**Executive Summary**
**UMR Doctor of Philosophy Program in Systems Engineering**
In the late 1990s, UMR, along with the University of Southern California, responded to and won The Boeing Company's "Request for Proposals" to provide a Systems Engineering Master of Science (MS) degree to Boeing engineers and its contractors worldwide and in 2000 the MS degree in Systems Engineering was approved by the CBHE. Currently, the program has over 270 students enrolled and has graduated over 150 students as of the fall 2005 semester. The Systems Engineering program is considered as one of the best programs in the nation and attracts students from diverse companies and laboratories, such as the U.S. Air Force, U.S. Army, National Geospatial-Intelligence Agency (NGA), Los Alamos National Laboratories, General Motors, Lockheed Martin, Raytheon, Sprint, Brewer Science, Briggs and Stratton, Hollister Corporation, and Singapore Airlines.

There are a limited number of PhD degree programs in U.S. universities. The Council of Engineering System Universities (http://www.cesun.org/) alone list over 10 faculty positions in Systems Engineering and/or areas related to Systems Engineering. *To meet this growing demand for trained systems engineers, UMR is proposing a PhD program in Systems Engineering that will springboard off the success of the current MS graduate program in Systems Engineering, and thereby help to meet the growing demand for doctorates with degrees in Systems Engineering.* The proposed PhD program in Systems Engineering will depend heavily on the MS degree program. It will maintain the same diversity among various disciplines by cutting across all four schools and colleges at UMR for the approximately 30 faculty who have agreed to participate in the Systems Engineering PhD degree program. Courses will be taught on-campus and broadcast live over the Internet using one of the many distance education classrooms at UMR. This infrastructure is in place at UMR in the form of the Video Communication Center (VCC).

The new degree proposed will require an additional cost burden to the university as it primarily uses existing courses and laboratories and brings in significant tuition revenue. Revenue for this degree program will be generated by tuition paid by off- and on-campus students. UMR is under contract to offer the Systems Engineering graduate program via the Internet to The Boeing Company employees. he current rate approved by the Board of Curators for these distance students is $3,802 per three credit hour course, whereas on-campus resident students are charged $937 plus IT, activity and health service fees.

A PhD in Systems Engineering is in line with the direction and strategic plan of the UMR campus (http://campus.umr.edu/chancellor/stratpln/). UMR has the goal of becoming one of the top five technological universities in the United States by 2010. he values of the entrepreneurial spirit and collaboration in interdisciplinary efforts that transcend traditional boundaries are also exemplified by the systems engineering program, both in content and direction of purpose. Finally, developing a doctoral program in systems engineering will also meet campus strategic initiatives by increasing enrollment, expanding research performance and reputation, enriching the student experience, and facilitate the pursuit of external opportunities.

## 1. NEW PROGRAM PROPOSAL

**Form NP**

**Sponsoring Institution:**    University of Missouri-Rolla

**Program Title:**    Systems Engineering

**Degree:**    Doctor of Philosophy (PhD) in Systems Engineering

**Options:**    No options

**Delivery Sites**:    University of Missouri-Rolla

**CIP Classification:**    14.2701

**Implementation Date:**    Fall 2006

**Cooperative Partners:**    No Partners

**Expected Date of First Graduation:** December 2007


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## 2. NEED

In the late 1990s, UMR responded to The Boeing Company's "Request for Proposals" (dated 12/1/98) to provide a Systems Engineering MS degree to Boeing engineers and its contractors worldwide. As a result, a joint effort was formed between the University of Southern California (USC) and the University of Missouri-Rolla (UMR). The UMR and USC team proposal was selected by The Boeing Company from among 15 competing proposals that included submissions from Ivy League universities. In 2000, the MS degree in Systems Engineering was approved by CBHE. During the December 2000 commencement ceremony, three students received their MS degrees in Systems Engineering as the first graduates of the UMR program. Currently, the program has over 270 students and has graduated over 150 students as of the Fall 2005 semester. The Systems Engineering program is considered as one of the best programs in the nation. It is attracting students from diverse companies and laboratories, such as the U.S. Air Force, U.S. Army, National Geospatial-Intelligence Agency (NGA), Los Alamos National Laboratories, General Motors, Lockheed Martin, Raytheon, Sprint, Brewer Science, Briggs and Stratton, University of Missouri System, Hollister Corporation, and Singapore Airlines. Nonetheless, The Boeing Company still remains the major source of students, and the cooperation and competition between UMR and USC for students from The Boeing Company is still healthy. UMR and USC continue to be the major suppliers of systems engineers for The Boeing Company as stated clearly in the following quotation by John Tracy, Vice President of Engineering of Boeing Integrated Defense Systems (IDS):

> *"Systems Engineering is very important to IDS and is becoming more so. It is a necessary way of doing business not only for the understanding and implementation of the most modern practices of systems engineering, but also for advancing our competitive posture in areas such as decision making, modeling and interdisciplinary integration. Systems Engineering is a foundational element in meeting our customer needs. USC and UMR have a contract with Boeing to provide a systems engineering graduate program – available over the Internet – for all Boeing employees. I encourage the engineers of Boeing to participate in this program. It will be beneficial for them and it is necessary for Boeing."*

Beyond interest from The Boeing Company, systems engineering is continuing to be recognized as a degree of choice for hiring new engineers working in defense, manufacturing, and industrial-based organizations. Unfortunately, companies can no longer simply hire electrical, mechanical, or other traditional engineers and then provide the typical 10-20 years of job rotations that are often required to develop the necessary and valuable systems engineering skills. The demand is too large, and companies can no longer simply cannibalize from each other. Recently, numerous speakers (both during industry and academic brainstorming sessions and plenary talks) at the most recent 2005 and 2006 International Council on Systems Engineering (INCOSE)

http://www.incose.org/) conferences discussed and considered new ways to meet current demand, as well as guide academia to accelerate, promote, and encourage new degrees in

the field of systems engineering. The current MS degree program will provide a sound foundation for the proposed PhD program in Systems Engineering, and will go a long way towards helping to meet industrial demand.

## 2.1 Societal Need

We are increasingly becoming a networked society. This is true in state, local and federal government, industry, and with individuals. Society is increasingly dependent on these networks. These new engineering systems are generally described as Mega Systems. Figures 1 and 2 provide operational concept views for some of these systems.
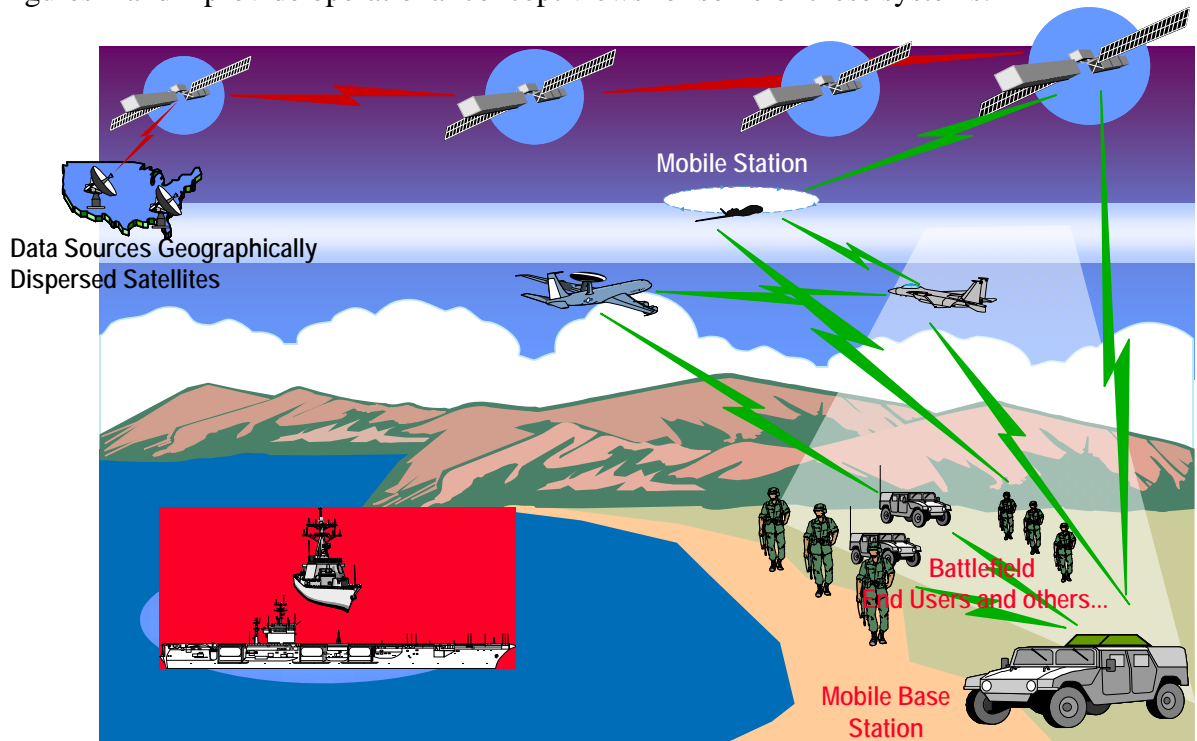


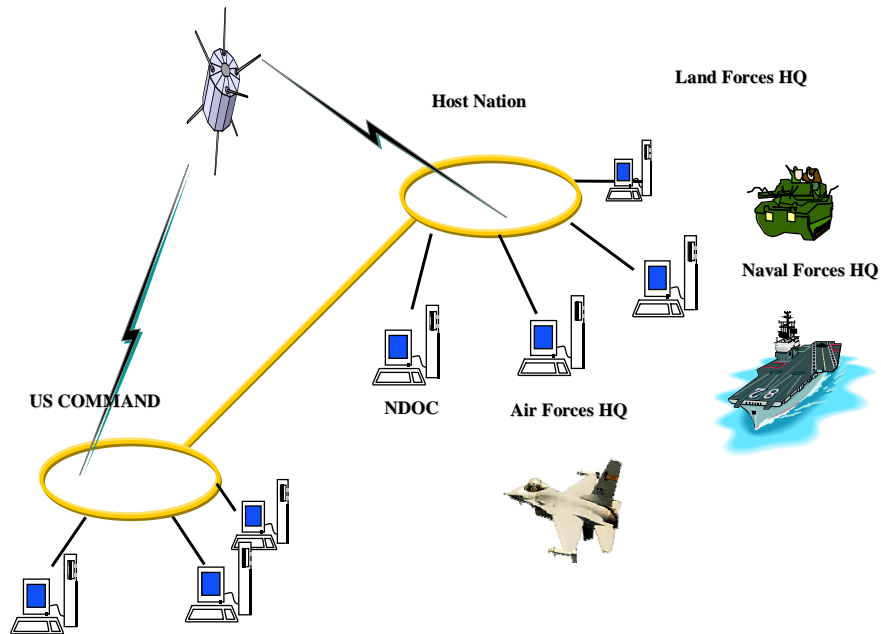Figure 1: Military Mega-Systems

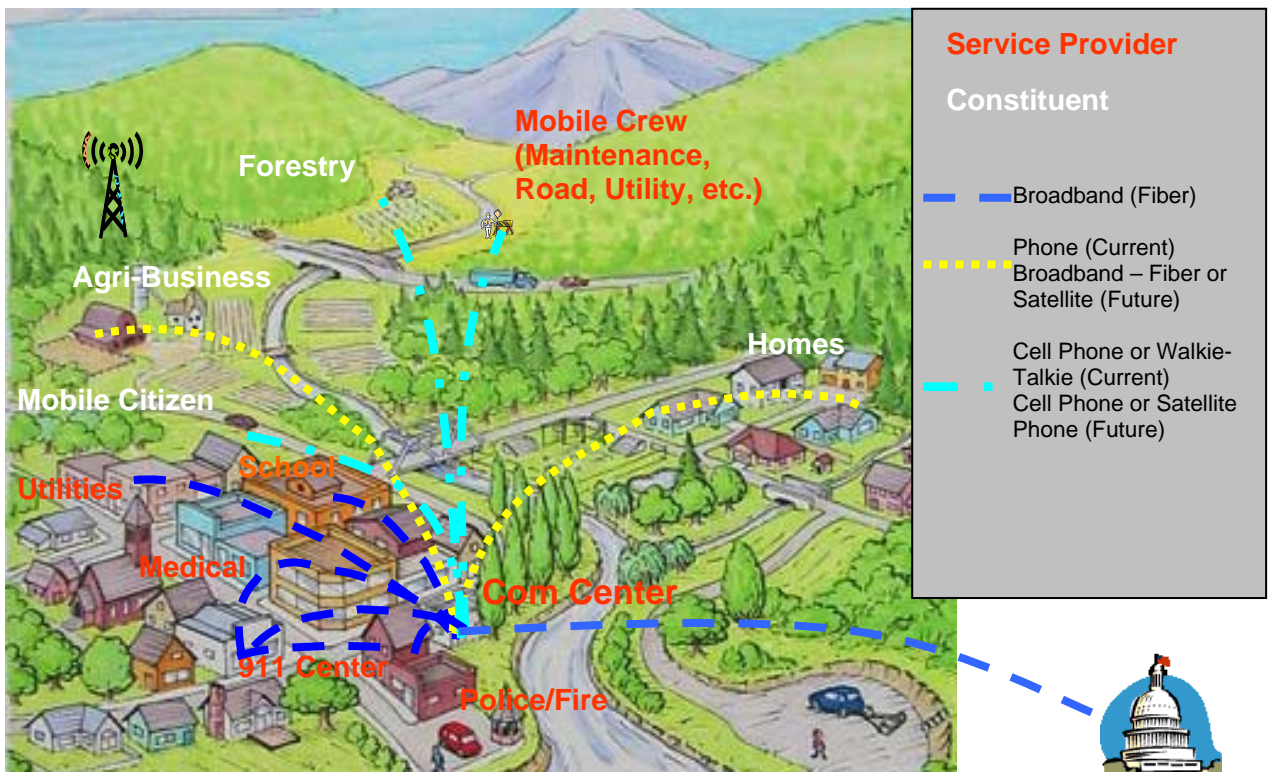Figure 2: Trans-National Military Mega-Systems



Figure 3: OV-1 High-Level Operational Concept Graphic Rural Country Management

It is possible to combine these systems and make them trans-national in responding to dynamically changing needs imposed by global events by creating system architectures that will be in effect for the duration of the event, thereby creating a need to develop new systems architecture for the next mission or the event. This fact is important as it complicates the systems architecting activities and also eliminates the static structure of classical architecting approaches. Hence, the architecture becomes a dominating but confusing concept in capability development. The same concepts can be applied to managing a rural country as well. Figure 3 (Charles J. Bryan SysEng 469 Fall 2004 course project) depicts the concept of operations for such a system.

These systems need to evolve in time to accommodate changes in technology and requirements. Hence, systems engineers need to monitor, evolve, and adapt systems architectures in time. This eliminates the classical concept that is used in the past, namely, that architectures are static. Figure 4 demonstrates this concept. These systems evolve by adding components, as in the case of electrical utilities creating a potential for hidden robustness (for example, load sharing across electric utilities), and also give rise to a potential for cascading failures as well, as in the case of August 14, 2003 blackout in Northeast U.S. Individual systems within the Systems-of-Systems (SoS) can be developed to satisfy the peculiar needs of a given group. The information they share is so important that the loss of a single system may deprive other systems of their data needs to achieve even minimal capabilities.
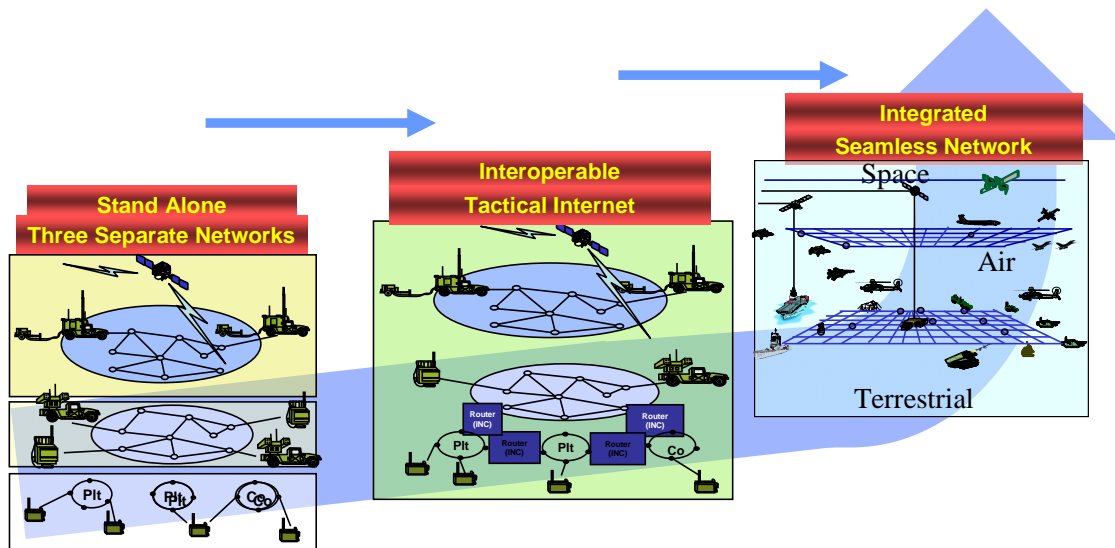


Figure 4: An Example of the Evolution of Systems-of-Systems

It is also possible to define a Family-of-Systems (FoS) as a set or arrangements of independent systems that can be arranged or interconnected in various ways to provide capabilities. The mix of systems can be tailored to provide desired capabilities, depending on the situation.

Although these systems can independently provide useful capabilities, in collaboration they can more fully satisfy a more complex and challenging capability. The SoS created from Network-Centric Operations (NCO) is a "super-system" comprised of elements that are themselves complex, independent systems that interact to achieve a common goal.

