INTEGRATION OF NASA RESEARCH INTO UNDERGRADUATE EDUCATION IN MATHEMATICS, SCIENCE, ENGINEERING AND TECHNOLOGY

Ajit D. Kelkar, Joseph Monroe*, Devdas Pai, Kenneth Roberts and Sid Wang

Department of Mechanical and Chemical Engineering
*College of Engineering
North Carolina A & T State University, Greensboro, NC 27411
kelkar@ncat.edu

INTRODUCTION

The NASA **P**artnership **A**ward for **I**ntegration of **R**esearch into undergraduate Education (PAIR) program incorporated the NASA-Sponsored research into the undergraduate environment at North Carolina Agricultural and Technical State University. This program is designed to significantly improve undergraduate education in the areas of mathematics, science, engineering, and technology (MSET) by directly benefiting from the experiences of NASA field centers, affiliated industrial partners and academic institutions.

The three basic goals of the program were enhancing core courses in MSET curriculum, up-grading core-engineering laboratories to compliment upgraded MSET curriculum, and conduct research training for undergraduates in MSET disciplines through a sophomore shadow program and through Research Experience for Undergraduates (REU) programs.

Since the inception of the program nine courses have been modified to include NASA related topics and research. These courses have impacted over 900 students in the past five years. Research training for A&T students was conducted through four different programs: Apprentice program, Developers program, Sophomore Shadow program and Independent Research program. These programs provided opportunities for an average of forty students per semester.

For each year of the program, NASA-PAIR Summer Undergraduate Research Experience (SURE) Program at North Carolina A&T State University recruited several talented pre-engineering candidates from 12 Southeastern institutions (majority-serving, HBCUs, Native American-serving and women-serving). Approximately 10 –15 science, mathematics, and pre-engineering students were trained and instructed by faculty mentors on NASA-sponsored research projects during 8 weeks in the summer. Students were encouraged to pursue advanced technical careers via professional development and mentoring activities.

NASA PAIR PROGRAM GOALS AND OBJECTIVES

Goals:

1. To increase the participation of underrepresented minorities and women in MSET disciplines
2. To foster the integration of NASA-sponsored research into undergraduate education and promote undergraduate research training
3. To increase quality of graduates through enhancement of core courses with research-based learning modules; use of research equipment or data; and the sophomore shadow program
4. To promote the research preparedness of undergraduates by integrating discovery-based learning techniques throughout the MSET curricula
5. To increase number of students going to graduate school through year-round research training and the sophomore shadow program
6. To increase collaboration among research and teaching faculty
7. To increase student and faculty exposure to NASA research
8. To develop and effective partnership program among NC A&T State University, NASA Centers, industries, and community colleges

Objectives:

1. Enhance core-courses in the MSET curriculum though the development of portable learning modules, inspired by NASA-sponsored research.
2. Upgrade core-engineering laboratories to complement upgraded MSET curriculum and its appropriate teaching modules, and develop new undergraduate laboratory for multidisciplinary dynamic systems and instrumentation.
3. Conduct research training for undergraduate in MSET disciplines through a sophomore shadow program with interaction among teaching and research faculty and through Research Experience for Undergraduate (REU) programs.

In order to achieve the goals and objectives stated above, several faculty members from various departments including Physics, Chemistry, Mathematics, Mechanical, Chemical and Electrical Engineering were invited to participate in the NASA PAIR program. These faculty members were provided with undergraduate student researchers under four different categories: Developer, Apprentice, Sophomore Shadow and Independent Researcher. Developer and Apprentice assisted faculty members in developing various modules involving NASA research. These modules were eventually integrated into undergraduate curriculum either as a part of the course or a laboratory. Some of these modules which were developed and were incorporated in an undergraduate curriculum, are discussed below:

MECHANICAL ENGINEERING MODULES

The first module developed was based upon the Pathfinder system. The Pathfinder system was sufficiently comprehensive to develop modules and experiments in statics, dynamics, engineering design, and system dynamics (1-3). The instrumented physical models and lab experiments enabled students to visualize practical applications of fundamental lecture topics. These computer models allowed students to simulate "what-if" situations. These teaching modules were developed and improved based on student feedback, and eventually disseminated into other sections of the pertinent courses.

