quantified.

**Fundamental Investigation on the Tribological Failure Mechanisms of Compressor Surfaces: Scuffing**
A. A. Polycarpou* (Mech. Engr.), T. F. Conry,* J. J. Patel, N. Yu
*National Science Foundation; Industry/University Cooperative Research Centers, Air Conditioning and Refrigeration Center*

The focus of this research is to investigate the cause of catastrophic failures, namely, scuffing for realistic compressor surfaces. The project has two major components. First, researchers will make a detailed characterization of the changes in surface topography and physical structure of mating surfaces from their initial (virgin) state up to the point of scuffing. After the material properties and surface topography are understood, a modeling effort will be initiated to describe the essential coupled processes of deformation and heat transfer and the resulting effects of stress and temperature at points in a contact interface.



*Denotes principal investigator.

# Journal Articles

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Cerven, W. T. and Bullo, F. **Constructive controllability algorithms for motion planning and optimization.** *IEEE Transactions on Automatic Control, 48:4*, 575-589 (Apr. 2003).

Lall, S. and Beck, C. L. **Guaranteed error bounds for model reduction of linear time-varying systems.** *IEEE Transactions on Automatic Control, 48:6*, 946-956 (Jun. 2003).

Martinez, S., Cortes, J., and Bullo, F. **Analysis and design of oscillatory control systems.** *IEEE Transactions on Automatic Control, 48:7*, 1164-1177 (Jul. 2003).

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## Design Theory and Methodology

Liu, M. and Burns, S. A. **Multiple fully stressed designs of steel frame structures with semi-rigid connections.** *International Journal for Numerical Methods in Engineering, 58:6*, 821-838 (Oct. 14, 2003).

Liu, M., Burns, S. A., and Wen, Y. K. **Optimal seismic design of steel frame buildings based on life cycle cost considerations.** *Earthquake Engineering and Structural Dynamics, 32:9*, 1313-1332 (Jul. 25, 2003).

Thurston, D. and Srinivasan, S. **Constrained optimization for green engineering decision making.** *Environmental Science and Technology, 37:23*, 5389-5397 (2003).

## Engineering Education

Vojak, B. A., Price, R. L., and Carnahan, J. V. **The relationship between department rank and college rank in engineering graduate program rankings conducted by *U.S. News and World Report*.** *Journal of Engineering Education, 92:1*, 65-72 (2003).

## Genetic and Evolutionary Computation

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Liu, M. and Burns, S. A. **Multiple fully stressed designs of steel frame structures with semi-rigid connections.** *International Journal for Numerical Methods in Engineering, 58*, 821-838 (2003).

Liu, M., Burns, S. A., and Wen, Y. K. **Optimal seismic design of steel frame buildings based on life cycle cost considerations.** *Earthquake Engineering and Structural Dynamics, 32*, 1313-1332 (2003).

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Yassine, A., Whitney, D., Daleiden, D., and Lavine, J. **Connectivity maps: Modeling and analyzing relationships in product development processes.** *Journal of Engineering Design, 14:3*, 377-394 (Sep. 2003).

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## Genetic and Evolutionary Computation

Butz, M. V. and Goldberg, D. E. **Generalized state values in an anticipatory learning classifier system.** In *Anticipatory Behavior in Adaptive Learning Systems*. (Butz, M. V., Sigaud, O. and Gerard, P., eds.) Physica-Verlag, Heidelberg, Germany (2003).

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# Papers Presented at Conferences and Symposia

## Advanced Technology Management

Vojak, B. A. and Cihan, N. **The propensity for Christensen-type disruptive innovation in the electron device industry.** 2003 International Engineering Management Conference: Managing Technologically Driven Organizations—The Human Side of Innovation and Change (Albany, NY, Nov. 2003). Proceedings of the 2003 International Engineering Management Conference: Managing Technologically Driven Organizations—The Human Side of Innovation and Change 537-541 (2003).