Unfortunately, the current body of knowledge in Systems Engineering is not sufficient for effective design and operation of these systems. There is a need to push the boundaries of technology and Systems Engineering and Systems Architecting research, both in industry and research universities, to meet the challenges imposed by these systems, as there is increased uncertainty about systems requirements coupled with continuous changes in technology and organization structures. A diverse spectrum of missions and operations requires development of system architectures that can adapt and evolve. This is possible through extensive collaborative research with industry and academia in Systems Engineering and Systems Architecting to answer the following questions for these emerging new engineering systems:

1. How can we assure trustworthiness, interoperability, large-scale design, test and evolutionary growth?
2. How can we deal with hidden interdependencies?
3. How can we guard against cascading failures?
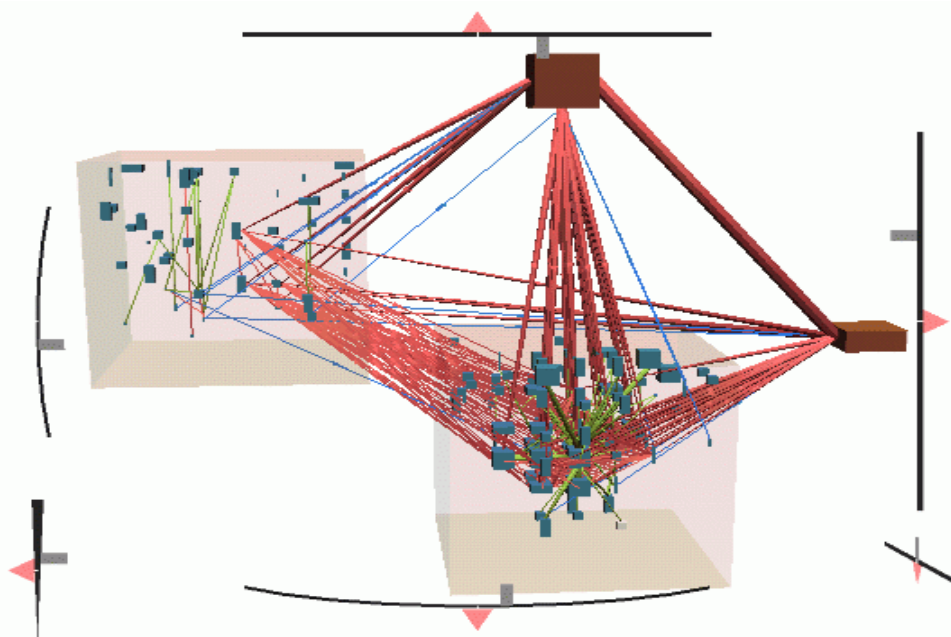4. How can we deal with complexity?



Figure 5: A graph representing almost 6 million lines of computer code. The graph contains approximately 33,000 nodes and 34,000 relations. Source: NATO Report on Visualization, 1999.

The four current PhD programs in the nation are not sufficient to meet this research challenge that requires extensive collaboration with industry. There is also a need to

restructure the classical PhD program structure to meet these new research demands, as it is difficult to bring these systems to a university laboratory.

The tremendous success of UMR's Systems Engineering MS degree program over the last six years, and strong ties of this program to The Boeing Company, both nationally and internationally, put UMR in an excellent position to respond to this need. We believe that the availability of such a program will have a positive impact on the state's economy in the future.

## 2.2 Student Demand

**Form SE: Total PhD Student Enrollment Projections (from year-to-year)**

Based on current interest both on-campus and from existing MS distance students, it is estimated that there will be 44 PhD students in the program at the end of five years. Approximately 60% of the student body will be part-time and 40% will be full-time students. Annual graduation rates at the end of three and five years are 6 and 12, respectively. Annual projections are given in the following tables.

### Projections Based on Market and Student Demand

| YEAR | 1 | 2 | 3 | 4 | 5 |
|------|----|----|----|----|----|
| FULL-TIME | 10 | 12 | 14 | 16 | 18 |
| PART-TIME | 12 | 16 | 20 | 24 | 26 |
| TOTAL | 22 | 28 | 34 | 40 | 44 |

### Enrollment at the end of Year 5 for the program to be Financially and Academically Viable

| YEAR | 5 |
|------|----|
| FULL-TIME | 18 |
| PART-TIME | 26 |
| TOTAL | 44 |

Based on current student interest, it is fully expected that enrollments numbers will meet, and most likely succeed, the projections listed in above tables. Nonetheless, based on current student interests and preliminary enrollments, even the most pessimistic numbers project that there will be at least 12 PhD students in the program at the end of five years,

with approximately 60% of the student body part-time and 40% full-time students. Under the worse case scenario, annual graduation rates at the end of three and five years are 2 and 6, respectively. Worse case student projections are given below in the following two tables.

**Worse Case Scenario Projections Based on Current Market and Student Demand**

| YEAR | 1 | 2 | 3 | 4 | 5 |
|------|---|---|---|---|---|
| FULL-TIME | 1 | 1 | 2 | 3 | 5 |
| PART-TIME | 1 | 3 | 4 | 5 | 7 |
| TOTAL | 2 | 4 | 6 | 8 | 12 |

**Worse Case Scenario Projections of Enrollment at the end of Year 5 for the program to be Financially and Academically Viable**

| YEAR | 5 |
|------|---|
| FULL-TIME | 5 |
| PART-TIME | 7 |
| TOTAL | 12 |

Once again, while the figures in the previous table list the number of students projected after five years to make the program viable in a worse case scenario, it is expected that the actual numbers will be much higher. Currently, five on-campus and five off-campus students have expressed interest in pursuing a PhD in Systems Engineering, most of which are preparing and/or delaying admission, until receipt of final approval. A conservative estimate would have at least half of these students formally deciding to pursue the PhD in Systems Engineering upon approval. Currently, the MS program generates significant cash flow. While building on the current infrastructure already in place for the MS program, enough free cash flow is available and can be used to support the program in the initial years. If for some reason interest in the PhD program is too low or insignificant, the burden on the existing MS program will be minimal since the infrastructure is already in place and will still be needed to support the highly successful MS program. Very few if any courses and/or faculty will be impacted. Furthermore, although the worse case numbers shown above (12 total students in five years) roughly equate to one PhD student per core systems engineering faculty, even this level of student enrollment would probably not be necessary since the overhead to run the program outside the existing MS program is low. Nonetheless, it is expected that the program will be a cash generator early in its development lifecycle, given the relatively low startup cost, and the current student interest. While not being the sole source of PhD students, interest for The Boeing Company alone should provide a healthy foundation during the initial lifecycle years (see the survey and responses by William Schoening, Boeing Coordinator for the Systems Engineering graduate program, (see page 1ll).

Demand projections are further highlighted by national need. The American Society for Engineering Education (ASEE) web site lists 22 universities that have MS degree programs in Systems Engineering. Every year new universities are being added to this list. Nationwide, 782 MS degrees were awarded in Systems Engineering in 2003 and this number jumped to 970 in 2004. These programs generally use practicing Systems Engineers as adjunct faculty, often with limited full time faculty. Hence, there is a great need for faculty with a PhD in Systems Engineering to teach graduate courses in Systems Engineering. Their responsibility will also include creation of a new body of knowledge in this field through research to help find solutions to the engineering problems in the design and operation of both defense and commercial complex network centric systems-of-systems and family-of-systems of the future.

However, there are a limited number of PhD degree programs in USA universities. The four basic programs at Massachusetts Institute of Technology, University of Virginia, Stevens Institute of Technology, and University of Arizona, along with a DSc program at The George Washington University and a closely related PhD degree program at George Mason University, are not sufficient to meet this demand. UMR's strong foundation in the MS degree program in Systems Engineering is an asset in starting the PhD program. There are currently 14 students in the Engineering Management PhD program who are conducting Systems Engineering related research. These students are not listed in the Student Enrollment Projection Table under Year 0.

Graduates of the Systems Engineering MS degree program will be the primary source of students for this new program. Defense industries, such as, but not limited to, The Boeing Company, will be the initial primary source for students, as well as the funding entity for the program through tuition reimbursement during the first five years of the program. On-campus students will be funded through research grants from industry and federal agencies. It will take approximately six years for a part-time student and three years for a full-time student to complete the degree after successful completion of their MS degree in Systems Engineering. The Boeing Company has agreed in principle to support the PhD program, including working with UMR and showing a willingness to consider joint contracts and grants that may be beneficial to both The Boeing Company and UMR, allowing PhD students the opportunity to work on research relevant to their home organizations, while still meeting any student and university academic obligations. Support letters from other companies and organizations have also been included, further highlighting the interest an applicability of the PhD degree in Systems Engineering.

In addition to academia, current employment opportunities for Systems Engineering doctorates are with defense companies who usually allow two tracks for promotion, namely, management and technical. There are many engineers who, aspiring to be technical fellows, would like to pursue a PhD degree in Systems Engineering. As an example within The Boeing Company, Systems Engineering is recognized as a technical area to select technical fellows only during the last six years. The Institute of Electrical and Electronics Engineers (IEEE) recently recognized Systems Engineering by forming a

Systems Engineering Council having representatives from 18 societies. These are clear indications that further justify the growing need for Systems Engineering professionals.

## 2.3 Market Demand

Systems Engineers are responsible for the design and management of complex systems. There is a need for engineers who are concerned with the whole system and can take an interdisciplinary and top down approach, who are problem definers, not just problem solvers, and who are involved with a system throughout its lifecycle from development through production, deployment, training, support, operation and disposal. The systems architecture is often arbitrary for these systems and interfaces are very significant and are generally unknown. Technical and domain expertise is important.

Systems engineering is non-linear journey from cradle to grave that result in a non-analytic top down design process. Solution concepts are not unique, global optimization is often not possible, and balance is sought. Societal factors are important and are sometimes difficult to predict. There is a need to iterate between form and function experimentally.

These characteristics necessitate engineers with diverse backgrounds of technical and domain specific experience. Companies have realized this need and have trained their engineers accordingly. However, as mentioned earlier, there have not been sufficient educational offerings to fulfill the current educational need. This has created a huge demand to provide an education to engineers so that they could receive their MS in Systems Engineering while working.

These recent changes have created the following two basic needs:
- Availability of full-time faculty to teach Systems Engineering courses in the universities that offer PhD degrees in Systems Engineering. The current practice in some universities is to use practicing Systems Engineers from industry as adjuncts professors to teach courses in these programs.
- Creation of a new body of knowledge in Systems Engineering to respond to new engineering challenges of tomorrow, along with the immediate transfer and creation of this knowledge within industries. This knowledge pushes the envelope of technology in a timely manner, while respecting proprietary information of the involved companies and providing for the education of a new generation of Systems Engineering faculty.

Within Missouri alone, the demand for engineers in general is expected to grow 8.2% from 2002 to 2012, while the growth for those teaching engineering is expected to outpace this number, increasing 29.8% over the same timeframe (http://www.ded.mo.gov/researchandplanning/). While these numbers are not specific to systems engineering, they do indicate the general need for engineering professors, at least at the state level. An official survey to predict the demand for Systems Engineering doctorates has not been conducted by professional societies or universities. However, the number of universities establishing graduate programs in Systems Engineering is

increasing. This increase became more pronounced after the establishment of interdisciplinary MS and PhD degree programs in Engineering Systems within the Engineering Systems Division at MIT. The University Council on Engineering Systems, which was formed three years ago under the leadership of MIT, had its bi-annual meeting at the Georgia Institute of Technology on December 14-15, 2005. This body, which is not affiliated to any professional society, represents 29 US universities including MIT, Berkley, Stanford and Cornell, and seven international universities from Europe including Cambridge and Technical University - Delft, Canada and Australia. UMR has been represented in this group from the beginning. Fifty-four faculty members were invited to the December 14-15, 2005 meeting at Georgia Tech. This group forms the critical mass in the Systems Engineering research and education community. This is a clear indication of the interest and need for new faculty at these institutions.

The tremendous success of the Systems Engineering MS degree program over the last six years, along with its strong ties to The Boeing Company, both nationally and internationally, uniquely positions UMR to respond to this need. See the attachment for additional information on The Boeing Company's commitment to the proposed Systems Engineering PhD degree program and a copy of the support letter. Additional letters are also included from current and former students, both within and outside The Boeing Company, along with other companies interested and supportive of a PhD degree in Systems Engineering. Other companies that have employees pursuing an MS in Systems Engineering at UMR include:

- General Motors
- Lockheed Martin
- Los Alamos National Laboratories
- National Geospatial-Intelligence Agency (NGA)
- Northrop Grumman
- Raytheon
- Rockwell Collins
- SAIC
- Sprint
- U.S. Air Force
- U.S. Army
- U.S. Department of Defense

**2.4 Marketing Plan**
In order to attract high quality applicants, doctoral students will be recruited from a number of sources in addition to he aforementioned companies listed above. Initially, PhD students will be recruited from the growing pool of successful past and current MS students, a number of which have already inquired about the degree and expressed their desire to enroll and work towards a doctorate. All students who have not already been accepted into and passed through the MS program will be expected to meet the high GRA standards of the program (which are higher than the minimum requirements of the School of Engineering at UMR). Traditional on-campus students, both currently enrolled at

UMR and at other universities, will also be recruited using resources and procedures currently in place that have been successful in the past for recruiting doctoral students in Engineering Management. This includes the recruitment of both domestic and international students. Posters, program descriptions, and research reports will also be sent to departments that offer undergraduate and graduate degrees in engineering. Current and past students will be notified of the opportunity to pursue a PhD in systems engineering. Many of the recent MS graduates are working professionals with numerous contacts and a high level of respect for the UMR graduate program. These professionals, even if not pursuing a doctorate themselves, will be recruited to help get the word out for this new graduate degree opportunity. The result of networking with these students has been very successful for increasing the MS student body numbers for within Engineering Management and Systems Engineering. This same network should prove beneficial for generating interest in the PhD program in Systems Engineering.

The aforementioned companies will provide a rich pool of students for recruiting Systems Engineering doctoral students. It should be noted that students from these companies have selected UMR by word-of-mouth and not as a result of any recruiting effort. Presumably, current enrollment can be increased significantly with the requisite promotion. As a result, site visits will be made to these locations, and/or video conferencing will be used. Additional companies will also be identified. UMR is already providing details to companies requesting information regarding individual courses, four course certificates, and customized graduate programs, all of which have been successful for attracting interest in additional graduate study. These students will also be recruited for doctoral study.

The EMSE department is also active in national and international Systems Engineering organizations. Every summer, various faculty from UMR attend the INCOSE (International Council on Systems Engineering) Symposium. In addition to presenting research papers, UMR also displays an information exhibit for recruiting purposes, host lunch seminars describing the program, and posts and distribute program information. Similar activities occur at the CSER (Conference on Systems Engineering Research) and IERC (Industrial Engineering Research Council) conferences. Faculty, including the director, Dr. Cihan Dagli, periodically give invited talks on systems engineering related research at companies and INCOSE chapter meetings, giving further opportunity to market the PhD program.

This approach has been successful for the MS program and will continue for the PhD program.

In summary, the proposed Systems Engineering PhD degree program will serve the needs of the State of Missouri and the nation in a timely manner. It will also maintain the leadership role of UMR, and in turn the State of Missouri, in Systems Engineering Graduate Education.

## 3. DUPLICATION AND COLLABORATION

UMR is the sole provider for the program. At the present time, no other institution of higher education in the State of Missouri offers programs that are similar to the proposed program.

## 4. PROGRAM STRUCTURE

### 4.1 Basic Structure

The proposed PhD program in Systems Engineering will depend heavily on the MS degree program and maintain the same diversity among various disciplines by cutting across all four schools and colleges at UMR. As indicated in an earlier section, it is not possible to generate the body of knowledge required in designing and operating and disposing the System-of-Systems of this century without integrating several engineering and scientific disciplines. Using the idea of Integrated Product and Process Development Teams (IPPD) that worked very well in the defense industry for several decades, faculty from different schools and departments are grouped together into different research areas within the Systems Engineering field, forming an interdisciplinary team that cuts across departments and schools. This diverse faculty will be involved in all aspects of the program under the leadership of Dr. Cihan H Dagli, who is the director of the Boeing Systems Engineering Graduate program, Professor of Engineering Management and Systems Engineering at UMR, and Director of the Smart Engineering Systems Lab.

The total credit requirements for graduation are 60 credits after successful completion of MS degree in Systems Engineering and 90 credit hours after a BS degree. Actual courses to be taken will be determined by the candidate's committee and his or her program of study. The student will be expected to complete all requirements listed in the UMR Graduate Catalog.

While not a requirement, all students will be able to apply for graduate research and teaching assistantships, although these assistantships will require a work and time component. As such, it is expected that non-full-time working on-campus students will be the most likely recipients of such assistantships. Assistantships will be funded from department funds and funds generated by the Systems Engineering graduate program.

### 4.2 Course Delivery

Courses are taught on-campus and broadcast live over the Internet using one of the many distance education classrooms. Excellent infrastructure for distance education and recent developments in communication technology, such as the availability of collaboration software such as WebEx and Blackboard, along with the growth of the Internet, will provide the needed communication structure among laboratories, faculty, and students. This infrastructure is also already in place at UMR in the form of the Video Communication Center (VCC), and through the use of the aforementioned collaborative Internet meeting software. Both on-campus and distance students have the opportunity to watch and interact with the class live, or watch the recorded and saved archived lectures

at a later time at their convenience. Tests and class assignments can be taken and submitted using collaborative software, such as Blackboard digital drop box, or taken at remotes sites with previously defined proctors. The VCC operation offers a virtually seamless transition between on-campus and distance learning, providing a similar on-campus learning experience for distance students, while at the same time providing the level of flexibility desired, and at times required, by many off-campus students. The distance education environment, driven by the VCC and the use of the WebEx collaborative software, allows students from diverse backgrounds (whether from different companies or organizations, or whether on-campus versus off-campus students), to enjoy an enriching and diverse interchange of ideas and learning experiences.