Preliminary design of physical models for classroom and lab modules

The following presentations were made to three Statics sections, one Dynamics section and one Kinematics section to a total of about 150 students:

1. Movie on the Mars Pathfinder Mission to demonstrate: Tower Flyby, Rocket Launch, Earth Orbiting, Flight to Mars, Mass Entry, Lander Opening, Rover Deployment
2. Discussion of Rover Design and Operation
3. Discussion of Rover Mobility System using 3D computer model
4. Demonstration of conventional suspension system using simplified 2D Working Model™
5. Comparison of Rover Mobility system and a conventional automobile system
6. For the statics class, a discussion on Free Body Diagrams, reaction forces, and internal forces in the members. For the dynamics and kinematics classes, a similar discussion that included motion.

Statics and Structures

Goal: To familiarize Statics and Structures classes with a typical NASA system and to demonstrate the need for static and structural analysis.

Upon analysis of various subsystems of the Mars Navigator, it was decided that the statics and structures classes benefited from the understanding the design of the structure of the Rover. The Rover consists of Solar panels, Laser Stripes, Charge Coupled Devices (CCDs), the mobility System, UHF antennas and a Warm Electronics Box (WEB). Each of these subsystems can be used for various classes but for the purpose of the statics and structures classes we selected the mobility system.

The mobility system referred to as the Rocker-Bogie Mobility System which has a set of wheels on a flexible chassis. This is designed to provide Rover stability and to prevent it from getting immobilized on the Martian Surface. Students need to understand the nature of the Martian surface and the need for the Rover to maneuver to get out of a jam. Thus the design must be different from the conventional suspension system of an automobile. In order to understand the design differences between the mobility system and the classical suspension system of a car, we decided to build a model of a suspension of an automobile and compare it with the Rover mobility system.

Laboratory-I

Goal: To demonstrate applications of core mechanics concepts with physical models.

Suspension tuning to attenuate basal excitation:

Variable-speed DC motor drives a sinusoidal displacement input to a platform (Figure 1). On the platform is mounted a tunable spring and damper assembly. On top of this assembly is mounted a small video camera. Instrumentation included an accelerometer, Linear Voltage Displacement Transducer (LVDT), and a tachometer on the mechanism drive input. Students studied the effect of changing spring and damper parameters on the motion of the camera in the presence of base excitations. Second-order system concepts such as natural frequency, damping ratio, amplification factor, and phase lag can be topics of discussion.

Dynamics of an electromechanical drive train

A variable-speed DC motor drives a mechanical load (flywheel) through a speed-reducing belt drive. Instrumentation includes a voltmeter and an optical tachometer. Students derived the equations of motion for the system and predicted system behavior to a step input. Measurements of the system's physical time response can be used for model validation and for experimental determination of the system's time constant.