Vojak, B. A. and Ho, W. H. **The potential for disruptive technical innovation in wireless communication applications in the frequency control industry.** 2003 IEEE International Frequency Control Symposium and PDA Exhibition Jointly with the 17th European Frequency and Time Forum (Tampa, FL, May 2003). Proceedings of the 2003 IEEE International Frequency Control Symposium 615-620 (2003).

## Communications Networks

Berestesky, P., Chopra, N., and Spong, M. W. **Discrete time passivity in bilateral teleoperation over the internet.** IEEE International Conference on Robotics and Automation (New Orleans, LA, Apr.-May 2003).

Sreenivas, R. S. **On partially controlled Petri nets that can be made live by supervision.** 42nd IEEE Conference on Decision and Control (Maui, HI, Dec. 2003). Proceedings of the 42nd IEEE Conference on Decision and Control 3730-3734 (2003).

## Control Systems

Bullo, F. **Trajectory design for mechanical systems: From geometry to algorithms.** 2nd International Federation of Automatic Control Workshop on Lagrangian and Hamiltonian Methods for Nonlinear Control (Seville, Spain, Apr. 2003). Proceedings of the 2nd International Federation of Automatic Control Workshop on Lagrangian and Hamiltonian Methods for Nonlinear Control 11-25 (2003).

Bullo, F. and Liberzon, D. **On quantized control and geometric optimization.** 42nd IEEE Conference on Decision and Control (Maui, HI, Dec. 2003). Proceedings of the 42nd IEEE Conference on Decision and Control (2003).

Chopra, N., Spong, M. W., Hirche, S., and Buss, M. **Bilateral teleoperation over the Internet: The time-varying delay problem.** American Control Conference (Denver, CO, Jun. 2003). Proceedings of the American Control Conference (2003).

Cortes, J. and Bullo, F. **From geometric optimization and nonsmooth analysis to distributed coordination algorithms.** 42nd IEEE Conference on Decision and Control (Maui, HI, Dec. 2003). Proceedings of the 42nd IEEE Conference on Decision and Control (2003).

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Medanic, J. **Design of nonlinear controls using structured representations.** 42nd IEEE Conference on Decision and Control (Maui, HI, Dec. 2003). Proceedings of the 42nd IEEE Conference on Decision and Control 4163-4168 (2003).

Samar, S. and Beck, C. L. **Model reduction of heterogenous distributed systems.** 42nd IEEE Conference on Decision and Control (Maui, HI, Dec. 2003). Proceedings of the 42nd IEEE Conference on Decision and Control (2003).

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Kaldate, A., Thurston, D., Rood, M., and Emamipour, H. **Development of cost-effective adsorption-electrothermal desorption system using activated carbon fiber cloths.** Air and Waste Management Association Conference (San Diego, CA, Jun. 2003). Proceedings of the Air and Waste Management Association Conference (2003).

Thurston, D. L. **Axioms for overcoming resistance to decision-based design.** National Science Foundation Design, Manufacturing, and Industrial Innovation Grantees Conference (Birmingham, AL, Jan. 2003). Proceedings of the National Science Foundation Design, Manufacturing, and Industrial Innovation Grantees Conference (2003).

## Environmental Design and Manufacturing

Emamipour, H., Rood, M., Kaldate, A., and Thurston, D. **Adsorption dynamics of organic vapors in activated carbon fiber cloth.** Air and Waste Management Association Conference (San Diego, CA, Jun. 2003). Proceedings of the Air and Waste Management Association Conference (2003).

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Butz, M. V. and Ray, S. **Bidirectional ARTMAP: An artificial mirror neuron system.** 2003 International Joint Conference on Neural Networks (Portland, OR, Jul. 2003). Proceedings of the 2003 International Joint Conference on Neural Networks, Vol. 2, 1417-1422 (2003).

Cantu-Paz, E. and Goldberg, D. E. **Are multiple runs of genetic algorithms better than one?** 2003 Genetic and Evolutionary Computation Conference (Chicago, IL, Jul. 2003). Proceedings of the 2003 Genetic and Evolutionary Computation Conference 801-812 (2003).