**Form PS**

**A. Total credits required for graduation:** <u>90</u>

**B. Residency requirements, if any:**
The program will follow the residency requirements listed in the UMR Graduate Catalog under the section entitled ***Doctor of Philosophy Degrees***. Distance students can satisfy the current two-semester residence at UMR requirement by meeting the following guidelines.

- The qualifying exam must be taken on-campus during the first year of enrollment. The exam can be taken up to two times. A second failure will generally result in the student not being accepted into the PhD program or being allowed to take the test for a third time. Nonetheless, under special circumstances, the student can petition the program director and be allowed to take the test more than two times if approved by the program director and department chair. The core faculty will be instrumental in preparing the exam, although other systems engineering faculty may participate in the preparation and administering of the exam.
- The student is expected to have at least two Internet video conference meetings per month with their advisor or committee member that they sign up with for the SysEng 490 research course.
- The student's PhD committee must include one member from the student's professional work location. While it is technically possible for the professional member to be at another location, it is desirable that this individual be in the same location to facilitate research mentoring and interaction. This individual must have a PhD degree and be familiar with the chosen research area of the student, but be an unbiased co-worker (i.e., preferably not a direct or indirect reporting supervisor or manager).
- The student will be expected to meet with his PhD committee on a regular basis as established by the committee through campus visits or internet video conferencing with a minimum of two meetings each semester.
- During any one year period, the student is expected to be on campus for a minimum of 16 days spread over at least four visits while taking courses toward the PhD.
- The student is expected to participate in all graduate courses synchronously with the class sessions based on the communication technology available in the

classroom. Full participation in class activities is expected within the limitations of the communication technology. Asynchronous participation may be allowed only on an exceptional basis for individual class sessions.

- The PhD comprehensive exam must be taken on campus. Students, whether on-campus or off-campus, will take the comprehensive exam on the same date and at the same time. The comprehensive exam will be given by the students' graduate PhD committee, along with others as chosen by the committee.

- The student has the option of selecting a dissertation topic in an area directly related to and beneficial to his/her professional work, and can carry out the associated research at the student's worksite. It is essential that the student's employer fully support the doctoral program.

- Defense of the dissertation must take place on campus.

**C. General education: Total credits**: 0

**D. Major requirements: Total credits:** 24 hours

PhD students are required to have knowledge in the core curriculum fundamentals in Systems Engineering. This includes knowledge of systems theory (SysEng 368, 468, and 469) and Engineering Economics and Project Management (SysEng 411, 412, and 413). SysEng 368 is a pre-requisite for SysEng 468. In addition, students are expected to have knowledge in the areas of Optimization and Statistics, as well as Systems Engineering Process Tools (SysEng 419 and 479). Students without previous graduate level exposure to the fundamentals and topics in optimization and statistics will be required to obtain this knowledge before taking the PhD Qualifying Exam. Students are also strongly encouraged to take a research methods course (such as EMgt 476 or 489) if they have not had previous experience conducting and carrying out research. Such decisions will take place between the advisor and student when planning their program of study.

Core Curriculum
- SysEng 368 Systems Engineering Analysis I (3 hours)

- SysEng 468 Systems Engineering Analysis II (3 hours)

- SysEng 469 Systems Architecting (3 hours)

- SysEng 411 Systems Engineering Management (3 hours)

- SysEng 412 Complex Engineering Systems Project Management (3 hours)

- SysEng 413 Economic Analysis of Systems Engineering Projects (3 hours)

- Courses in Systems Engineering Process Tools, Optimization and Statistics

- SysEng/CpE 419 Network-Centric Systems Architecting and Engineering (3 hours)

- SysEng 479 Architectures for Smart Engineering Systems (3 hours)

**E. Free elective credits:** <u>66 hours</u>
Systems Engineering Process Tools, Optimization and Statistics elective courses (12 hours)

Research Specialization Areas courses (24 hours)

- Network Centric Systems

- Systems Architecting

- Systems Engineering Process and Design

- Distributed Systems Modeling

- Infrastructure Systems and Structures

- Network Centric Manufacturing and Control

- Risk Modeling and Assessment

- Modeling and Simulation

- Computational Intelligence

- Research SysEng 490 (30 hours)

(Sum of C, D, and E should equal A.)

**F. Requirements for thesis, internship or other capstone experience:**
Students will conduct original research demonstrated by journal or refereed proceedings publications under the supervision of a doctoral advisor, and communicate their findings, write a dissertation on research conducted, and provide satisfactory defense of their dissertation in a final oral examination.

**G. Any unique features such as interdepartmental cooperation:**
This interdisciplinary degree program cuts across all four schools and colleges within UMR. Courses for the degree will be taught mainly by engineering faculty. However, the 30 plus faculty who have agreed to participate in the Systems Engineering PhD degree program together bring a combined 130 years of distance teaching, 400 years of graduate teaching, and 160 years of industrial experience. Their joint contribution to the literature is over 2,500 scholarly articles. The 30 plus faculty represent membership at different levels in over 30 different professional societies and bring the level of diversity required in designing and operating the Systems-of-Systems of today. The open architecture concept used in designing both

the MS and PhD graduate program in Systems Engineering enables the aggregation of this strong faculty for the program. This capability can be expanded even further by transferring courses from USC. Inclusion of Boeing researchers with a PhD to dissertation committees and selecting research topics from Boeing that push the boundaries of knowledge and technology will make this new degree program one of the best in the world. Furthermore, while not residing within the Department of Engineering Management and Systems Engineering, external faculty are already teaching and performing research in systems engineering related topics within their specific disciplines. As such, minimal modification to existing teaching and research programs are necessary for faculty supporting one or more of the defined research specialization areas. Faculty are also encouraged to visit supporting companies and agencies, both for student recruitment and research collaboration and sponsorship.

This level of cutting edge research is already happening with students who are currently in the Engineering Management PhD program and who are doing Systems Engineering research. The strong foundation of the MS degree program both on- and off-campus, and excellent support from The Boeing Company, will make this new program a success. It will only be a matter of time that UMR will see similar support for this program from other defense and commercial companies, many who are already participating and have expressed interest. This program interest is already happening in the Systems Engineering MS degree. This support will continue as long as courses are updated, new courses are developed, and new knowledge produced through research in the PhD program is disseminated to MS degree courses. Currently, research focus in the Systems Engineering PhD program is concentrated in nine areas, namely, network centric systems, systems architecting, systems engineering process and design, modeling and simulation, structures, computational intelligence, risk modeling and assessment, distributed system modeling, and manufacturing and control. These clusters will change in time.

For example, the network-centric research cluster is discussed here in more detailed.

*Network-centric systems comprise a diverse category of large and complex systems whose primary purpose is to provide distributed, network-type services. Infrastructures such as the electric power grid, oil and gas distribution systems, pipelines, financial networks, and corporate intra-nets are commercial examples of network-centric systems. Military examples include command and control systems, communications systems, and information fusion intelligence systems. These are multi-tiered systems, ranging small devices such as sensors to large-scale servers and computers and are themselves frequently "a system-of-systems". Our society is greatly dependent on such systems since the networked components yield a system that is truly greater than the sum of the parts, offering increased effects and robustness. However, a failure in one node can have a rippling effect, resulting in cascading failures throughout the system. The failure could be caused by a natural disaster, human error, or a malicious attack. The research emphasis in this area spans the entire life cycle from system*

*concept through maintenance and phase-out, with special interests in architecture, assurance, reliability, and security of network-centric systems.*

**4.3 Faculty Research and Teaching Experience**
The faculty characteristics representing these research clusters are provided in Table I on the following page. Some faculty may hold joint appointments with the Department of Engineering Management and Systems Engineering, or other departments. If junior faculty hold joint appointments, tenure decisions will be dictated by the joint appointment agreement between the two departments. The primary department responsible for tenure (as defined in the joint appointment agreement for those faculty holding joint appointments), will set faculty systems engineering teaching assignments after consultation with the systems engineering program director. Core faculty will meet regularly during the academic year to discuss program content, student recruitment, participating faculty, course offerings, and research directions. Faculty will be added as new research specializations and courses are added to the program.

## Table I: Faculty Research and Teaching Experience

| Faculty | Distance Teaching Experience | Graduate Teaching Experience | Industrial Experience | Professional Societies | Highest Degree and University | Number of Publi-cations |
|---|---|---|---|---|---|---|
| Venkat Allada | 3 | 11 | 1 | SME, IIE | PhD, University of Cincinnati | 80 |
| S. N. Balakrishnan | 1 | 19 | N/A | AIAA | PhD, The University of Texas Austin | 100+ |
| Abdeldjelil Belarbi | 1 | 14 | 1 | ASCE, ACI, ASEE, PCI, NEES, TMS, TRB, EERI, Sigma Xi | PhD, University of Houston | 85+ |
| K. Chandrashekhara | 4 | 20 | 2 | ASME, SAMPE, AIAA, ASEE | PhD, Virginia Tech | 150+ |
| Minsu Choi | 3 | 3 | N/A | IEEE, Sigma, Xi | PhD, Oklahoma State University | 35 |
| Cihan H. Dagli | 15 | 26 | 15 | INCOSE, IEEE, IIE, INNS, INFORMS, ASEM, ASEE | PhD, University of Birmingham, England | 250+ |
| Lokesh R. Dharani | 5 | 23 | 9 | AIAA, ASME, ASEE | PhD, Clemson University | 193 |
| Xiaoping Du | 0 | 11 | 2 | ASME, AIAA, ASEE | PhD, University of Illinois at Chicago | 50+ |
| David Enke | 5 | 8 | 5 | AFA, ASEM, ASEE, FMA, GARP,IAFE, IIE, PRMIA | PhD, UMR | 50+ |
| Kelvin Erickson | 0 | 18 | 1 | IEEE, ISA | PhD, Iowa State University | 40+ |
| Barry Flachsbart | 6 | 38 | 35 | ACM, IEEE, ASCE | PhD, Stanford | 40+ |
| Scott Grasman | 4 | 5 | 3 | ASEE, ASEM, DSI, IIE, INFORMS | PhD, Univ. of Michigan | 30+ |
| Isaac Kakkattukuzhy | 2 | 5 | 5 | AIAA, Combustion Institute, ASME | PhD, Virginia Tech | 100+ |
| K. Krishnamurthy | 1 | 18 | 1 | ASME, IEEE, SME | PhD, Washington State University | 50+ |
| Robert G. Landers | 5 | 12 | 0 | ASEE, ASME, IEEE, SME | PhD, University of Michigan at Ann Arbor | 50+ |
| Jennifer Leopold | 2 | 3 | 12 | IEEE, ACM | PhD, University of Kansas | 16 |
| Frank W. Liou | 6 | 18 | 2 | ASME, SME, ASEE | PhD, University of Minnesota | 100+ |
| Frank Liu | 6 | 11 | 0 | IEEE | PhD, Texas A&M Univ. | 50+ |
| Ronaldo Luna | 3 | 10 | 7 | ASCE, EERI, GI, NSPE, MSPE, ASEE, ISSMGE | PhD, Georgia Institute of Technology | 55+ |
| Sanjay Kumar Madria | 4 | 10 | 0 | IEEE | PhD, IIT, India | 100+ |
| Ann Miller | 8 | 19 | 13 | IEEE, ASEEE | PhD, Saint Louis University | 70+ |
| John Myers | 1 | 6 | 10 | ACI, ASCE, PCI, NSPE, TMS, SEI, AEI | PhD, University of Texas-Austin | 60+ |
| Kenneth M Ragsdell | 32 | 33 | 6 | ASME, ASEE | PhD, The University of Texas, Austin | 100+ |
| Jagannathan Saranapani | 3 | 9 | 7 | IEEE, CS, Control, INNS, ASEE, Sigma Xi and Eta Kappa Nu | PhD, University of Texas - Arlington | 130+ |
| R Joe Stanley | 2 | 4 | 2 | IEEE, ASEE, NAFIPS | PhD, University of Missouri-Columbia | 37 |
| Daniel Tauritz | 1 | 3 | 1 | ACM SIG, IEEE | PhD, Leiden University | 9 |
| Chung-Li Tseng | 1 | 7 | 3 | INFORMS, IEEE, ASCE | PhD, University of California Berkeley | 27 |
| Ganesh Kumar Venayagamoorthy | 0 | 6 | 3 | IEEE, ASEE, INNS | PhD, University of Natal, Durban, South Africa | 120+ |
| Donald C Wunsch II | 1 | 12 | 10 | IEEE, INNS, ASEE, Phi Kappa, Phi, Eta Kappa NU | PhD, University of Washington | 245+ |
| Franck Xia | 4 | 5 | 6 | IEEE | PhD, University of Paris | 40+ |

The interdisciplinary nature of the PhD program, the configuration of the students (namely, part-time students working on projects for their dissertation for corporations

pushing the boundaries of technology and knowledge, on-campus students working at various research units), and the diversity of specialization areas create a different laboratory need for this degree program.  Hence, it will not be possible to identify a single laboratory.

The number and location of laboratories will depend on the dissertation topics.  Excellent infrastructure for distance education and recent developments in communication technology, such as the availability of collaboration software like WebEx and the Internet, will provide the needed communication structure among laboratories, faculty, and students.  However, most of the research work will be abstract and algorithm based. The Smart Engineering System Laboratory (SESL) in Engineering Management and Systems Engineering Department will serve as the prime laboratory.  The Department established the SESL to develop approaches in building complex systems that can adapt to changes in the environments in which they operate.  The focus of the SESL is in developing smart engineering architectures that integrate and/or enhance current and future technologies necessary for developing smart engineering systems while illustrating the real-life application of these architectures.

The SESL is equipped with the necessary computers and software, both for development and for distance interaction, to make it a useful lab for distance student research, learning, and interaction.  In addition to standard personal computer desktops, laptops, and parallel processing machines, the lab also has manufacturing, robotics, and cameras for performing systems architecting, systems design, and intelligent system research. Current research topics include data mining, artificial life, evolutionary robotics, internet-based pattern recognition, and systems architecture assessment based on the Department of Defense Architecture Framework (DoDAF).  Capabilities of the developed computational intelligence models are demonstrated physically in the lab through mini-autonomous research robots.

The University has also entered into an Industry/University Cooperative Research Center (I/UCRC) program has created an on-campus center to research and develop intelligent sensor-based decision making agents with wireless communication technologies in order to deploy these complex systems as monitoring, diagnostic, and prognostic tools in an effort to result in better system performance, minimal unscheduled downtime, and reduced maintenance and operating cost.  These complex industrial systems are truly nonlinear, contain deterministic and stochastic components, and have spatial and temporal characteristics.  Research and knowledge in systems engineering is essential in this area since these systems comprise numerous components and their sum effect is not just an aggregation of individual outputs.  The center's affiliation with the University of Cincinnati and the University of Michigan further extend its outreach beyond UMR, both for research production and systems engineering doctoral student recruitment.

The Engineering Management and Systems Engineering Department also has been providing a forum for international researchers by hosting the ANNIE (Artificial Neural Networks in Engineering) conferences, held every year in St. Louis, Missouri since 1991.

The Conference is an international gathering of researchers interested in Smart Engineering System Design.

The theme of this year's sixteenth ANNIE conference is *Computational Intelligence and Systems Engineering*. The research papers presented at the ANNIE conferences by interdisciplinary engineering and scientific teams enhance the engineering tools and algorithms that can be used in building today's complex System-of-Systems and Family-of-Systems.

This is in line with the current research focus in the SESL laboratory that involves developing solutions to the research challenges in Systems Engineering that are imposed by today's complex, adaptive, distributed, cooperative and dynamically changing engineering systems.

## 4.4 Financial Projections

**FORM FP**

### 4.4.1 Expenditures and Revenue
The new degree proposed will not bring an extra cost burden to the university as it primarily uses existing courses and laboratories from multiple departments across campus, and brings in significant tuition revenue.

|                                          | Year 1    | Year 2    | Year 3    | Year 4    | Year 5    |
|------------------------------------------|-----------|-----------|-----------|-----------|-----------|
| **1. Expenditures**                      |           |           |           |           |           |
| A. One-time                              |           |           |           |           |           |
|   Course Development (3)        | $ 24,000  |           |           |           |           |
|   Total for One-time Expenditures | $ 24,000 |           |           |           |           |
| B. Recurring                             |           |           |           |           |           |
|   Faculty                      | $ 35,000  | $ 35,000  | $ 70,000  | $ 70,000  | $ 70,000  |
|   Staff                        | $ 20,000  | $ 20,000  | $ 20,000  | $ 20,000  | $ 20,000  |
|   Benefits                     | $ 17,900  | $ 18,700  | $ 31,700  | $ 33,600  | $ 33,600  |
|   E&E                          | $ 30,000  | $ 30,000  | $ 30,000  | $ 30,000  | $ 30,000  |
|   Library (Electronic Journals) | $  5,000 | $  5,000  | $  5,000  | $  5,000  | $  5,000  |
|   Distance Education and Technology Costs | $ 50,000 | $ 50,000 | $ 50,000 | $ 50,000 | $ 50,000 |
| Total for Recurring Expenditures         | $157,900  | $158,700  | $206,700  | $208,600  | $208,600  |
| **TOTAL EXPENDITURES (A+B)**             | **$181,900** | **$158,700** | **$206,700** | **$208,600** | **$208,600** |
| **2. Revenues**                          |           |           |           |           |           |
| State Aid – CBHE                         |           |           |           |           |           |
| State Aid – DESE                         |           |           |           |           |           |
| Tuition/Fees                             |           |           |           |           |           |
|   Off-campus enrollment        | $141,662  | $195,494  | $252,920  | $314,127  | $352,215  |
|   (# off-campus students)      | (12)      | (16)      | (20)      | (24)      | (26)      |
|   On-campus enrollment         | $ 58,158  | $ 72,230  | $ 87,217  | $103,161  | $120,139  |
|   (# on-campus students)       | (10)      | (12)      | (14)      | (16)      | (18)      |
| Institutional/Other Resources            |           |           |           |           |           |
| **TOTAL REVENUES**                       | **$199,820** | **$267,724** | **$340,137** | **$417,288** | **$472,354** |

Notes:

*Faculty: One supporting faculty will be hired to teach, advise students and secure research contracts and grants.  This faculty position will start as half-time for the first two years and become full-time by the end of the third year.