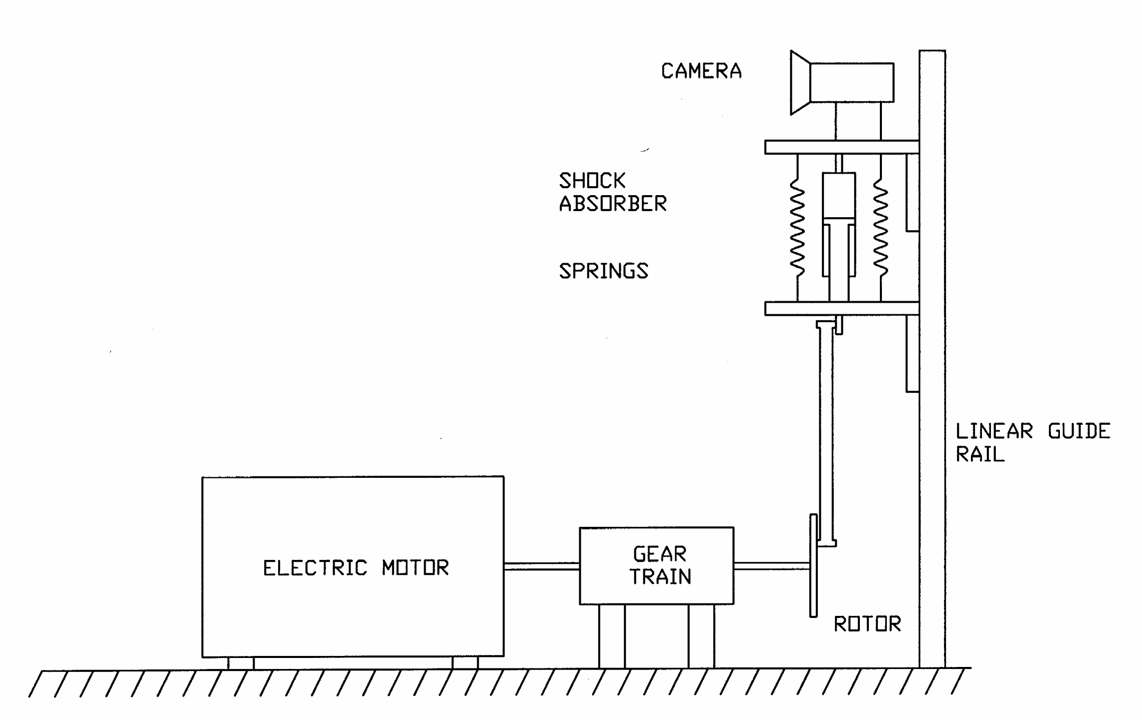

Figure 1 Basal excitation model

Laboratories – II

A frequency response apparatus was developed. The original inspiration for this apparatus was the navigational cameras on the Mars Rover. The motion of these cameras, rising and falling as the Rover climbs over obstacles, gave us the idea to design an apparatus that would subject a small video camera to vertical vibration with a video feed to a monitor for real-time visualization. The obvious application of such an apparatus for visualizing frequency response led us to emphasize the system-dynamics aspects of the experiment instead of the Rover aspects. Consequently, the only feature the final apparatus has in common with the Rover is a camera subjected to vertical motion. The prototype apparatus is a vertical mass-spring-damper system that can be used to illustrate several concepts in instrumentation and system dynamics.

A conceptual sketch of the apparatus is shown in Figure 2. Variable-speed DC motor drives a connecting rod attached to a slider on a vertical linear rail. This slider-crank mechanism provides a nearly sinusoidal input to a spring and damper suspension connected to an upper slider on the linear rail. The system output is the oscillation of the upper slider, viewed on a video monitor via a small video camera mounted to the upper slider.

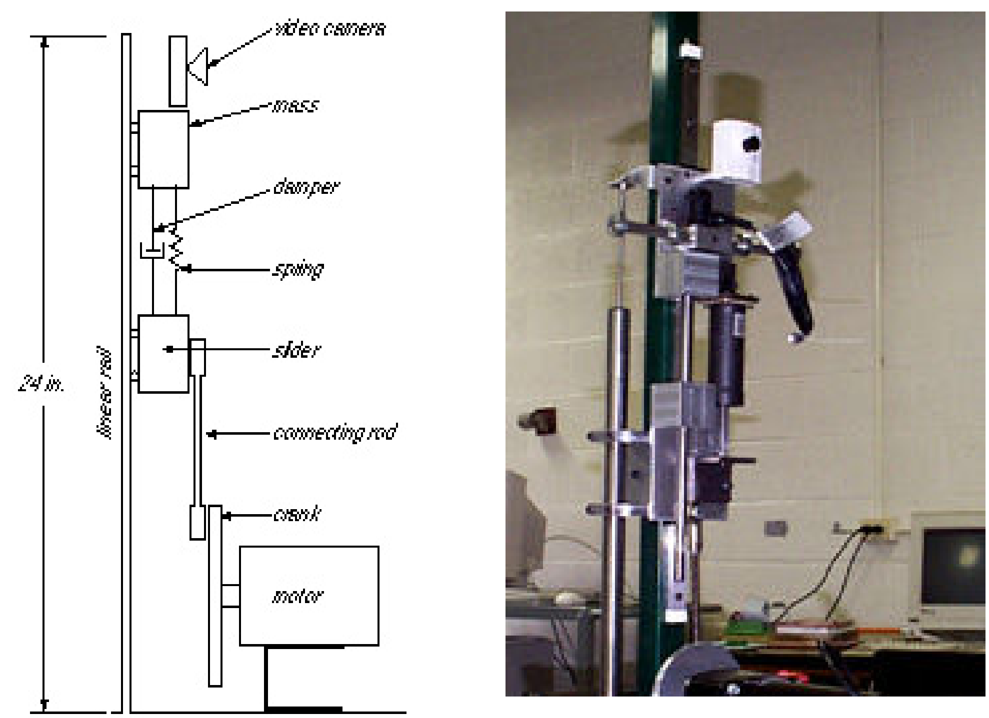

Figure 2 Schematic and photograph of frequency response apparatus

Dynamic Systems

Goal: To familiarize Dynamics and System Dynamics classes with a typical NASA system and to demonstrate the need for dynamic analysis.