Chen, Y. P. and Goldberg, D. E. **Tightness time for the linkage learning genetic algorithm.** 2003 Genetic and Evolutionary Computation Conference (Chicago, IL, Jul. 2003). Proceedings of the 2003 Genetic and Evolutionary Computation Conference 837-849 (2003).

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Espinoza, F., Minsker, B. S., and Goldberg, D. E. **Local search issues for the application of a self-adaptive hybrid genetic algorithm in groundwater remediation design.** American Society of Civil Engineers Environmental and Waste Resources Institute Conference (Philadelphia, PA, Jun. 2003).

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Llora, X. and Goldberg, D. E. **Wise breeding GA via machine learning techniques for function optimization.** 2003 Genetic and Evolutionary Computation Conference (Chicago, IL, Jul. 2003). Proceedings of the 2003 Genetic and Evolutionary Computation Conference 1271-1282 (2003).

Ohnishi, K. **Adapting genotype-phenotype-mapping by using redundant real representation.** IEEE International Conference on Systems, Man and Cybernetics (Washington, DC, Oct. 2003). Proceedings of the IEEE International Conference on Systems, Man and Cybernetics 3583-3588 (2003).

Pelikan, M. and Goldberg, D. E. **Hierarchical BOA solves ising spin glasses and MAXSAT.** 2003 Genetic and Evolutionary Computation Conference (Chicago, IL, Jul. 2003). Proceedings of the 2003 Genetic and Evolutionary Computation Conference 1271-1282 (2003).

Sastry, K. and Goldberg, D. E. **Probabilistic model building and competent genetic programming.** Genetic Programming Theory and Practice 2003 Workshop (Ann Arbor, MI, May 2003). Proceedings of the Genetic Programming Theory and Practice 2003 Workshop 205-220 (2003).

Sastry, K. and Goldberg, D. E. **Scalability of selectorecombinative genetic algorithms for problems with tight linkage.** 2003 Genetic and Evolutionary Computation Conference (Chicago, IL, Jul. 2003). Proceedings of the 2003 Genetic and Evolutionary Computation Conference 1332-1344 (2003).

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Singh, A., Minsker, B. S., and Goldberg, D. E. **Combining reliability and pareto optimality: An approach using stochastic, multi-objective genetic algorithms.** American Society of Civil Engineers Environmental and Waste Resources Institute Conference (Philadelphia, PA, Jun. 2003).

Yu, T. L., Chen, Y. P., Goldberg, D. E., and Chen, J. H. **An adaptive sampling scheme for genetic algorithms on the sampled OneMax problem.** Conference on Artificial Neural Networks in Engineering (St. Louis, MO, Nov. 2003). Proceedings of the Conference on Artificial Neural Networks in Engineering 39-44 (2003).

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## Integrated Mechanical and Structural Design

Burns, S. A. **The impact of initial design selection in optimal frame design.** American Society of Civil Engineers Structures Congress 2003 (Seattle, WA, May-Jun. 2003).

Liu, M., Burns, S. A., and Wen, Y. K. **Life cycle seismic design of steel frame buildings.** 9th International Conference on Applications of Statistics and Probability in Civil Engineering (San Francisco, CA, Jul. 2003).

## Nonlinear Controls

Cronin, B. and Spong, M. W. **Switching control for multi-input cascade nonlinear systems.** 42nd IEEE Conference on Decision and Control (Maui, HI, Dec. 2003). Proceedings of the 42nd IEEE Conference on Decision and Control (2003).

Martinez, S., Cortes, J., and Bullo, F. **A catalog of inverse-kinematics planners for underactuated systems on matrix Lie groups.** IEEE/Robotics Society of Japan International Conference on Intelligent Robots and Systems (Las Vegas, NV, Oct. 2003).