*Staff: There is additional need for a new staff to support the new PhD students and constantly expanding Systems Engineering Graduate Program.

*E&E: New PhD students will increase the current operating expenses of the Systems Engineering Graduate Program. New E&E monies will be required.

*Library: Due to the large off-campus student component of the PhD program and limited electronic journals in Systems Engineering area, there is a need to support the UMR library to purchase Systems Engineering Electronic journals.

*Distance Education and Technology Cost: This budget item reflects the cost of transmitting courses to off-campus students.

## 4.4.2 Budget Justification

The budget includes one-time and recurring costs. The one-time cost will be for developing three new courses during the first year of the program. These three new courses will be at the 400-level and will cover the main topic of complex engineering systems management for the systems-of-systems and family-of-systems of today. Currently, there are no courses at UMR that cover these topics. Recent natural disasters such as Hurricane Katrina and other man-made disasters are a testimony for the need of such courses.

The recurring costs are for salaries and operating expenses for the degree program. The salaries include the position of a faculty member at 50% during the first two years and increasing to 100% thereafter to support the increased enrollment, and a secretary to help with the promotion and administration of the degree program. Staff benefits are calculated using the UM financial planning model. Other recurring expenses include E&E, electronic journal subscription by the library, and distance education delivery and technology costs. Most of the supplies and distance education infrastructure is in place as a result of the successful operation of UMR Video Communication Center (VCC) response to the MS program in Systems Engineering. Current capacity should be able to accommodate the shorter-term 5 year projections of new PhD students, but may need to be augmented with additional distance education capable classrooms as enrollments increase in the future.

Revenue for this degree program will be generated by tuition paid by off- and on-campus students. UMR is under contract to offer the Systems Engineering graduate program via the internet to The Boeing Company employees. The current rate approved by the Board of Curators for these distance students is $3,802 per three credit hour course, whereas on-campus resident students are charged $937 plus information technology, activity facility and health service fees. A factor of 1.035 is used to adjust for inflation in the revenue calculations. On-campus systems engineering students will have opportunities to receive fee waivers and graduate fellowships, just as normal on-campus students. Each off-campus student will take at least nine credit hours per year on average (the present average for the MS program in Systems Engineering is above this number). It is estimated that the each on-campus student will take 18 credit hours per year on average. It should be noted that the M.S. program in System Engineering brought in $1,657,305 in tuition from off-campus students during FY 2005 (FS 04, SP 05 and SS 05) and the total revenue generated by the program since its inception in WS 2000 is in excess of $7 million. This source of revenue is used for course delivery at the graduate level.

## 5. PROGRAM CHARACTERISTICS AND PERFORMANCE GOALS

**FORM PG**

**Institution Name:**    The University of Missouri-Rolla
**Program Name:**    Doctor of Philosophy in Systems Engineering
**Date:**    September 2006

## 5.1 Student Preparation

Admission to the graduate program in Systems Engineering is limited to applicants with BS degree in engineering and certain physical sciences, such as mathematics or computer science. Students must also have a superior academic record. Applicants are required to submit the Graduate Record Examination (GRE) scores for admission evaluation. Applicants whose native language is not English are also required to take the Test of English as a Foreign Language (TOFEL).

Admission standards for a PhD in Systems Engineering include the following:

- BS in engineering or hard science and MS in Systems Engineering or related field with a 3.5 GPA.
- Minimum three years experience is recommended.
- All students must submit GRE scores. (Verbal plus Quantitative greater than 1150 and Analytical Writing greater than 4.5).
- All international applicants must submit TOFEL score. (237 or higher)
- All applicants must submit a statement of purpose.

Current Engineering Management PhD students whose research area is in systems engineering and who have passed their qualifying or comprehensive exam can transfer to the Systems Engineering PhD program if it is approved by their advisor and committee during the initial transition period.

A candidate for the PhD in Systems Engineering must complete the equivalent of at least three years of full time-time work beyond the Bachelor's degree. The content of all PhD programs is individually structured by the student in consultation with and approved by the student's advisory committee. All requirements for the degree must normally be completed within an eight-year period. At appropriate points in their program, PhD students must pass both a qualifying examination and a comprehensive examination. Off-campus students are expected to complete all requirements listed in the UMR Graduate Catalog under the section entitled Doctor of Philosophy Degrees and follow all procedures listed under the Procedures for PhD Candidates**.**

## 5.2 Faculty Characteristics

As mentioned earlier, this degree is interdisciplinary and cuts across all four schools and colleges within UMR. Courses for the degree will be taught mainly by engineering faculty. It is required that the faculty who will be teaching in this graduate program should have PhD degree in engineering or hard science. The 30 plus faculty who agreed

to participate in the Systems Engineering PhD degree program fulfill this requirement. See Section 2.4 for a listing of faculty, along with their research interest, publication production, and teaching experience.

Dr. Cihan Dagli, Professor of Engineering Management and Systems Engineering, is the director of the Systems Engineering graduate program and will be responsible for administrative requirements of the program. The twelve core faculty will be responsible for teaching the core required courses, helping to design curriculum, and respond to specialized certificate and program offerings from industry and students. Additional faculty will teach specialization track course related specifically to their areas of expertise.

### 5.3 Enrollment Projections
It is estimated that there will be 44 PhD students in the program at the end of five years. Approximately 60% of the student body will be part time and 40% will be full time students. The worse case scenario estimates that there will be 12 PhD students in the program at the end of five years, again with approximately 60% of the student body part-time and 40% full-time students. Students will come from both industry and campus, with students initially recruited heavily from the pool of industry students that are currently enrolled or have recently graduated from the MS in Systems Engineering program and have already inquired and expressed interest in the doctoral program. See sections 2.2 and 2.3 for details.

### 5.4 Student and Program Outcomes
Annual graduation rates at the end of three and five years are 6 and 12, respectively. For the worse case scenario, annual graduation rates at the end of three and five years are 2 and 6, respectively. Even the projected three and five year annual graduation rate numbers of 6 and 12, respectively, are expected to increase, based on the pool of MS degree students in Systems Engineering. There will be feedback loops that require input from the students, as well as other stakeholders, incorporated in the educational program.

### 5.5 Program Accreditation
No discipline specific accreditation will be sought at the Ph.D. level since engineering accreditation is granted at the BS or MS level. Nonetheless, periodically review of the program will be carried out, with feedback being sought from students, faculty, and administrators both on- and off-campus.

### 5.6 Alumni and Employer Survey
Three years after a student completes a degree program, he or she will be supplied with a questionnaire to evaluate the benefit of the program for their needs. This will include questions such as, "Which class or classes were the most useful to you and were there any impediments in the medium of instruction and learning format that need to be addressed to improve your education?" The results obtained will be summarized and

used as feedback to improve the program.  This type of evaluation is already being done for the MS degree program in Systems Engineering.  The research quality of the program will be measured by the number of research grants and projects secured, achievable journals and papers published, and the number of graduates in getting faculty appointments and research jobs in industry and federal laboratories.

**Form CC**

**CBHE Clarifying Comments**

**A.) Alignment with Institutional Mission**

The proposed PhD program will have a positive impact on the reputation of the University within both industry and academic circles.  In a little over five years the UMR Systems Engineering program has established itself as one of the best programs in the nation for systems engineering.  UMR is a leader in research and instruction in systems engineering, and finds itself compared to other successful Systems Engineering programs, including the University of Southern California (USC), the University of Virginia, the University of Arizona, Cornell University, and the Massachusetts Institute of Technology (MIT), among others.

Offering a PhD in Systems Engineering is congruent with a current *UMR Strategic Objective to offer PhD degrees in Biology, Information Science and Technology, Systems Engineering, and Bioinformatics*.  Furthermore, the University has expressed interest in further building relationships with industry.  As a result of the MS program in Systems Engineering, UMR has built a strong relationship with The Boeing Company. While The Boeing Company currently remains the major source of students, the current MS program is also attracting students from diverse companies and laboratories, such as the U.S. Air Force, U.S. Army, National Geospatial-Intelligence Agency (NGA), Los Alamos National Laboratories, General Motors, Lockheed Martin, Raytheon, Sprint, Brewer Science, Briggs and Stratton, the University of Missouri System, Hollister Corporation, and Singapore Airlines.  UMR has also taken this opportunity to build further educational and research relationship with many of these organizations.  UMR has also recently begun training twelve Italian Engineers in Systems Engineering as part of an offset program with The Boeing Company, further increasing the international exposure of UMR offerings in Systems Engineering and Mechanical Engineering.

The offering of a PhD in Systems Engineering is in line with the direction and strategic plan of the UMR campus and direction of its current chancellor (http://campus.umr.edu/chancellor/stratpln/).  UMR has recognized the need to train leaders that can identify and solve complex societal and technical challenges by creating, assimilating, synthesizing, and communicating knowledge, which in effect are the hallmarks of a good systems engineer.  To achieve this mission and vision, UMR has the goal of becoming one of the top five technological universities in the United States by 2010.  The values of the entrepreneurial spirit and collaboration in interdisciplinary efforts that transcend traditional boundaries are also exemplified by the systems engineering program, both in content and direction of purpose.  Finally, developing a doctoral program in systems engineering will also meet campus strategic initiatives by increasing enrollment, expanding research performance and reputation, enriching the student experience, and facilitate the pursuit of external opportunities.

**B.) Student and Market Demand**

As mentioned in Section 2, the demand for individuals trained in the field of systems engineering is growing rapidly, yet as engineering systems become more complex, companies are finding they need additional systems engineers, but can no longer afford to wait the 10-20 years necessary to train an engineer in the tools and techniques of systems engineering. The demand for individuals with PhDs in systems engineering is also increasing at a similar rate to help educate the systems engineers of the 21st century, as well as research and develop new approaches in systems theory and systems architecting for the design of the systems-of-systems and family-of-systems of the future.

The INCOSE Vision Statement stresses the need to new thinking and education, focusing on a new worldview that considers "systems-of-systems" that are highly networked, or "net-centric," As highlighted in their Systems Engineering Technical Vision Statement, INCOSE underscores how industry has become more interested in systems engineering training, and is getting more involved in systems engineering research activities. Systems thinking and systems engineering shall continue to widen the scope of the domains and areas to which they are applied, causing education to merge systems thinking and systems engineering into additional academic disciplines. To this end, INCOSE members and studies indicate that in the near future more educators are needed with degrees in systems engineering, or with degrees that have a heavy emphasis in systems engineering, and that competition for systems engineering research findings will increase. INCOSE also sees distance education as a way to meet this demand, allowing for worldwide education that allows for new ways to merge ideas and assimilate education of systems engineering ideas and topics, acting as an "inter-disciplinary connector".

The American Society for Engineering Education (ASEE) web site lists 22 universities that have MS degree programs in Systems Engineering. See Section 2 (page 10) for specific national projections and current degree offering universities. In addition to ASEE projections, the Council of Engineering System Universities (http://cipd2.mit.edu/) alone list over 10 faculty positions in Systems Engineering and/or areas related to Systems Engineering (as of 06/01/06), including positions at Massachusetts Institute of Technology, Stanford University, George Mason University, Rensselaer Polytechnic Institute, and the Navel Postgraduate School, among others. UMR on-campus interest in systems engineering has also continued to increase every year since the inception of the MS program in Systems Engineering, with many on-campus students also expressing interest in a PhD program in Systems Engineering. Based on current interest both on-campus and from existing MS distance students, it is estimated that there will be 44 PhD students in the program at the end of five years. Approximately 60% of the student body will be part-time and 40% will be full-time students. See Section 2 (page 10) for more specifics.

**C.) Efficient Use of Resources**

The new degree proposed will not bring an extra cost burden to the university as it primarily uses existing courses and laboratories and brings in significant tuition revenue. The interdisciplinary nature of the PhD program, the configuration of the students (namely, part time students working on projects for their dissertation for corporations pushing the boundaries of technology and knowledge, on campus students working at various research units), and the diversity of specialization areas create a different laboratory need for this degree program. Hence, it will not be possible to identify a single laboratory.

The number and location of lecture rooms and laboratories will depend on the courses taken and dissertation topics chosen by the students. Excellent infrastructure for distance education and recent developments in communication technology, such as the availability of collaboration software like WebEx and the Internet, will provide the needed communication structure among laboratories, faculty, and students. This infrastructure is also ready in place at UMR in the form of the Video Communication Center (VCC), and through the use of the WebEx collaborative Internet meeting software previously mentioned.

Many of the laboratories will reside in the departments of the faculty acting as research advisors for the PhD students. Nonetheless, most of the research work will be abstract and algorithm based. As a focal point, the Smart Engineering System Laboratory (SESL) in Engineering Management and Systems Engineering Department will serve as the prime laboratory. The Department established the SESL to develop approaches in building complex systems that can adapt to changes in the environments in which they operate. This lab is in place and already equipped. It will not require any extra funds to begin PhD student education and research in Systems Engineering.

Faculty will initially come from existing programs on campus. Most of core faculty are currently members of the Department of Engineering Management and Systems Engineering. As the program grows, additional systems engineering core faculty may need to be hired to teach the required core courses, but faculty teaching specialization track courses and providing specialization track research opportunities are currently in place.

The interdisciplinary Systems Engineering degree program cuts across all four schools and colleges within UMR. Courses for the degree are taught by engineering faculty that are currently teaching within their respective programs. For instance, faculty with the Electrical Engineering department that are specializing in computer and communication sensor systems, and already offering graduate courses to both on- and off-campus students, currently teach and advise MS systems engineering students. This holds true for other engineering and non-engineering departments that are participating in the program.

In most cases, faculty do not need to give up other major activities to work within the systems engineering program, but simply have another avenue to recruit students to their classes, and work with students on mutually interesting research opportunities. In

essence, faculty chosen to be in the Systems Engineering program have research and teaching interest that are already inline with systems engineering and systems theory principles. These faculty are chosen precisely since they do not have to change their current teaching and research focus. Having said that, success does build interest and opportunity. Many faculty have incorporated systems engineering ideas into their teaching and research, and have begun offering these classes to distance students. While this can involve initial time and cost overhead in the first semester, the program home and department of the faculty member also benefits from the change, such that their own degree seeking students can now also take these courses at a distance, increasing enrollments in other programs in addition to systems engineering. Finally, whether or not a faculty offers a distance-oriented systems engineering course, they are still free to choose whether or not to work on research with MS and PhD systems engineering students. As with on-campus students, faculty can choose whom to work with based on mutual research interest, identified problems, and available time, just as with students from existing programs.

The PhD program will continue to allow the current MS-related graduate research opportunity to present itself for both faculty and students, but now at a level that allows each to perform research at a higher level. The flexibility offered by the interdisciplinary nature of the program is truly unique, not only providing additional opportunities to faculty and students, but doing so without changing focus or structure. Once again, the infrastructure is already in place since the program builds on current course offerings and research focus. Furthermore, the students are given tremendous flexibility since the program resides outside the walls of a single department. They also benefit from the interaction with a number of different types of students (on-campus versus off-campus, working versus full-time, in department versus out of department), allowing for stimulating classroom environments that convey both theoretical and practical knowledge.

The open architecture concept used in designing both the MS and PhD graduate program in Systems Engineering enables the aggregation of this strong faculty for the program. Inclusion of researchers with a PhD to dissertation committees and selecting research topics from companies and company advisors that push the boundaries of knowledge and technology will make this new degree program one of the best in the world.

### D.) Benefits of Collaboration
The new PhD program in Systems Engineering will not adversely affect the quality of existing programs. In fact, the new PhD program builds upon existing courses already in place for the current Masters of Science in Systems Engineering, and will continue to foster and promote interdisciplinary collaboration. Furthermore, the PhD program will provide new opportunities for students and faculty members.
Systems Engineering is an interdisciplinary field that exists at the interface of systems theory, mathematics, computer science, management, operations research, and the various engineering and applied science disciplines.

The value of the proposed PhD in Systems Engineering to existing programs is further highlighted by the positive support it has received from a large and diverse cross-section of faculty members and administrators at UMR. The 30 plus faculty who have agreed to participate in the Systems Engineering PhD degree program come not only from diverse departments within all four schools and colleges at UMR, but they also bring a wealth of experience and dedication to research and teaching. The cross disciplinary research that will results from the Systems Engineering PhD program will only help to further increase the outstanding research and scholarly production of the participating faculty. Multi-disciplinary teams of UMR instructors and researchers have already collaborated on proposals sent to federal, state, and local funding agencies. This level of collaboration should increase as the systems engineering research component is elevated to the PhD level. The PhD in Systems Engineering is a unique program and does not provide duplication with existing programs. Nonetheless, given the multidisciplinary nature of the program, it is expected that existing collaboration resulting from the M.S. in Systems Engineering will continue at the PhD level, and will most likely intensify.

**Form CP**

**The University of Missouri President's Criteria**

**A. Implementation of the New Program:**
The new PhD program in Systems Engineering will not adversely affect the quality of existing programs. In fact, the new PhD program builds upon existing courses already in place for the current Masters of Science in Systems Engineering, and will continue to foster and promote interdisciplinary collaboration. Furthermore, the PhD program will provide new opportunities for students and faculty members. Systems Engineering is an interdisciplinary field that exists at the interface of systems theory, mathematics, computer science, management, operations research, and the various engineering and applied science disciplines. See Section 4.2 for an overview of the backgrounds and experience of the 30 plus faculty from various departments within UMR that have agreed to participate in the Systems Engineering PhD program.