Motion simulation files based on Working Model 2DTM were developed to simulate Mars Rover's mobility system. The rover's mobility system, referred to as the Rocker-Bogie Mobility System, consists of six wheels on mobile links (photograph in Figure 3) to provide the maneuverability to traverse on the rocky and sandy surface on Mars. Case study courseware was developed to demonstrate the mobility of the vehicle and highlight the need for dynamic analysis, and surveys were conducted for feedback and improvement after class presentation.

Working Model 2D (WM2D) is a powerful engineering analysis and motion simulation software on personal computers. A user can sketch a mechanical system (Figure 4) using a variety of simple geometric primitives. Then sketch additional constraints (joints, springs, and dampers) and actuators (cylinders and motors). WM2D then uses its simulation engine to set the mechanical system in motion. Video simulation files can be generated from these WM2D files to be replayed independent of the WM2D program.

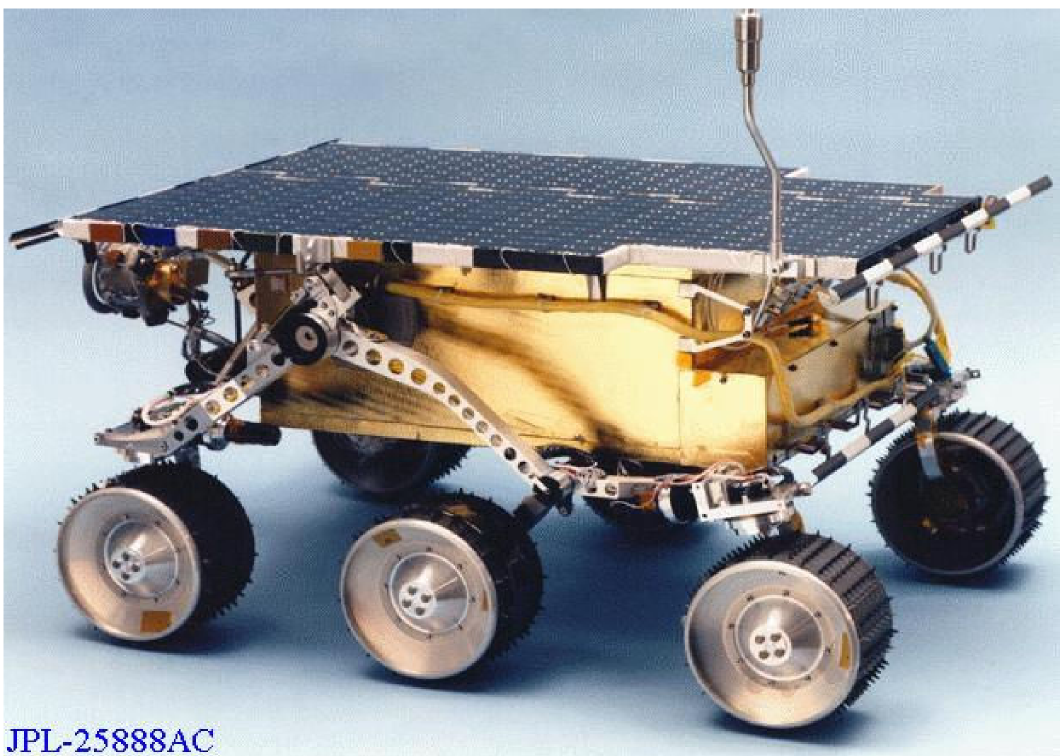

Figure 3 Photograph of Sojourner Rover

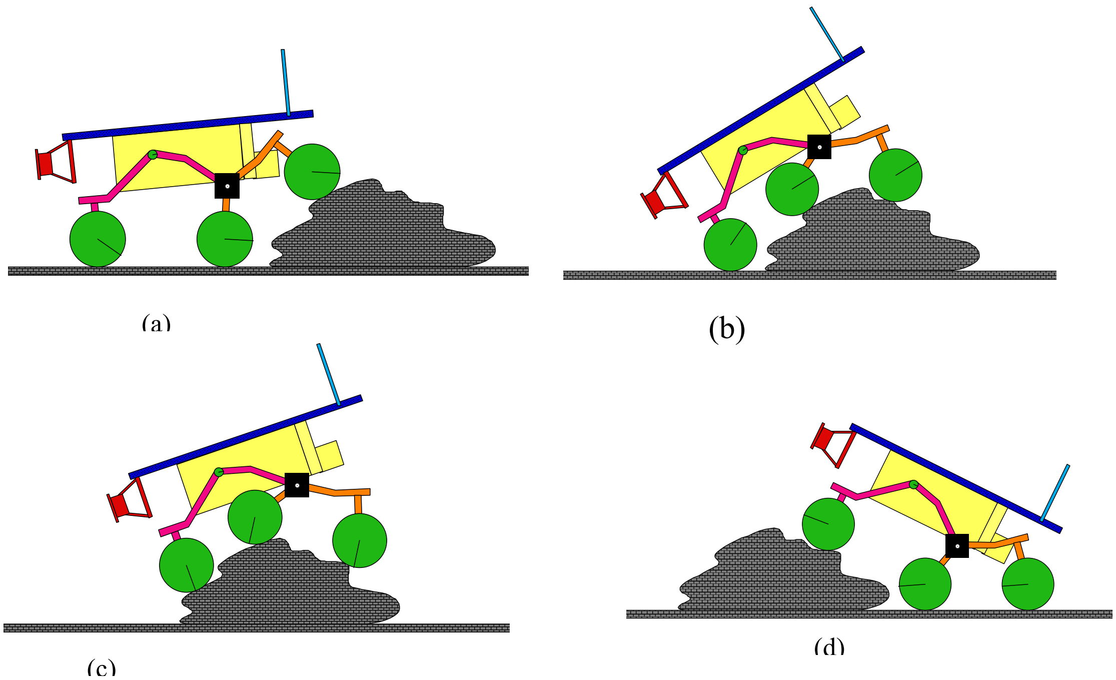

Figure 4 Working Model schematic of Rover

CHEMICAL ENGINEERING MODULES

Macromedia software products were used to produce multimedia modules of NASA projects that can be used in a variety of undergraduate courses. Previous work has involved identifying and testing the capabilities and ease of use of a variety of multimedia software packages. A basic module template was developed that requires students to apply a problem solving methodology to NASA problems, compare their ideas to the approach taken in NASA research projects, and analyze data from the research projects. The first module developed involved the NASA microgravity bioreactor (4-8). Four undergraduate students were involved in developing the NASA microgravity bioreactor module.