## Product Development

Shariff, S., Diaz, F., Yassine, A., and Sidhu, I. **Capability-market matrix analysis for economic development policy.** 2003 International Engineering Management Conference: Managing Technologically Driven Organizations—The Human Side of Innovation and Change (Albany, NY, Nov. 2003). Proceedings of the 2003 International Engineering Management Conference: Managing Technologically Driven Organizations—The Human Side of Innovation and Change 368-372 (2003).

## Robotics

Khraief, N., M'Sirdi, N. K., and Spong, M. W. **Nearly passive dynamic walking of a biped robot.** European Control Conference (Cambridge, UK, Sep. 2003).

Spong, M. W. and Bhatia, G. **Further results on control of the compass gait biped.** IEEE/Robotics Society of Japan International Conference on Intelligent Robots and Systems (Las Vegas, NV, Nov. 2003).

# Theses

## Advanced Technology Management

Cihan, N. **The propensity for Christensen-type disruption in the electron device industry.** M.S. thesis, B. A. Vojak, advisor (2003).

Maloney, M. M. **Technical visionaries and product champions.** M.S. thesis, R. L. Price, advisor (2003).

Suarez-Nunez, C. A. **Improving product attribute forecasts at the component and subsystem levels of the value chain.** M.S. thesis, B. A. Vojak, advisor (2003).

## Communications Networks

Chirayathumadom, R. P. **The postage stamp protocol: A solution to fairness in anarchic mobile *ad hoc* networks.** M.S. thesis, R. S. Sreenivas, advisor (2003).

## Control Systems

Chopra, N. **Teleoperation over communication networks.** M.S. thesis, M. W. Spong, advisor (2003).

Lakshmikantha, A. **Robustness issues involving real and virtual queue schemes.** M.S. thesis, C. Beck, advisor (2003).

Pokorny III, J. W. **Pole-placement design of state and output feedback controls for switched systems.** M.S. thesis, J. V. Medanic, advisor (2003).

Robinson, C. L. **Distributed sensor-based exploration algorithms.** M.S. thesis, F. Bullo, advisor (2003).

Sharma, P. **Modelling and distributed control of spatial array systems.** M.S. thesis, C. Beck, advisor (2003).

Sinha, K. **Telesupervised multiagent simulator.** M.S. thesis, M. W. Spong, advisor (2003).

## Design Theory and Methodology

Navarrete, D. O. **Experimental design and response surface studies of thermoforming processes and environmental remediation systems.** M.S. thesis, J. V. Carnahan, advisor (2003).

Schrader, R. S. **Feature-based costing of sheet metal and axisymmetric turned parts.** M.S. thesis, Philpott, M. L., advisor (2003).

## Genetic and Evolutionary Computation

Khan, N. **Bayesian optimization algorithms for multiobjective and hierarchically difficult problems.** M.S. thesis, D. E. Goldberg, advisor (2003).

## Microelectromechanical Systems (MEMS)

Shrivastava, V. **Fast meshless boundary-integral formulations for 3D exterior analysis.** M.S. thesis, N. R. Aluru, advisor (2003).

## Nondestructive Evaluation and Testing

Borgerson, J. L. **Detection of broken rail using an acoustic approach.** M.S. thesis, H. L. M. dos Reis, advisor (2003).

Ervin, B. L. **Detection of corrosion in reinforced concrete structures using an ultrasonic approach.** M.S. thesis, H. L. M. dos Reis, advisor (2003).

# Patents

## Advanced Technology Management

Sidhu, I. **Hi-Fidelity Line Card**, # US6567399, May 2003.

Sidhu, I. **Method and Apparatus for Controlling Transmission of Media Signals over a Data Network in Response to Triggering Events at Participating Stations**, # US6570606, May 2003.

Sidhu, I. **Method and Protocol for Distributed Network Address Translation**, # US6567405, May 2003.

Sidhu, I. **Method and System for Facilitating Increased Call Traffic by Switching to a Low-Bandwidth Encoder in a Public Emergency Mode**, # US6625119, Sep. 2003.