The proposed PhD program will also have a positive impact on the reputation of the University within both industry and academic circles. In a little over five years the UMR Systems Engineering program has established itself as one of the best programs for systems engineering in the nation. UMR is a leader in research and instruction in systems engineering, and finds itself compared to other successful systems engineering programs, including the University of Southern California (USC), the University of Virginia, the University of Arizona, Cornell University, and the Massachusetts Institute of Technology (MIT), among others. Offering a PhD in Systems Engineering is also congruent with a current UMR Strategic Objective to offer PhD degrees in Biology, Information Science and Technology, Systems Engineering, and Bioinformatics. Furthermore, although The Boeing Company currently remains the major source of students, the current MS program is also attracting students from diverse companies and laboratories, such as the U.S. Air Force, U.S. Army, National Geospatial-Intelligence Agency (NGA), Los Alamos National Laboratories, General Motors, Lockheed Martin, Raytheon, Sprint, Brewer Science, Briggs and Stratton, the University of Missouri System, Hollister Corporation, and Singapore Airlines. UMR has also recently begun training twelve Italian Engineers from companies such as; Alenia, CIRA, Piaggio Aero in Systems Engineering as part of an offset program with The Boeing Company, further increasing the international exposure of UMR offerings in Systems Engineering and Mechanical Engineering. On-campus interest in systems engineering has also continued to increase every year since the inception of the MS program in Systems Engineering. Many on-campus students have also expressed interest in a PhD program in Systems Engineering.

**B. Market Analysis**
As previously highlighted in Form CC and Section 2, the demand for individuals trained in the field of systems engineering is growing rapidly. Please see Section 2 for an overview of program need, student demand, and marketing plans.

**C. Business Plan**

A viable business plan for attracting successful students to the PhD program in Systems Engineering will require identifying the proper students, having the right faculty, having positive enrollment estimates, having student and program outcomes that can be tracked and monitored, consideration of accreditation if appropriate, and soliciting and responding to alumni feedback. These areas are discussed in the following sections.

**Student Preparation (see Form PS for further details)**
Admission to the graduate program in Systems Engineering is limited to applicants with BS degree in engineering and certain physical sciences, such as mathematics or computer science. Students must also have a superior academic record. Applicants are required to submit the Graduate Record Examination (GRE) scores for admission evaluation. Applicants whose native language is not English are also required to take the Test of English as a Foreign Language (TOFEL). A candidate for the PhD in Systems Engineering must complete the equivalent of at least three years of full time-time work beyond the Bachelor's degree. The content of all PhD programs is individually structured by the student in consultation with and approved by the student's advisory committee.

**Faculty Characteristics (see Section 4.3 for further details*)***
The Systems Engineering program is interdisciplinary and therefore cuts across all four schools and colleges within UMR. Courses for the degree will be taught mainly by engineering faculty. It is required that the faculty who will be teaching in this graduate program should have PhD degree in engineering or hard science. It is expected that 85% of credit hours will be assigned to full-time faculty.

**Enrollment Projections (see Section 2.2 for further details)**
It is estimated that there will be 44 PhD students in the program at the end of five years. Approximately 60% of the student body will be part time and 40% will be full time students.

**Student and Program Outcomes (see section 2.2 for further details)**
Annual graduation rates at the end of three and five years are 6 and 12, respectively. These numbers may increase, based on the pool of MS degree students in Systems Engineering. There will be feedback loops that require input from the students, as well as stakeholders, incorporated in the educational program.

**Program Accreditation**
No discipline specific accreditation will be sought at the PhD level since engineering accreditation is granted at the BS or MS level. Nonetheless, program content will take into consideration standards set by the International Council of Systems Engineering to insure the program is current and meeting the needs of students and industry.

**Alumni and Employer Survey**

Three years after a student completes a degree program, he or she will be supplied with a questionnaire to evaluate the benefit of the program for their needs. This will include questions such as, "Which class or classes were the most useful to you and were there any impediments in the medium of instruction and learning format that need to be addressed to improve your education?" The results obtained will be summarized and used as feedback to improve the program. This type of evaluation is already being done for the MS degree program in Systems Engineering. The quality of research conducted will be measured by the number of research grants and projects secured, archived journals and papers published, and the number of graduates receiving faculty appointments and research jobs in industry and federal laboratories.

**ATTACHMENTS**

**A.1 The Boeing Company's Commitment to UMR Systems Engineering PhD Degree Program**

The Boeing Company fully supports the proposed Systems Engineering PhD degree program and considers it to be of substantial value to their employees, particularly those interested in the Boeing Technical Fellowship. The program will also be of significant value to the company as there is a need for engineers who have the educational background to extend and modify the underlying concepts to maintain the company's leadership role in systems engineering thinking in the years to come. A copy of the letter of support is included in Section A.3.

The Boeing Company's support is also structured around identifying their research needs in Systems Engineering, and allowing and scheduling special presentation sessions to their employees at 22 company sites three times a year for recruiting purpose. These visits are widely publicized through the Boeing News web site prior to the visits and are fully supported by the Systems Engineering functional mangers at each site.

The Boeing Company evaluates annually the impact of the currently offered MS Systems Engineering degree program. A recent report prepared by William Schoening, Boeing Coordinator for the Systems Engineering graduate program, is included in the next section. The high quality of the master's program will be most beneficial in recruiting students for the proposed PhD degree program.

**A.2 The Boeing Company UMR and USC Systems Engineering MS Degree Program Evaluation (Written by William Schoening)**

- *Surveys were sent to 172 employees who have earned an MS in systems engineering through our program with USC and UMR and to 330 employees currently enrolled. The response was outstanding with 324 (65%) replying. In addition, current and former students were asked to requested supervisors of their choice to respond to a similar survey. Responses from all groups indicate strong support for the program. That does not mean there were no suggestions for change. Comments relevant to USC and UMR will be sent to the respective program directors.*

**Results**

- *In response a question about their degree objective, 3 indicated they were aiming for a Certificate in systems engineering, 12 for a PhD, and the remainder for an MS.*

- *47% of the respondents are currently employed in jobs that they characterize as primarily systems engineering, compared with 33% before they enrolled in the program. While we definitely want to increase the number of systems engineers, it is significant that 53% are in jobs that are not primarily systems engineering. Given the responses in the charts below, it is evident that many engineers in other disciplines are finding the program very valuable.*

*The next three charts address*

  1. *Impact on ability to do the current job*
  2. *Impact on ability to contribute to team success*
  3. *Impact on career*

- *The fourth chart addresses willingness to encourage others to participate in the program, and the fifth chart asks whether supervisors are willing to encourage others to participate in the program.*

- *Support for the program is very strong.  Unfortunately, I do not have data about those who may have dropped out of the program.*

- *Following those charts I have include a few demographics about the students.*

*Impact on Ability to Do the Current Job*
*The figure on the right illustrates the distribution of respondents who characterize the impact of the program on their ability to perform their job.  This chart and the others about ability to contribute to team success and to own career are is limited to respondents who have competed at least 3 courses.  Those 2 or fewer courses are less likely to observe a positive impact, although the percentage see no*

**To What Degree Has Your Experience with the Program Affected Your Ability to Do Your Job?**



*impact rises to only 13% for current systems engineers and 17% for those who are not systems engineers if all students are included in the summary.  For current systems engineers, the responses are heavily skewed toward significant impact.  As one might expect, the distribution is a little more concentrated in the moderate and somewhat categories for those in other disciplines.*
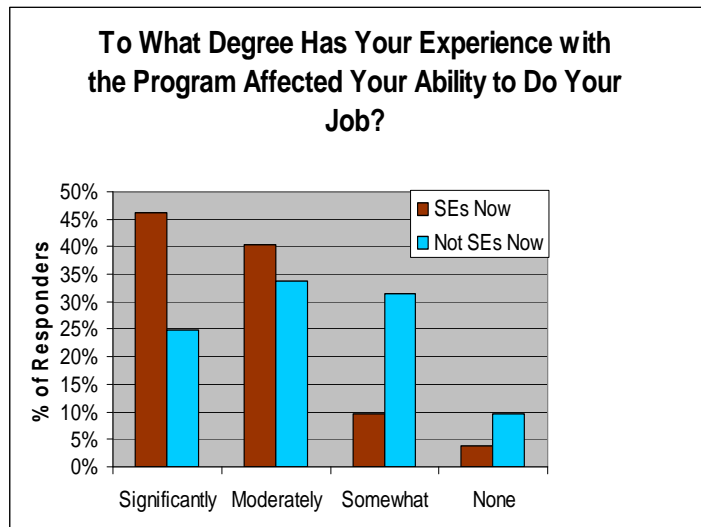
**To what degree has your experience with the program affected your ability to contribute to the overall success of your team?**
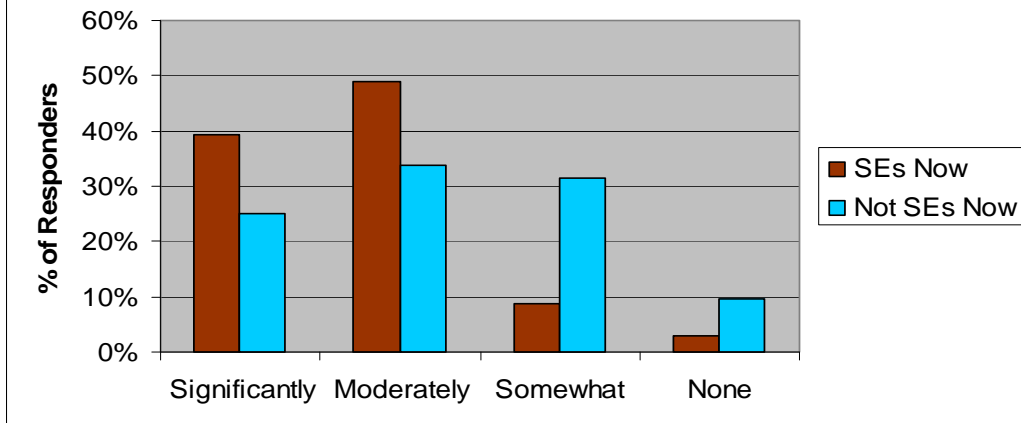
*Impact on Ability to Contribute to Team Success*
*If we now switch to ability to contribute to team success, there is a slight shift in the distribution of responses for current SEs, but there are still 88% (86% for own job) who believe that the program has had at least a moderate impact.*
*Among non-systems engineers, 80% cite at least a moderate impact (compared to 73% for own job.)*

*Impact on Career*
*As expected, the career impact is greater for those who are now in jobs that are primarily systems engineering. However, even among the rest, 61% responded that the program has had at least a moderate impact on their careers.*



**To what degree has your experience with the program affected your career (beyond your current job)?**
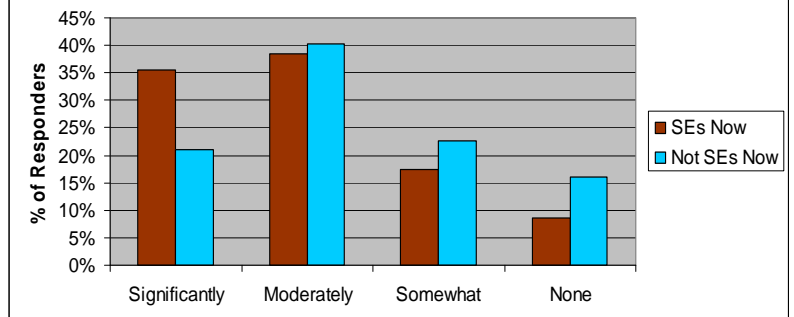
## Willing to Encourage Others to Participate

*As illustrated in the chart on the right, the vast majority of respondents would encourage others to participate in the program either strongly or moderately. Support and encouragement for prospective students is clearly coming from those who have participated. This conclusion is supported by the number of current and former students who appear voluntarily at open houses to speak to those considering the program. (One current student said he would actively oppose participation, but is enrolled in another course, so I am not sure what to make of his responses other than to say the written comments also indicate dissatisfaction.)*

## Supervisor Opinions

*Students were asked to pass on a similar survey to supervisors of their choice. While there were only 62 responses, their responses to the questions asked are reflected in the chart on the right. When asked whether they would actively encourage others to participate in the program, 86% said they would do so at least moderately.*
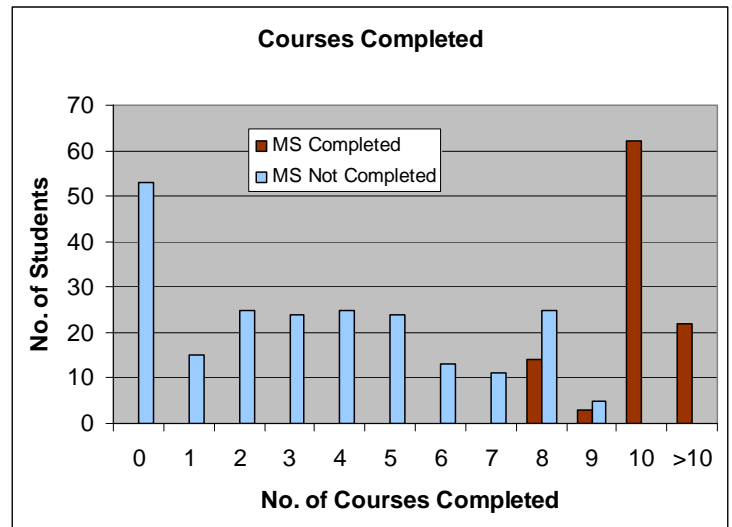
**To what degree would you encourage others to participate in this program?**



**To What Degree Would You Actively Encourage Others to Participate in This Program?**
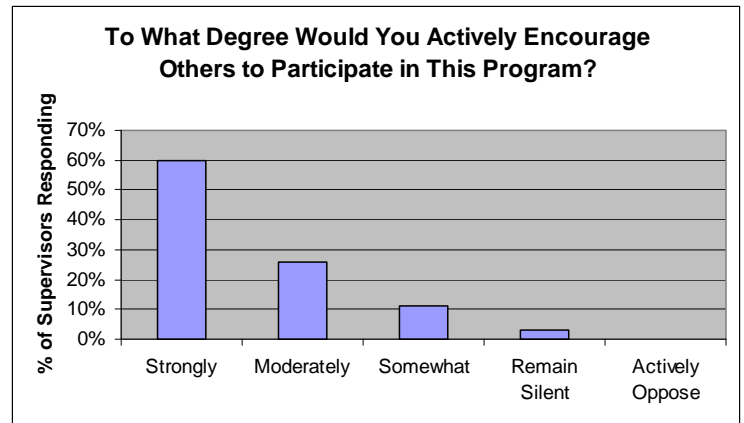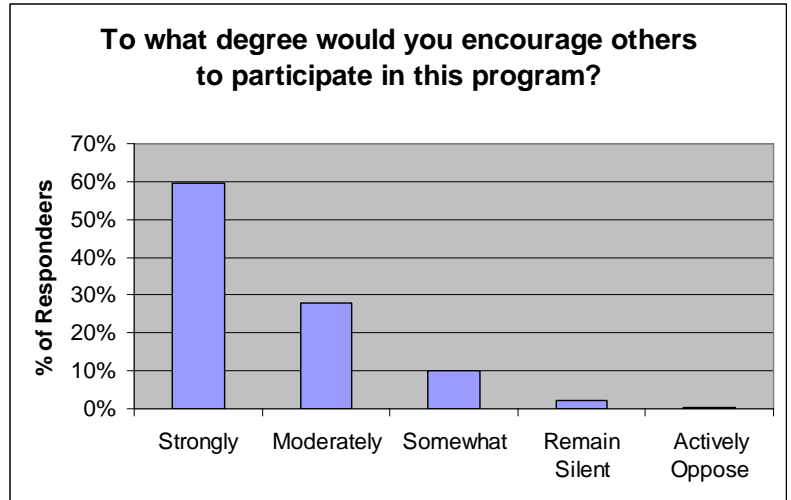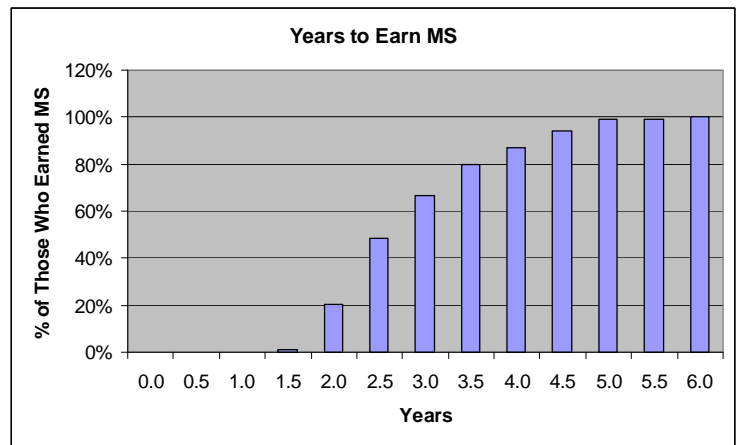
## Demographics

*The following chart illustrates the number of courses completed. "Zero completed"*

*applies to students who have just started and are taking their first course. In addition, since up to two courses outside this program may count toward an MS in systems engineering, a few have earned their degree with fewer than 10 courses. Notice that 22 respondents have chosen to take at least one additional course.*

**Courses Completed**

*No. of Students* (vertical axis, 0 to 70)

*No. of Courses Completed* (horizontal axis: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, >10)

- MS Completed
- MS Not Completed

*Of those responding who have earned an MS in systems engineering, 80% took 3 years or less to do so. Six needed 5.5-6 years to earn an MS.*

**Years to Earn MS**

*% of Those Who Earned MS* (vertical axis, 0% to 120%)

*Years* (horizontal axis: 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0)

The report clearly indicates the satisfaction of The Boeing Company with the Systems Engineering program. As long as UMR's collaboration and competition with USC remains healthy, and the proposed interdisciplinary architecture for the PhD degree in Systems Engineering with 12 core faculty and 22 research and teaching faculty can enhance Systems Engineering research in line with The Boeing Company research needs (and transfer the results to graduate courses at both the MS and PhD levels), it is possible to repeat this excellent evaluation from The Boeing Company. As a critical mass of students form in other companies, similar surveys will be conducted.