PHYSICS MODULES

Physics department developed a microcomputer based physics laboratory and further developed the course module on Stress and Strain. Compression strain video and data had been collected last year. In addition, animations from PEARLS physics software were combined with Stress-Strain module (9).

MATHEMATICS MODULES

This module was developed by integrating Calculus with applications especially to Astronomy. Instructor gave a project entitled "**Vector Analysis and Planetary Motion**" to calculus III students. The project was carefully designed and helpful hints were given. Students were required to work in groups of four, and they used what they learned in Calculus to derive Kepler's laws: Law of orbits--each planet in solar system moves in an elliptical orbit with the Sun at a focus; Law of Areas—equal areas are swept out in equal times by the line from the Sun to a planet; Law of Periods—The squares of the periods of planet orbiting around the Sun are proportional to the cube of the major semi axis of their respective elliptic orbits. The class had 48 students. They were given about a month to finish the project. Most groups did very good job in deepening their understanding of vector analysis and their written presentation. In addition, instructor used Maple to help students' understanding of mathematics numerically and graphically. Instructor gave some mini worksheets to students and they were required to use Maple to do some problems in Calculus.

ELECTRICAL ENGINEERING MODULES

Module for modeling aircraft wing deflection with their RLC equivalents was developed and was adopted in Circuits course. In addition a module "Not all Coffee cups are the same: A comparison of McDonald's and Burger King's Styrofoam cups" to study the concepts of heat transfer and thermodynamics was developed.