Sidhu, I. **Profile-Based Method for Packet Header Compression in a Point-to-Point Link**, # US6542504, Apr. 2003.

Sidhu, I. **Remote Access Server for Multiple Service Classes in IP Networks**, # US6587433, Jul. 2003.

Sidhu, I. **System and Method for Providing Call-Handling Services on a Data Network Telephone System**, # US6584490, Jun. 2003.

Sidhu, I. **System and Method for Using a Portable Information Device to Establish a Conference Call on a Telephony Network**, # US6577622, Jun. 2003.

Sidhu, I. **System for Adjusting Billing for Real-Time Media Transmissions Based on Delay**, # US6512761, Jan. 2003.

# Awards and Honors

**Carolyn L. Beck**
Alcoa Foundation Award, 1997
Junior Faculty Award, Oak Ridge Associated Universities, 1997
Faculty Early Career Development Program (CAREER) Award, National Science Foundation, 1998-2002
ONR Young Investigator Award, 2001-2004
Accenture Outstanding Advisor Award, 2004

**Francesco Bullo**
Gamma Epsilon Excellence in Teaching Award, Department of General Engineering, 2001
Best Paper Award Finalist, Institute of Electrical and Electronics Engineers (IEEE) Robotics and Automation Conference, 2002
Best Student Paper Award, IEEE Decision and Control Conference, 2002
Xerox Foundation Award for Faculty Research, University of Illinois College of Engineering, 2003

ONR, Young Investigator Award, 2003
Outstanding Advisor Award, University of Illinois College of Engineering, 2004
SemiPlenary Speaker, International Symposium on Mathematical Theory of Networks and Systems, 2004
Senior Member, IEEE, 2004

**Scott A. Burns**
Gamma Epsilon Teaching Excellence Award, University of Illinois Department of General Engineering, 1989, 1990, 1992, 1998
Presidential Young Investigator Award, National Science Foundation, 1989
Everitt Award for Teaching Excellence, University of Illinois College of Engineering, 1990
Beckman Associate, University of Illinois Center for Advanced Study, 1992
Engineering Council Advisors List for Outstanding Advising, University of Illinois, 1996
State-of-the-Art of Civil Engineering Award, American Society of Civil Engineers, 1998

**James V. Carnahan**
Gamma Epsilon Teaching Excellence Award, University of Illinois Department of General Engineering, 1986, 1991
Everitt Award for Teaching Excellence, University of Illinois College of Engineering, 1989
Andersen Consulting Award for Excellence in Advising, University of Illinois College of Engineering, 1990, 1991, 1992, 1993, 2000
Engineering Council and Accenture Award for Excellence in Advising, 2001, 2002
Excellence in Teaching Award, Department of General Engineering, 2003

**Thomas F. Conry**
Fellow, American Society of Mechanical Engineers

**Wayne J. Davis**
Andersen Consulting Award for Excellence in Advising, University of Illinois College of Engineering, 1990, 1993
Engineering Council Advisors List for Outstanding Advising, University of Illinois College of Engineering, 1995
Coauthor of Outstanding Technical Handbook Award, American Publishers Association, 1998
University of Illinois Department of General Engineering Excellence in Teaching Award, 2000

**David E. Goldberg**
Presidential Young Investigator Award, National Science Foundation, 1985-1990
Prater Exchange Professor, University of Alabama and National Taiwan University, 1986
Capstone Engineering Society Outstanding Research Award, University of Alabama, 1989-1990
Distinguished Visiting Professor, ITESM, Monterrey, Mexico, 1990
Associate, University of Illinois Center for Advanced Study, 1995-1996
Wickenden Award, American Society for Engineering Education, 1996
Gambrinus Fellow, University of Dortmund, Germany, 1997
Editor, *Kluwer Series on Genetic Algorithms and Evolutionary Computation*, 2000-
Outstanding Instructor Award, National Technological University, 2001-2002
Senior Fellow, International Society for Genetic and Evolutionary Computation, 2003
Jerry S. Dobrovolny Distinguished Professor in Entrepreneurial Engineering, University of Illinois, 2003-