The students from Boeing who are interested in the PhD mentioned in the report will form the initial group of Boeing Systems Engineering students. They are enrolled at UMR as Engineering Management PhD students or Systems Engineering MS students taking Systems Engineering courses and working on system engineering related research with the intention of switching to a Systems Engineering PhD when the proposed program is approved.

# A.3 Letters of Support from The Boeing Company

The Boeing Company
P.O. Box 516
St. Louis, MO 63166-0516
(314) 232-0232 TELEX 44-857

28 November 2005

Dr. Robert Mitchell, Dean
School of Engineering
Room 101
Engineering Research Lab
University of Missouri - Rolla
Rolla, MO 65409-0840

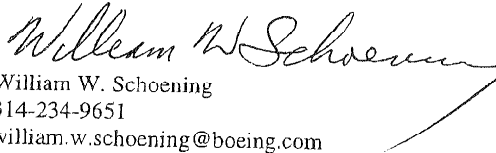**BOEING**

Dear Dean Mitchell,

A PhD program for systems engineering at UMR will be of substantial value to Boeing employees, particularly those interested in the Boeing Technical Fellowship career path. A PhD will allow systems engineers to be more competitive for entering the Fellowship or rising through its ranks. Since there are no quotas or other guidelines by discipline for Boeing Technical Fellows, we compete against electrical engineers, mechanical engineers, physicist, etc. Those who have earned a PhD have a distinct advantage.

While there are other PhD programs in systems engineering around the world, most Boeing employees actively seeking to extend there education in this field are enrolled in the Masters programs at either UMR or USC. Consequently, a PhD program has a ready-made source of PhD students numbering about 25 per year plus many others who earned their MS over the past 5 years. By the same token, I suspect that most students desiring to continue in a PhD program would be most comfortable doing so with the university in which they earned their MS.

The PhD program will be of significant value to Boeing. It is essential that we increase the number of systems engineers who are far more than excellent practitioners of the discipline. We need people who have the educational background to modify and extend the underlying concepts so that we can continue to be at the forefront of systems engineering and systems thinking.

The reputation of UMR in systems engineering has grown considerably over the last five years as a result of the high quality of graduates and the irrefutable quality of the education. I would imagine that a PhD program would cement UMR's position at the top of the systems engineering graduate education.

I am the Boeing coordinator for the systems engineering graduate program, a Boeing Technical Fellow in systems engineering, and a Fellow and past president of the International Council on Systems Engineering. I have been coordinating the MS program for Boeing since the inception of our collaboration in 2000, I conduct guest lectures every semester, and advise employee-students in the program.

William W. Schoening
314-234-9651
william.w.schoening@boeing.com

# Email from Boeing Manager of Current Student

From:     Sifford, Douglas P [mailto:douglas.p.sifford@boeing.com]
Sent:     Friday, August 25, 2006 12:06 PM
To:       Berkelman, Gwendolyn
Cc:       Adler, Charles O
Subject:  Endorsement for Mr. Charles Adler for the UMR Systems
          Engineering degree program

Sir or Madam,

Mr. Charles O. Adler is pursuing a PhD in Systems Engineering with your UMR program. Systems Engineering is considered a core competence for The Boeing Company and is an increasingly high demand skill set across the broad set of system, space, communication, aircraft and transportation programs across the company. The successful completion of this PhD will expand career opportunities within Boeing for Mr. Adler in the area of research, program execution and technical leadership. This degree will be a major contribution to his successful application and progression into our elite Technical Fellowship program. Additionally, his planned focus on collaborative systems should provide significant benefit to the Boeing company in the areas of developmental systems and network based approaches. As one of our leading engineers in networked systems engineering Charles and The Boeing Company will benefit greatly from his participation in your program.

I appreciate your attention and endorse Mr. Adler's participation in your program.

Doug Sifford

Douglas P. Sifford

Manager, International NCO Programs
NCO Programs & Technologies
IDS Advanced Systems
The Boeing Company

Office 253-773-3426
International Cell 206-390-8196

**A.4 Systems Engineering Graduate Program**
**Support Letters and Correspondences from Companies and Individuals**
**Outside of The Boeing Corporation**

**Email from Alejandro Gastelum (employee from Northrop Grumman)**

August 30, 2006
Board of Curators:

I am writing to you, in support of the PhD program in System Engineering at UMR.  I am a System Engineering Graduate student, and with the help of this program, I was able to excel and move much higher in my previous company and to get a job in System Engineering even before I get my degree.  Dr. Dagli and Dr. Miller also inspired and motivated me into publishing a paper at INCOSE earlier this year, an accomplishment I wouldn't have been able to do, without a program like the one you already have.  As I start a new job, I went from a team of about ninety Software Engineers divided into smaller teams, to a large System Engineering team, where everything I have learned in this program will be used.  I work with a variety of Engineers, some of them working as System Engineers without having a degree in it, but having the experience to do the job, others have a title in System Engineering, and there are a few of us, who are getting a MS in System Engineering.  I am very confident, in the education I'm receiving, and I have no doubts that entering a PhD program will help me in future leadership roles within the company.  I have looked around for what degree to pursue after my MS, but none of the programs offer me what UMR does, great reputation, familiarity with some of the instructors, previous classes to build on and the ability to do it online, is something that I can't even begin to describe how amazing it would be.  In today's workforce, people move around, different companies, different cities, to be tied down to one place while I complete a degree, doesn't allow me to pursue better opportunities, if they arise, by doing it online, I can begin and stay with the program, independently of where or for who I'm working for.  I can even persuade current and former colleagues to join in, knowing them, their schedule and work ethic we could collaborate at a level that feels more like a real working environment, while getting an advance degree.

Alejandro Gastelum
Global Hawk System Engineer
UMR System Engineer Graduate Student.

**A.5    Systems Engineering Graduate Program Faculty Research and Resumes**
**A.5.1   Systems Engineering Faculty Focus Areas and Interdisciplinary
           Organization of the Graduate Program**

**Table 2 Systems Engineering Research Focus Area**

| | |
|---|---|
| **Allada, Venkat** | Systems Architecting, Systems Engineering Process and Design, Network Centric Systems |
| **Balakrishnan, S.N.** | Network Centric Systems, Distributed Systems Modeling, Network Centric Manufacturing and Control, Computational Intelligence |
| **Belarbi, Abdeldjelil** | Structures |
| **Chandrashekhara, K** | Structures, Network Centric Manufacturing and Control |
| **Choi, Minsu** | Network Centric Systems, Distributed Systems Modeling, Network Centric Manufacturing and Control, Risk Modeling and Assessment, Modeling and Simulation |
| **Dagli, Cihan** | Network Centric Systems, Systems Architecting, Systems Engineering Process and Design, Modeling and Simulation, Computational Intelligence |
| **Dharani, Lokesh** | Modeling and Simulation, Structures |
| **Du, Xiaoping** | Modeling and Simulation |
| **Enke, David** | Computational Intelligence, Risk Modeling and Assessment, Modeling and Simulation |
| **Erickson, Kelvin** | Network Centric Manufacturing and Control |
| **Flachsbart, Barry** | Computational Intelligence |
| **Grasman, Scot** | Modeling and Simulation, Systems Engineering Process and Design, Systems Architecting, Network Centric Systems, Risk Modeling and Assessment |
| **Isaac, Kakkattukuzhy** | Modeling and Simulation |
| **Krishnamurthy, K** | Network Centric Manufacturing and Control |
| **Landers, Robert** | Network Centric Manufacturing and Control, Modeling and Simulation |
| **Leopold, Jennifer** | Systems Engineering Process and Design, Distributed Systems Modeling, Modeling and Simulation, Computational Intelligence |
| **Liou, Frank** | Network Centric Manufacturing and Control, Modeling and Simulation |
| **Liu, Xiaoqing (Frank)** | Systems Architecting, Systems Engineering Process and Design |
| **Luna, Ronaldo** | Infrastructure Systems |
| **Madria, Sanjay** | Network Centric Systems, Distributed Systems Modeling |
| **Miller, Ann** | Network Centric Systems, Systems Engineering Process and Design, Network Centric Manufacturing and Control |
| **Myers, John** | Structures |
| **Nanni, Antonio** | Structures |
| **Ragsdell, Kenneth** | Systems Engineering Process and Design |
| **Richards, Von** | Network Centric Manufacturing and Control, Structures |
| **Sarangapani, Jagannathan** | Computational Intelligence, Network Centric Systems, Network Centric Manufacturing and Control |
| **Stanley, R. Joe** | Computational Intelligence, Modeling and Simulation |
| **Tauritz, Daniel** | Computational Intelligence |
| **Tseng, Chung-Li** | Computational Intelligence, Risk Modeling and Assessment, Systems Architecting, Systems Engineering Process and Design, Modeling and Simulation |
| **Venayagamoorthy, Ganesh** | Computational Intelligence, Modeling and Simulation, |
| **Wunsch II, Donald** | Network Centric Systems, Modeling and Simulation, Computational Intelligence |
| **Xia, Franck** | Distributed Systems Modeling |
| **Zhao, Ying** | Computational Intelligence |

## A.5.2 Interdisciplinary Systems Engineering Graduate Program Organization

The Systems Engineering Graduate Program builds on sound Engineering undergraduate education and experience, and maintains engineering specialization diversity in its graduates at both the MS and PhD level.  The same diversity is also kept in its faculty as well.  This is also maintained in the formation of the research areas within the PhD program.  Current research areas include:

- Network Centric Systems
- Systems Architecting
- Systems Engineering Process and Design
- Distributed Systems Modeling,
- Infrastructure Systems and Structures
- Network Centric Manufacturing and Control
- Risk Modeling and Assessment
- Modeling and Simulation
- Computational Intelligence.

The objective of the graduate program is do interdisciplinary research in Systems Engineering with extensive cooperation with both defense and commercial industry to be measured by the number of journal publications and research funding and grant MS and PhD degrees in Systems Engineering both on campus and off campus to be measured by number of graduates.

The program is organized based on matrix organization. It is composed of a program director, core faculty, research and teaching support faculty that support the research areas identified. Program director with the help of core faculty who are in tenured or tenured track positions in their respected departments is responsible for running the program in coordination with the chairs where the core faculty has their positions. It is possible for the core faculty to have joint appointments with two or more departments depending on their overlapping research areas within Systems Engineering. It is also expected for the program director to set up and industrial advisory board to constantly update the graduate program by creating new courses, modifying the current MS degree program, Graduate Certificate Programs to respond to the changing needs of the industry and provide avenues for extensive research cooperation with industry.

IEEE and IIE are professional societies responsible for the accrediting Systems Engineering degree programs for ABET. It is accepted that this degree program to be accredited within the next accreditation cycle at UMR. There currently 34 faculty in the program with 12 core faculty representing Engineering Management and Systems Engineering Department (8 faculty), Electrical and Computer Engineering Department (3 faculty), Mechanical and Aerospace Engineering (1 faculty). It is accepted that there will be core faculty from other departments as program grows. Systems engineering graduate program has a senior secretary and is housed in Engineering Management and Systems Engineering department where most of the core faculty is located. The names of the core faculty are; **Venkat Allada, K. Chandrashekhara, Cihan H Dagli (Program Director), David Enke, Scott Grasman, Ann Miller, Kenneth Ragsdell, Sreeram Ramakrishnan, Jagannathan Saranapani, Can Saygin, Chung-Li Tseng, and Donald C Wunsch II.**

**The table in the next pages gives the detailed information for the entire faculty.**

**Table 1 Faculty Systems Engineering Research Areas and Teaching Contributions**

| FACULTY NAME | ENGINEERING PROGRAM ON | DEPARTMENT PROVIDING TENURED OR TENURE TRACK POSITION | PRIMARY GRADUATE PROGRAM | SECONDARY GRADUATE PROGRAMS | SYSTEMS ENGINEERING RESEARCH AREAS | SYSTEMS ENGINEERING COURSES | JOINT APPOINTMENTS |
|---|---|---|---|---|---|---|---|
| Venkat Allada | Faculty | Engineering Management and Systems Engineering | Systems Engineering | Engineering Management, Manufacturing Engineering | Network Centric Manufacturing and Control, Systems Engineering Process and Design | SysEng 468 Systems Engineering Analysis II | |
| S.N. Balakrishnan | Research and Teaching Support Faculty | Mechanical and Aerospace Engineering | Aerospace Engineering, Mechanical Engineering | Systems Engineering | Computational Intelligence | | |
| Abdeldjelil Belarbi | Research and Teaching Support Faculty | Civil, Architectural Environmental Engineering | Civil Engineering | Systems Engineering | Structures | | |
| K. Chandrashekhara | Core Faculty | Mechanical and Aerospace Engineering | Aerospace Engineering, Mechanical Engineering | Systems Engineering | Structures | | |
| Minsu Choi | Research and Teaching Support Faculty | Electrical and Computer Engineering | Electrical Engineering, Computer Engineering | Systems Engineering | Modeling and Simulation | | |
| Cihan H Dagli | Core Faculty and Program Director | Engineering Management and Systems Engineering | Systems Engineering | Engineering Management | Network Centric Systems, Systems Architecting, Systems Engineering Process and Design, Modeling and Simulation, Computational Intelligence | SysEng 469 Systems Architecting, SysEng/CpE 419 Network-Centric Systems SysEng 479 Architectures for Smart Engineering Systems SysEng 378 Introduction to Neural Networks, SysEng 478 Advanced Neural | |
| Lokesh R. Dharani | Research and Teaching Support Faculty | Mechanical and Aerospace Engineering | Aerospace Engineering, Mechanical Engineering | Systems Engineering | Structures | | |
| Xiaoping Du | Research and Teaching Support Faculty | Mechanical and Aerospace Engineering | Aerospace Engineering, Mechanical Engineering | Systems Engineering | Modeling and Simulation | | |

| FACULTY NAME | SYSTEMS ENGINEERING GRADUATE PROGRAM ASSOCIATION | DEPARTMENT PROVIDING TENURED OR TENURE TRACK POSITION | PRIMARY GRADUATE PROGRAM | SECONDARY GRADUATE PROGRAMS | SYSTEMS ENGINEERING RESEARCH AREAS | SYSTEMS ENGINEERING COURSES | JOINT APPOINTMENTS |
|---|---|---|---|---|---|---|---|
| David Enke | Core Faculty | Engineering Management and Systems Engineering | Systems Engineering | Engineering Management | Risk Modeling and Assessment, Computational Intelligence | SysEng 413 Economic Analysis of Systems Engineering Projects | |
| Kelvin Erickson | Research and Teaching Support Faculty | Electrical and Computer Engineering | Electrical and Computer Engineering | Systems Engineering | Network Centric Manufacturing and Control | | |
| Barry Flachsbart | Research and Teaching Support Faculty | Information Science & Technology | Information Science & Technology | Systems Engineering | Computational Intelligence | | |
| Scott Grasman | Core Faculty | Engineering Management and Systems Engineering | Systems Engineering | Engineering Management | Modeling and Simulation | Eng 368 Systems Engineering Analysis I | |
| Kakkattukuzhy M. Isaac | Research and Teaching Support Faculty | Mechanical and Aerospace Engineering | Aerospace Engineering, Mechanical Engineering | Systems Engineering | Structures | | |
| K. Krishnamurthy | Research and Teaching Support Faculty | Mechanical and Aerospace Engineering | Mechanical Engineering, Aerospace Engineering | Systems Engineering | Network Centric Manufacturing and Control | | |
| Robert G. Landers | Research and Teaching Support Faculty | Mechanical and Aerospace Engineering | Mechanical Engineering, Manufacturing Engineering | Systems Engineering | Network Centric Manufacturing and Control | | |
| Jennifer Leopold | Research and Teaching Support Faculty | Computer Science | Computer Science | Systems Engineering | Computational Intelligence | | |
| Antonio Nanni | Research and Teaching Support Faculty | Civil, Architectural and Environmental Engineering | Civil Engineering | Systems Engineering | Systems Architecting | | |
| John Myers | Research and Teaching Support Faculty | Civil Architectural Environmental Engineering | Civil Engineering | Systems Engineering | Structures | | |
| Kenneth Ragsdell | Core Faculty | Engineering Management and Systems Engineering | Systems Engineering | Engineering Management | Systems Engineering Process and Design | SysEng 411 Systems Engineering Management | |
| Jennifer Leopold | Research and Teaching Support Faculty | Computer Science | Computer Science | Systems Engineering | Computational Intelligence | | |
| Sreeram Ramakrishnan | Core Faculty | Engineering Management and Systems Engineering | Systems Engineering | Engineering Management | Distributed System Modeling, Systems Engineering Process and Design | SysEng 433 Distributed System Modeling SysEng 412 Complex Engineering Systems Project Management | |
| Jagannathan Saranapani | Core Faculty | Electrical and Computer Engineering | Computer Engineering | Systems Engineering | Network Centric Systems, Network Centric Manufacturing and Control | | |

| FACULTY NAME | SYSTEMS ENGINEERING GRADUATE PROGRAM ASSOCIATION | DEPARTMENT PROVIDING TENURED OR TENURE TRACK POSITION | PRIMARY GRADUATE PROGRAM | SECONDARY GRADUATE PROGRAMS | SYSTEMS ENGINEERING RESEARCH AREAS | SYSTEMS ENGINEERING COURSES | JOINT APPOINTMENTS |
|---|---|---|---|---|---|---|---|
| Can Saygin | Core Faculty | Engineering Management and Systems Engineering | Systems Engineering | Engineering Management, Manufacturing Engineering | Network Centric Manufacturing and Control | | |
| R Joe Stanley | Research and Teaching Support Faculty | Electrical and Computer Engineering | Computer Engineering | Systems Engineering | Computational Intelligence | | |
| Daniel Tauritz | Research and Teaching Support Faculty | Computer Science | Computer Science | Systems Engineering | Computational Intelligence | | |
| Chung-Li Tseng | Core Faculty | Engineering Management and Systems Engineering | Systems Engineering | Engineering Management | Systems Engineering Process and Design Modeling and Simulation, Distributed Systems Modeling | SysEng 368 Systems Engineering Analysis I SysEng 468 Systems Engineering Analysis II | |
| Ganesh Kumar Venayagamoorthy | Research and Teaching Support Faculty | Electrical and Computer Engineering | Computer Engineering | Systems Engineering | Computational Intelligence | CpEng/CS/SysEng 458 Adaptive Critic Design | |
| Donald C Wunsch II | Core Faculty | Electrical and Computer Engineering | Computer Engineering | Systems Engineering | Computational Intelligence | CpEng/CS/SysEng 458 Adaptive Critic Design | |
| Von L. Richards | Research and Teaching Support Faculty | Material Science and Engineering | Metallurgical Engineering | Manufacturing Engineering Systems Engineering | Network Centric Manufacturing and Control | | |
| Franck Xia | Research and Teaching Support Faculty | Computer Science | Computer Science | Systems Engineering | Distributed System Modeling | | |

## A.5.3 Systems Engineering Core Faculty

**Venkat Allada**
Department of Engineering Management and Systems Engineering
University of Missouri - Rolla

## Current Position
- Associate Professor, Department of Engineering Management and Systems Engineering University of Missouri - Rolla (UMR)

## Education
- Ph.D, Industrial Engineering, University of Cincinnati, 1994
- M.Tech., Management & Systems, Indian Institute of Technology, New Delhi, India
- 1990 B.E., Production Engineering, VJTI, University of Bombay, India, 1987

## Research Interests and Fields of Specialization
- Lean Systems Engineering, New Product Development (NPD), Product Family Design and Product Platforms, Supply Chain Networks

## Systems Engineering Research Focus
- Systems Architecting, Systems Engineering Process and Design, Network Centric Systems.