RESEARCH TRAINING FOR UNDERGRADUATES

One of the objectives of NASA PAIR program was involvement of undergraduate students into NASA sponsored research program. In order to achieve this objective undergraduate students were assigned to the principal investigator of one of the several NASA and DoD funded research programs at North Carolina A&T State University. This arrangement provides undergraduate students with different techniques and methodologies of conducting research.

<u>Sophomore Shadow Program:</u>

It can be costly for a researcher to train undergraduate students, especially at the freshman or sophomore levels. Researchers can be hesitant to allocate funds to provide research training for these students. The Sophomore Shadow Program addressed this training. Each year ten sophomores were provided stipends by the PAIR program to work with or "shadow" upper class or graduate students to get the training needed by the NASA PI. If the student did a good job, the PI agreed to support the student in subsequent years. Both the students and PIs benefited from this program. PIs got students trained in their field of expertise at no cost and no risk and students got an opportunity to work on a research project early in their college careers.

NASA-SURE PROGRAM

As a part of NASA PAIR program, in addition to North Carolina A&T State University, students from several other HBCUs/MI were involved in various MSET related activities. North Carolina A&T State University conducted a NASA Summer Undergraduate Research Experience (NASA-SURE) workshop. The details of NASA-SURE are given below:

- Students were identified from each participating institution
- Students were provided an undergraduate research training in the appropriate MSET area, focusing primarily on the techniques and methodologies of conducting research
- Students prepared a summary report, and made presentations.

In addition one-day field trip to one of the NASA Centers for SURE participants was planned. Each year NASA-SURE program recruited 15 pre-engineering students from 10 different institutions.

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BIOGRAPHY

DR. AJIT D. KELKAR is a Professor of Mechanical Engineering at North Carolina A&T State University. His research interests include manufacturing of composite materials, finite element modeling, fracture mechanics, high temperature materials, ceramics and composites. Specifically, his work has included the low cost manufacturing of composite materials, damage characterization of thin and thick composite laminates subjected to low velocity impact loadings, three dimensional finite element micro mechanics modeling of composites, modeling of textile composites, geometrically nonlinear plate and membrane problems, modeling of ceramic composites, fracture toughness studies of high strength materials, finite element modeling of offset car crash simulations. He is the member of several professional societies including ASME, AIAA, and ASEE.

DR. JOSEPH MONROE is a Dean and Ronald E. McNair Endowed Chair Professor of College of Engineering at North Carolina A&T State University. During the past twenty-five years, his work has primarily focused on establishing, developing, and evaluating programs of higher education in the field of computer science. Dr. Monroe is a founding member of the inaugural Computer Science Honor Society, Upsilon Pi Epsilon (UPE). He is a member of the Board of Directors for the Industries of the Blind since 1995, the Board of Directors for Computing for NASA since 1995, and the Board for Engineering and Surveying for North Carolina since 1998.

DR. DEVDAS M. PAI is a Professor of Mechanical Engineering at NC A&T State University and Associate Director (Operations) of the Center for Advanced Materials and Smart Structures. He received his M.S. and Ph.D. from Arizona State University. He teaches manufacturing processes and tribology related courses. A registered Professional Engineer in North Carolina, he serves on the Mechanical PE Exam Committee of the National Council of Examiners for Engineers and Surveyors and is active in several divisions of ASEE.

DR. KENNETH L. ROBERTS is an Associate Professor in the Department of Chemical Engineering at North Carolina A&T State University. Dr. Roberts is a member of the American Institute of Chemical Engineers (AIChE), the North American Catalysis Society (NACS), and the American Society for Engineering Education (ASEE). Roberts has research interests in the areas of materials chemistry and materials processing specifically involving environmental catalysis, electro catalytic materials & fuel cells, nanoscience & nanotechnology. Dr. Roberts also served as Program Coordinator for the NASA-Summer Undergraduate Research Experience (SURE) Program in the College of Engineering at North Carolina A&T State University for pre-engineering science, mathematics, and technology students from several partnered U.S. colleges and universities.

DR. SHIH-LIANG (SID) WANG is Professor and Director of Mechanical Engineering in the Department of Mechanical and Chemical Engineering at North Carolina A&T State University. Dr. Wang received his Ph.D. in mechanical engineering at Ohio State University in 1986. His research interests include computer-aided design, machine and mechanism design, motion simulation of mechanical systems, design theory and methodology, and robotics.