**W. Brent Hall**
Engineering Council Advisors List for Outstanding Advising, University of Illinois, 1995, 1996
Excellence in Teaching Award, University of Illinois Department of General Engineering, 1995, 1997
General Electric Scholar, Academy for Excellence in Engineering Education, University of Illinois, 1998
General Electric Fellow, University of Illinois Academy for Excellence in Engineering Education, 1999

**Juraj V. Medanic**
Dusan Mitrovic Award for Best Paper in Control, ETAN (Yugoslavia), 1983
"Technology Transfer Success Story," Air Force Office of Scientific Research, 1996

**Manssour H. Moeinzadeh**
Ralph R. Teetor National Educational Award for Teaching Excellence, Society of Automotive Engineers, 1984
Centennial Recognition for Exceptional Contribution to American Society for Engineering Education and the Profession of Engineering, 1993
Development Program Award for Collaborative Research and Educational Projects with Overseas Institutions, United Nations, 1994-1995, 1995-1996
Teachers Rated Excellent by Their Students, 2000, 2001, 2002

**Raymond L. Price**
Honorary Knight of St. Patrick, University of Illinois College of Engineering, 2001
Accenture Outstanding Advisor Award, 2001

**Henrique L. M. dos Reis**
Fellow, Acoustic Emission Working Group
Fellow, British Institute of Nondestructive Testing
Fellow, the American Society for Nondestructive Testing

**Ikhlaq Sidhu**
3Com/U.S. Robotics Silver Inventor, 3Com/U.S. Robotics, 1997
3Com Gold Inventor, 3Com, 1998
3Com Platinum Inventor, 3Com, 1998
3Com Inventor of the Year, 1999-2000

**Mark W. Spong**
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Research Initiation Award, National Science Foundation, 1982
Best Paper Award, Robotics and Expert Systems Symposium, 1987
Editor, *IEEE Transactions on Control Systems Technology,* 1997-2000
Visiting Professor, Catholic University, Leuven, Belgium, 1997
Best Video Award, IEEE International Conference on Robotics and Automation, 1998
Engineering Council Advisors List for Outstanding Advising, University of Illinois, 1998
Senior U.S. Scientist Award, Alexander von Humboldt Foundation, Germany, 1999
Visiting Professor, National University of Singapore, 1999
IEEE Third Millennium Medal, 2000
Southwest Mechanics Lecture Series Distinguished Speaker, 2001
Hugo Schuck Best Paper Award, American Automatic Control Council, 2002
Distinguished Member Award, IEEE Control Systems Society, 2002
Donald Biggar Willet Professor of Engineering, 2003

**R. S. Sreenivas**
Research Initiation Award, National Science Foundation, 1994

**Deborah L. Thurston**
Initiation Award, National Science Foundation, 1988
Presidential Young Investigator Award, National Science Foundation, 1989
Andersen Consulting Award for Excellence in Advising, University of Illinois College of Engineering, 1990, 1993, 1994
Xerox Award for Faculty Research, University of Illinois College of Engineering, 1992, 1995
Eugene L. Grant Award for best paper of the year in *The Engineering Economist* (with A. Locascio), 1996
Runner up for Best Paper of the Year Award, *IEEE Transactions on Engineering Management*, 2002

**Louis Wozniak**
Fellow, Institute of Electrical and Electronics Engineers
Gamma Epsilon Teaching Excellence Award, University of Illinois Department of General Engineering, 1985
Andersen Consulting Award for Excellence in Advising, University of Illinois College of Engineering, 1989, 1991, 1992, 1994, 1995
Energy Development and Power Generation Committee Prize Paper Award, International Joint Power Generation Conference, 1990, 1993
Engineering Council Advisors List for Outstanding Advising, University of Illinois, 1996
Editor, *IEEE Transactions on Energy Conversion,* 1999
Energy Development and Power Generation Committee Prize Paper Award, 1999