## Research and Scholarly Production
- Number of Archived Publications (Journals, Conference Proceedings, and Book Chapters) - 100+
- Total Funding - $2.39 Million

## Sample Journal Publications
1. Rai, R., and Allada, V., Agent-Based optimization for product family design, <u>Annals of Operations Research</u> (accepted).
2. Kumar, R., and Allada, V., Scalable platforms using Ant colony optimization, <u>Journal of Intelligent Manufacturing</u> (accepted).
3. Viswanathan, S., and Allada, V., Product configuration optimization for disassembly planning: A differential approach, <u>Omega: The International Journal of Management Science</u> (accepted).
4. Anam, F., and Allada, V., An activity-product affiliation network approach to study product convergence opportunities, <u>International Journal of Innovation and Technology Management</u>, No. 3, 2004, pp. 249-268.
5. Rai, R., and Allada, V., Modular product family design: agent-based Pareto-optimization and quality loss function-based post-optimal analysis, <u>International Journal of Production Research</u>, Vol. 41, No. 17, 2003, pp. 4075-4098.

## Awards

- Recipient of the 1998 Society of Manufacturing Engineers (SME) *Dell K. Allen Outstanding Young Manufacturing Engineer Award.*
- Recipient of the 1998 *Dow Outstanding New Faculty Award* by the American Society of Engineering Education (ASEE).
- Best Paper Award at the 2000 ASME International Design Engineering Technical Conferences (DFM Conf.).
- Recipient of the University of Missouri-Rolla *Faculty Excellence Award* (1998-99, 99-00, 00-01, 05-06).
- Outstanding Teaching Award of Excellence by the UMR School of Extended Learning, 2005.
- Outstanding Contributions Award by the Lean Aerospace Initiative at the Massachusetts Institute of Technology, 2005.

## K. CHANDRASHEKHARA
Professor, Department of Mechanical and Aerospace Engineering
University of Missouri-Rolla

## EDUCATION
- Ph.D. Engineering Science and Mechanics, Virginia Polytechnic and State University, Blacksburg, Virginia, 1985.
- M.S. Aerospace Engineering, Indian Institute of Technology, Kanpur, India, 1979.
- B.S. Aerospace Engineering, Madras Institute of Technology, Madras, India, 1977.
- B.S. Applied Mathematics, University of Mysore, India, 1974.

## RESEARCH INTERESTS
- Composite Materials, Smart Structures, Structural Dynamics, Biocomposites, Nanocomposites, Finite Element Analysis, Damage Monitoring, Neural Networks, Composite Manufacturing and Experimental Characterization.

## JOURNAL PAPERS:
1. G. Song, K. Chandrashekhara, W. F. Breig, D. L. Klein and L. R. Oliver, " J-Integral Analysis of Cord-Rubber Serpentine Belt Using Neural Network Based Material Modeling," *Fatigue & Fracture of Engineering Materials & Structures,* Vol. 28, pp. 847-860, 2005.
2. G. Liang, A. Garg, K. Chandrashekhara, "Cure Characterization of Pultruded Soy-based Composites," *Journal of Reinforced Plastics and Composites*, Vol. 24, No. 14, pp. 1509-1520,2005.
3. .P. Kumar, K. Chandrashekhara and A. Nanni, "Structural Performance of a FRP Bridge Deck," *Construction and Building Materials*, Vol. 8, pp. 35-47, 2004.
4. S. E. Watkins, R. H. Hall, K. Chandrashekhara and J. M. Baker, "Interdisciplinary Learning through a Connected Classroom," *International Journal of Engineering Education*, Vol. 20, pp. 176-187, 2004.

5. Y. Shen, K. Chandrashekhara and S. Agarwal, "Recurrent Neural Networks for Robust Vibration Control of Composite Shells," *International Journal of Smart Engineering System Design,* Vol. 3, pp. 175-185, 2001.

**MISCELLANEOUS**
- Director of Composite Manufacturing Laboratory.
- Research Grants Generate - over 9 million with a share of over $ 2.6 million.
- Publications - over 150 including 68 journal articles.
- Text Book (Co-Author): Analysis and Performance of Fiber Composites, Third Edition, John Wiley & Sons, 2006.
- NSF-PATH Focus Group Panel Member on Affordable Housing Initiative, 2004
- Fellow of American Society for Mechanical Engineers, 2002.
- UMR Faculty Excellence Awards, 1994, 1996, 2001.
- Academy of Mechanical Engineers Faculty Research Excellence Award, 2000.

## CIHAN H. DAGLI
Engineering Management and Systems Engineering Department
University of Missouri-Rolla

**PROFESSIONAL EXPERIENCE (Last Five Years):**
- 2000- Present - Director, Boeing Systems Engineering Graduate Program, Department of Engineering, Management and Systems Engineering, University of Missouri-Rolla, Rolla, Missouri.
- 2004- Present - Associate Chair – Systems Engineering, Department of Engineering Management and Systems Engineering, University of Missouri-Rolla, Rolla, Missouri.
- 1995- Present - Professor and Director of Smart Engineering System Design Laboratory, Department of Engineering Management and Systems Engineering, University of Missouri-Rolla, Rolla, Missouri.

**LAST DEGREE:**
- Ph.D. 1979, School of Manufacturing and Mechanical Engineering, The University of Birmingham, England.

**RESEARCH INTERESTS**:
- Systems Architecting and Engineering, System of Systems, Smart Engineering System Design, Neural Networks, Fuzzy Logic, Evolutionary Programming, Data Mining, Nesting Problems.

**SYSTEMS ENGINEERING RESEARCH FOCUS:**
- Network Centric Systems, Systems Architecting, Systems Engineering Process and Design, Modeling and Simulation and Computational Intelligence.

**TOTAL GRANTS GENERATED - $ 2,322,923**

**NUMBER OF ARCHIVABLE PUBLICATIONS: 189**

**JOURNAL PAPERS:**
1. A software architecture for testing intelligent path planning algorithms for automated guided vehicles, with Lakshmanan Meyyappan, Nebil Buyurgan and Can Saygin, **Journal of Manufacturing Technology Management,** (Accepted for Publication).
2. Neural Networks as a Decision Maker for Stock Trading: A Technical Analysis Approach, with Thawornwong, S., D. Enke, *Journal of Smart Engineering Systems Design*, Vol. 5 Number 4 (2004): 313-325.
3. Ensemble of Evolving Neural Networks in Classification, with Sunghwan Sohn, **Neural Processing Letters 19:** 191-203, 2004.
4. Genetic Neuro-Nester, with Pipatpong Poshyanonda, **Journal of Intelligent Manufacturing,** 15, 203-220, 2004.
5. Employing Subgroup Evaluation for Irregular-Shape Nesting with Amber Fischer, **Journal of Intelligent Manufacturing,** 15, 189-201, 2004.

**MISCELLANEOUS:**
- **International Journal of General Systems,** Intelligent Systems Design Area Editor, **(**Four issues per Volume, Volume 34/5 in print)**, Taylor and Francis and Informa.**
- **International Journal of Smart Engineering System Design,** Editor-In-Chief **(**Four issues per Volume, Volume 5/4)**, Taylor and Francis Group.**
- Founder and chair of ANNIE Artificial Neural Networks in Engineering conferences which is being held in St. Louis since 1991.

### DAVID ENKE
Department of Engineering Management and Systems Engineering
University of Missouri - Rolla

**Current Position**
- Associate Professor, Department of Engineering Management and Systems Engineering University of Missouri - Rolla

**Education**
   University of Missouri - Rolla (UMR)
- Ph.D. in Engineering Management, 6/94-5/97, Chancellor's Fellow.
- M.S. in Engineering Management, 1/93-5/94, Chancellor's Fellow.
- B.S. in Electrical Engineering, 8/84-5/90, Summa Cum Laude.

**Research Interests and Fields of Specialization**
- Financial Engineering (derivatives, financial risk analysis, portfolio theory, value-at-risk, hedging).
- Financial Forecasting (regression, ARIMA, GARCH, intelligent systems)
- Investment (stocks, bonds, options, futures, valuation, market efficiency,

behavioral finance).
- Intelligent Systems (neural networks, genetic and evolutionary algorithms, fuzzy logic, data mining).
- Electricity Markets (deregulation, market structure, load forecasting, price forecasting).
- Engineering Economics (capital planning and budgeting, project evaluation, sensitivity analysis).

**Systems Engineering Research Focus**
- Computational Intelligence, Risk Modeling and Assessment, Systems Architecting, Systems Engineering Process and Design, Modeling and Simulation.

**Research and Scholarly Production**
- Number of Archived Publications (Journals, Conference Proceedings, and Book Chapters) - 64.
- Total Research Funding - $1,821,690

**Five Recent Journal Publications**
1. Enke, D., B. Chowdhury, G. Gelles, and E.K. Stanek, "Concepts on Market-Oriented Transmission Investment", *Journal of Power and Energy Systems*, in-press, 2006.
2. Enke, D., and S. Thawornwong, "The Use of Data Mining and Neural Networks for Forecasting Stock Market Returns", *Expert Systems with Applications*, Volume 29, No. 4 (2005): 927-940.
3. Lewis, N., D. Enke, and D. Spurlock, "Valuation for the Strategic Management of Research and Development Projects: The Deferrel Option", *Engineering Management Journal*, Vol. 16, No. 4 (2004): 36-48.
4. Thawornwong, S., and D. Enke, "The adaptive selection of financial and economic variables for use with artificial neural networks", *Neurocomputing*, Vol. 56 (2003): 205-232.
5. Thawornwong, S., D. Enke, and C. Dagli "Neural Networks as a Decision Maker for Stock Trading: A Technical Analysis Approach," *Journal of Smart Engineering Systems Design*, Vol. 5, No. 4 (2003): 313-325.

**Miscellaneous (Professional Societies, Center Memberships, Fellowships, Awards, etc)**
- Laboratory for Investment and Financial Engineering (LIFE), Director.
- Member of the Smart Engineering Systems Lab, Intelligent Systems Center, Energy Research Center.
- Member of Eight Professional Societies and Four Honor Societies.
- Six UMR Outstanding Faculty Teaching Awards, Both for On-Campus and Distance Instruction.
- Three Best Paper Awards (One Journal and Two Refereed Conference Proceedings).

- Artificial Neural Networks in Engineering Conference, Co-Chair, 2004-2006.

## SCOTT E. GRASMAN
Department of Engineering Management and Systems Engineering
University of Missouri - Rolla

## Current Position
- Assistant Professor (since 2001), Department of Engineering Management and Systems Engineering University of Missouri - Rolla (UMR).

## Education
- Department of Industrial and Operations Engineering.
- College of Engineering, University of Michigan, Ann Arbor, Michigan.
- Ph.D., Industrial and Operations Engineering, August 2000.
- M.S.E., Industrial and Operations Engineering, December 1995.
- B.S.E., Industrial and Operations Engineering, May 1994.

## Research Interests and Fields of Specialization
- Connective Technologies in Supply Chain Management.
- Inventory Routing and Transportation Problems.
- Development of Hydrogen Infrastructure.
- Manufacturing and Service Management.
- Mathematical Modeling and Optimization.

## Systems Engineering Research Focus
- Modeling and Simulation, Systems Engineering Process and Design, Systems Architecting, Network Centric Systems, Risk Modeling and Assessment.

## Research and Scholarly Production
- Number of Archived Publications (Journals, Conference Proceedings, and Book Chapters) - 31.
- Total Research Funding - $1,265,665.

## Five Recent Journal Publications
1. Grasman, S.E., "Dynamic Programming Approach to Strategic and Operational Multimodal Routing Decisions", International Journal of Logistics Systems and Management 2(1), 96-106, 2006.
2. Akcora, E., Grasman, S.E., and Saygin, C., "A Job Shop Scheduling Heuristic for Varying Reward Structures", Mathematical and Computer Modeling 42(11-12), 1163-1174, 2005.
3. Srinivasan, S.R., Ramakrishnan, S., and Grasman, S.E., "Identifying Effects of Product Cannibalization on Product Portfolio", Marketing Intelligence and Planning 23(4), 359-371, 2005.
4. Grasman, S.E., Olsen, T.L., and Birge, J.R., "Finite Buffer Polling Models

with Routing", European Journal of Operational Research 165(3), 794-809, 2005.
5. Grasman, S.E., Saygin, C., and Najm, M., "Computer-Simulated Enterprise Management Educational Environment", Decision Sciences Journal of Innovative Education 3(1), 183-188, 2005.325.

## Miscellaneous (Professional Societies, Center Memberships, Fellowships, Awards, etc)
- Member of the Smart Engineering Systems Lab, 6 Professional Societies.
- Regional Board of Director, American Society for Engineering Management.
- Division Officer, American Society for Engineering Education.
- Acknowledged Reviewer of 3 Textbooks.
- Ad Hoc Reviewer for 6 Journals and 7 Conferences, Various Proposals.
- Various UMR/SOE/EMSE Committees.

## ANN MILLER
Department of Electrical and Computer Engineering
University of Missouri - Rolla

## Current Position (since June 1999)
- Cynthia Tang Missouri Distinguished Professor of Electrical and Computer Engineering.

## Prior Positions
- Three years of Senior Executive Service in the U.S. Department of Defense and the Department of the Navy; Meritorious Civilian Service Award, May 1999.
- Twelve years of experience in Motorola, Inc. in various positions of software and systems engineering; various technical awards; one patent in satellite communications.

## Education
- Ph.D. 1972, M.S. 1970, B.S. 1968, all from Saint Louis University in Mathematics.

## Research Interests and Fields of Specialization
- Trustworthy systems, including computer and network security, information assurance, and software reliability/survivability. Large-scale networked systems, particularly Supervisory, Control, and Data Acquisition (SCADA) systems and process control systems.

## Systems Engineering Research Focus
- Network Centric Systems, Systems Engineering Process and Design, Network Centric Manufacturing and Control.

## Sample Publications
1. Stanilka, S., C. H. Dagli, A. Miller, "Object-Oriented Development for DoDAF System of Systems", INCOSE International Symposium, July 2005.

2. Gideon, J. H. C. H. Dagli, A. Miller, "Taxonomy of Systems-of-Systems", Conference on Systems Engineering Research, March 2005.
3. Miller, A. and K. T. Erickson, "Multi-Layer Vulnerability Assessment of a SCADA Network", invited keynote talk, Workshop on **R**esearch and **Ed**ucation in **Co**ntrol and **S**ignal Processing, **REDISCOV**ER 2004**,** June 2004.
4. Miller, A. and K. T. Erickson, "Network Vulnerability Assessment:  A Multi-Layer Approach to Adaptivity", NATO Symposium on Adaptive Defense in Unclassified Networks, April 2004.
5. Erickson, K.T., A. Miller, E. K. Stanek, and S. Dunn-Norman , Reliability of SCADA Systems in Offshore Oil and Gas Platforms, Chapter 20 of Stability and Control of Dynamical Systems with Applications, Liu and Antsaklis, Editors, Birkhauser Press, 2003.
6. *Developing Fault Tolerant Software*, IEEE Tutorial on CD, ISBN 0-7803-6843-6, 2002, Presentations by Voas, J. M., J. Bechta Dugan, M. Vouk, A. Miller.

**Sample Professional Activities**
- Chair, NATO Information Systems Technology Panel, 1997 – present.
- Member, NATO Task Group of Dual Use of High Assurance Technologies, 2004 – present.
- Member, IEEE Reliability Society Administrative Committee, 2002 – present.
- Member, National Academies Study Board on the Role of Naval Forces in the Global War on Terrorism, 2005 – present.
- Associate Editor-in-Chief, IEEE SOFTWARE, 2000 – 2004.

## KENNETH M. RAGSDELL

Engineering Management and Systems Engineering Department
University of Missouri-Rolla

**PROFESSIONAL EXPERIENCE (Last Five Years):**
- Professor of Engineering Management and Systems Engineering, University of Missouri-Rolla.

**LAST DEGREE:**
- Ph.D. 1972, Mechanical Engineering, The University of Texas.

**RESEARCH INTERESTS**:
- Product Development, Engineering Design and Optimization, Quality Management and Quality Engineering.
- SYSTEMS ENGINEERING RESEARCH FOCUS:
- Product Development, Engineering Design and Optimization, Quality Management and Quality Engineering.

**TOTAL EXTERNAL RESEARCH FUNDING ~$3,000,000**

**NUMBER OF PUBLICATIONS - 120**

**RECENT JOURNAL PAPERS:**

1. Tsai, S.C. and K.M. Ragsdell, "Optimization Efficiency of Taguchi-class Experimental Design Using Conjugate Arrays", JOURNAL OF ENGINEERING DESIGN, vol. 4, no. 3, 1993.
2. Ragsdell, K. M., "Total Quality Management", ASME Manufacturing Review, vol. 7, no. 3, September, 1994, pp. 194 - 204.
3. Smith, L. R. and K. M. Ragsdell, "Winning Today's Quality Challenge: The Role of the Taguchi System of Quality Engineering", Japanese Quality Engineering Journal, 10th Anniversary Edition, October 2002, in Japanese and English.
4. Hui, C. T., J. A. Mosier, S. Soans, C. S. Fraley, T. E. Emery, and K. M. Ragsdell, "Robust Injection Molding: The Waviness Index", Japanese Quality Engineering Journal, October 2002, in Japanese and English.
5. Ragsdell, K.M., Design Stability, SAE Transactions, 2006.

**RECENT CONFERENCE PAPERS:**
1. Hong, Cudney, Taguchi, Jugulum, Paryani and Ragsdell, "A Comparison Study of Mahalanobis-Taguchi System and Neural Network for Multivariate Pattern Recognition" ASME World Congress, Nov. 2005.
2. Jikar, Vivek and K.M. Ragsdell, "Functional Flow Down Tool Set", ASME IDETC, Sept. 2006.
3. Hui, C.T. and K.M. Ragsdell, "Robust Injection Molding Of An Automotive Exterior Body Panel Using The Waviness Index", International Auto Body Conference, 2005.

## JAGANNATHAN SARANGAPANI

Director, Embedded Systems and Networking Laboratory
University of Missouri - Rolla

**Current Position**
- Professor, Department of Electrical and Computer Engineering.
- Site Director, NSF Industry/University Cooperative Research Center on Intelligent Maintenance University of Missouri - Rolla (UMR)

**Education**
- B.E. in Electrical Engineering, 1986, Anna University, Chennai, India, *University Topper & Gold Medalist*.
- M.S. in Electrical Engineering, 1989, University of Saskatchewan, Saskatoon, Canada, *Fellowship holder*.
- Ph.D. in Electrical Engineering, 1994, University of Texas, Texas, *Fellowship holder*.

**Research Interests and Fields of Specialization**
- Intelligent Control & Robotics (Neural Networks, Fuzzy Logic, Swarm Intelligence, AI).
- Wireless Networking, Wireless Sensor Networks, Protocols, UMR Mote.

- Network Centric Systems, Control, RFID Protocols and Hardware.

**Systems Engineering Research Focus**
- Computational Intelligence, Network Centric Systems, Network Centric Manufacturing and Control.

**Research and Scholarly Production**
- Number of Archived Publications (Journals, Conference Proceedings, and Book Chapters) - 160.
- Number of Patents - 17.
- Total Research Funding (My credit) - $6,163,637 Total Funding: $19,148,122 (including industry support).

**Recent Journal Publications**
1. "Distributed power control of wireless cellular networks in the presence of fading channels," S. Jagannathan, Maciej Zawodniok, and Q. Shang, IEEE Transactions on Wireless Communications, to appear in Feb 2006.
2. "Admission control design for high speed networks: A hybrid system approach," S. Jagannathan, Journal of High-Speed Networks, Vol. 14, pp. 263-281, 2005.
3. "End to end congestion control in high-speed networks," X. Peng, S. Jagannathan and S. Subramanya, Journal of High-Speed Networks, to appear in 2006.
4. "Neuroemission controller for reducing cyclic dispersion in lean combustion spark ignition engines," P. He and S. Jagannathan, Automatica, Vol. 41, pp. 1133-1142, July 2005.
5. "Reinforcement-based neuro-output feedback control of discrete-time systems with input constraints," P. He and S. Jagannathan, IEEE Tran. On Systems, Man and Cybernetics-Part B, Vol. 35, no. 1, pp. 150-154, 2005.
6. "Adaptive critic neural network–based object grasping controller using a three-fingered gripper," S. Jagannathan and Gustavo Galan, IEEE Trans. on Neural Networks, Vol. 15, No. 2, pp. 395-407, March 2004.

**Miscellaneous (Professional Societies, Center Memberships, Fellowships, Awards, etc)**
- Program Chair, 2007 IEEE International Symposium on Intelligent Control
- Invited Session Chair for the 2006 International Symposium on Intelligent Control and Publicity Chair for the 2006 IEEE International Conference on Networking, Sensing and Control
- Associate Editor for IEEE Transactions on Control Systems Technology and IEEE Transactions on Neural Networks
- Several awards including outstanding advisor award for the IEEE student branch in 2005
- Several past awards-best paper awards, NSF Career Award, Presidential Award for Research Excellence
- Member of Intelligent Systems Center and Center for Aerospace Manufacturing Technologies

**CHUNG-LI TSENG**

Department of Engineering Management and Systems Engineering
University of Missouri - Rolla

**Current Position**
- Associate Professor, Department of Engineering Management and Systems Engineering - University of Missouri - Rolla (UMR)

**Education**
- University of California at Berkeley, Berkeley, CA - Ph.D. in Industrial Engineering and Operations Research, 1/93-12/96
- University of California at Davis, Davis, CA - M.S. in Electrical and Computer Engineering, 8/90-11/92
- National Taiwan University, Taipei, Taiwan - B.S. in Electrical Engineering, 8/84-7/88

**Research Interests and Fields of Specialization**
- Service Operations Management (finance, energy, and infrastructure).
- System Analysis and Design.
- 

**Systems Engineering Research Focus**
- Computational Intelligence, Risk Modeling and Assessment, Systems Architecting, Systems Engineering Process and Design, Modeling and Simulation.

**Research and Scholarly Production**
- Number of Archived Publications (Journals 16, Conference Proceedings 7, and Book Chapters 2).
- Total Research Funding - $299,953.

**Five Recent Journal Publications**
1. C. L. Tseng and K. Lin, "A Framework Using Two-Factor Price Lattices for Generation Asset Valuation," *Operations Research* (accepted).
2. T. Zhao and C. L. Tseng, "Flexible Facility Interior Layout: A Real Options Approach," *Journal of Operational Research Society* (accepted).
3. C. L. Tseng, K. Lin, and S. K. Sundararajan, "Managing Cost Overrun Risks in Project Funding Allocation," *Annals of Operations Research*, 135(1), 127-153, 2005.
4. T. Zhao, S. K. Sundararajan, and C. L. Tseng, "Highway Development Decision-Making under Uncertainty: A Real Options Approach," *Journal of Infrastructure Systems*, 10(1), 23-32, 2004.
5. T. Zhao and C. L. Tseng, "Valuing Flexibility in Infrastructure Expansion," *Journal of Infrastructure Systems*, 9(3), 89-97, 2003.

**Miscellaneous (Professional Societies, Center Memberships, Fellowships, Awards, etc)**
- Associate Editor, Journal of Energy Engineering, ASCE, 2003-Present.

- Editorial Board, International Journal of Electronic Business Management, 2005-Present.
- Special Editor, "Quantitative Models for Energy Systems," *Journal of Energy Engineering*, Apr, 2005.
- Special Editor, "Quantitative Models for Energy Markets," *Journal of Energy Engineering*, Aug, 2005.
- President, Section on Energy, Natural Resources, and Environment (ENRE), INFORMS, 2002-2004.
- Best paper award in the 31st Hawaii International Conference on System Sciences, Jan 1998.

## DONALD C. WUNSCH
Department of Electrical and Computer Engineering
University of Missouri-Rolla

## PROFESSIONAL EXPERIENCE:
- 1999- Present - *M.K. Finley Missouri Distinguished Professor*, Department of Electrical & Computer Engineering, joint appointments in Systems Engineering, Computer Science and Business Administration.
- 1993- 1999 - *Assistant, Associate Professor*, Department of Electrical & Computer Engineering, Texas Tech University, Lubbock, TX.
- *Engineer, Research Engineer, Senior Principal Scientist*, The Boeing Company, Seattle, WA.

## Education:
- MBA, July 2006, Washington University in St. Louis.
- Ph.D., Electrical Engineering, 1991, University of Washington, Seattle, WA.
- M.S., Applied Math, 1987, University of Washington, Seattle, WA.
- B.S., Applied Math, 1984, University of New Mexico, Albuquerque, NM.

## RESEARCH INTERESTS:
- Neural Networks, Fuzzy Logic, Evolutionary Programming, Reinforcement Learning, Unsupervised Learning / Clustering, many application areas.

## SYSTEMS ENGINEERING RESEARCH FOCUS:
- Network Centric Systems, Modeling and Simulation and Computational Intelligence.

## TOTAL GRANTS GENERATED - $ 5,038,507

## NUMBER OF PUBLICATIONS - over 200

## SELECTED RECENT JOURNAL PAPERS:
1. "A Heuristic Dynamic Programming based Power System Stabilizer for a Turbogenerator in a Single Machine Power System", Wenxin Liu, Ganesh K. Venayagamoorthy, and Donald C. Wunsch, *IEEE Transactions on Industry Applications*, vol. 41, issue 5, September 2005.

2. "Negative Reinforcement and Backtrack-Points for Recurrent Neural Networks for Cost-Based Abduction," Ashraf M. Abdelbar, Mostafa A. El-Hemaly, Emad A.M. Andrews and Donald C. Wunsch, *Neural Networks*, 18, August 2005, pp. 755 – 764.
3. "Detection of Basal Cell Carcinoma using Electrical Impedance and Neural Networks," R. Dua, D. Beetner, W. V. Stoecker, and D.C. Wunsch, *IEEE Transactions on Biomedical Engineering*, Vol. 51, No. 1., January 2004, pp. 66-71.
4. "Query-Based Learning for Aerospace Applications," Emad W. Saad, Jai J. Choi, John L. Vian, and Donald C. Wunsch II, *IEEE Trans. on Neural Networks*, Vol. 14, No. 6, November 2003, pp. 1437-1448.
5. "Signed Graphs for Portfolio Analysis in Risk Management," M.H. Lim, Frank Harary and Donald C. Wunsch II, *IMA Journal of Management Mathematics*, (2002) 13, 201-210.
6. "Million City Traveling Salesman Problem Solution by Divide and Conquer Clustering With Adaptive Resonance Neural Networks," Sam Mulder and Donald C. Wunsch II, *Neural Networks*, July 2003.

**MISCELLANEOUS:**
- Past President 2006, International Neural Networks Society
- IEEE Fellow.

**A.5.4 Systems Engineering Contributing Faculty**

**S. N. BALAKRISHNAN**
Dept. of Mechanical and Aerospace Engineering,
University of Missouri-Rolla

**Current Position**
- Professor, Aerospace Engineering

**Education**
- Ph.D. (Aerospace Engineering), University of Texas at Austin, Texas, 1984.

**Research Interests**
- Guidance, Stability, Control and Estimation, Pattern Recognition, Stochastic Processes, Optimization, Neural Network Applications to Control, Numerical Methods.

**Systems Engineering Research Focus**
- Network Centric Systems, Distributed Systems Modeling, Network Centric Manufacturing  and Control, Computational Intelligence

**Research Supervision**
- Number of students graduated – 28.
- I have directed an M.S. thesis in Engineering Management, an M.S. thesis in Computer Science, an M.S. thesis in Electrical Engineering, a PhD dissertation in Electrical Engineering and several M.S. and PhDs in Mechanical Engineering and Aerospace Engineering.
- Grants generated in last 5 years - 9 grants totaling $894,053.

**Representative Publications**
1. Xin, Ming and Balakrishnan, S.N., "Missile Longitudinal Autopilot Design Using A New Suboptimal Nonlinear Control Method" IEE Proceedings Control Theory and Applications, Vol. 150, No.6, Nov. 2003, pp.577-584.
2. Prabhat, P., Look, D.C., and Balakrishnan, S.N., "Experimental Model determination for Neurocontrol of a Thermal Conduction System" AIAA Journal of Thermal Physics and Heat Transfer, Vol. 17, No.4, October-December 2003, pp. 471-480.
3. Padhi, R., and Balakrishnan, S.N.,"Proper Orthogonal Decomposition based Optimal  Neurocontrol Synthesis of a Chemical Reactor Process Using Approximate Dynamic Programming" Neural Networks, Vol. 16, 2003, pp. 719-728.
4. Padhi, R. and Balakrishnan, S.N., "Development and Analysis of a Feedback
5. Treatment Strategy for Parturient Paresis of Cows," IEEE Transactions on Control Systems Technology, Vol. 12, No. 1, January, 2004, pp.52-64.

6.  Hu, Z. and Balakrishnan, S.N.,"Parameter Estimation in Nonlinear Systems Using Hopfield Neural Networks," AIAA Journal of Aircraft, Vol. 42, no.1, Jan.-Feb. 2005, pp. 41-53.

## SPECIAL DISTINCTIONS (RECOGNITIONS, FELLOWSHIPS, INVITED LECTURES, PUBLICATIONS)

- ASME Best Paper Award, Applicon Best Paper Award for CAD/CAM Theory and Applications, ASME Design Automation Conference, September 15, 1997 (Co-authors K. Srikanth and F. Liou).
- Cited by Paul Werbos, NSF Program director and a pioneer in neural networks, as one of the top four researchers (or groups) in the U.S. in implementing latest "brain-like intelligent control" for nonlinear control problems. Refer to: "Optimization Methods for Brain-Like Intelligent Control," Paul J. Werbos, Proceedings of the 34th IEEE Conference on Decision and Control, New Orleans, LA, December 1995, pp. 579-584.
- *Aerospace/Space Technology, a Russian journal in selects a few articles of interest in American journals and translates to Russian and publishes them. A Russian translation of my paper (co-authored with Dr. B. D. Tapley), "Multi-target Classification and Estimation Using Clustering Techniques," AIAA Journal of Guidance, Control, and Dynamics, Jan.-Feb. 1990, pp. 121-127, appeared in Aeronautics/Space Technology in October 1991.*
- Associate Editor, AIAA Journal of Guidance, Control, and Dynamics, 1994.
- Commendation letter, Outstanding Teaching, UMR, 2001-2002.
- Consultant and Member, Missile System Evaluation team to assess the HAG Guidance, Missile Defense Agency, August 2004**.**
- Four student advisees have won national/international awards for our papers.

## ABDELDJELIL BELARBI, PH.D., P.E.
Department of Civil Engineering
University of Missouri-Rolla

## PROFESSIONAL HISTORY *(Last 5 years):*
- Jan. 2005 – present - University of Missouri-Rolla; Distinguished Professor.
- Aug 2003 - Dec. 2004 - University of Missouri-Rolla; Professor.
- Aug 2002 - present University of Missouri-Rolla; Assistant Chairman for Distance Education.
- Aug 1997 - July 2003 University of Missouri-Rolla; Associate Professor.

## EDUCATION:
- University of Sciences and Technology of Oran, Algeria Civil Engineering B.S. in 1983.
- University of Houston, Houston, Texas Structural Engineering M.S. in 1986.
- University of Houston, Houston, Texas Structural Engineering Ph.D. in 1991.

## SUMMARY OF RESEARCH GRANTS AND THESIS SUPERVISED:
- Total research grants - $5,287,400 (total).

- Thesis supervised: Ph.D. - 5 completed plus 3 in progress.
- M.S. - 22 completed plus 3 in progress.

## RESEARCH INTERESTS:
- Analytical and experimental investigation of structural systems.
- Use of FRP composites for strengthening and rehabilitation of civil infrastructure.
- Smart structures and smart sensors as applied to civil engineering structures.

## SELECTIVE TECHNICAL PUPLICATIONS *(Total: over 90 publications, with **two** Award Papers)*

1. Myers, J.J., **Belarbi, A.**, and El-Domiaty, K.A., "Blast Resistance of Fiber Reinforced Polymer (FRP) Retrofitted Un-Reinforced Masonry (URM) Walls with and without Arching Action," The Masonry Society Journal (in press).

2. **Belarbi, A.,** and Greene, G.G., "Reinforced Concrete Box Girders Under Cyclic Torsion," <u>Proceedings of the 13<sup>th</sup> World Conference on Earthquake Engineering</u>, Vancouver, B.C., Canada, August 1-6, 2004, 15 pages. (Published in CDROM).

3. Mosallam, A. and **Belarbi, A. "**Strengthening and Repair Applications of Polymer Composites: A State-of-the-Art Review," Proceedings of the Ninth East Asia-Pacific Conference on Structural Engineering and Construction, Bali, Indonesia, December 16-18, 2003, pp. KS41-50. ***(Invited Paper and Keynote Presentation).***

4. "The Boumerdes, Algeria, Earthquake of May 21, 2003," An EERI Learning from Earthquakes Reconnaissance Report, Reported by Earthquake Engineering Research Institute, *Author of Chapter 4 and **Member** of the EERI Reconnaissance Team*, October 2003, 57 pages.

5. **Belarbi, A.** Watkins, S.E., Chandrashekhara, K., Corra, J., and Konz, B., "Smart Fiber-Reinforced Polymer Rods Featuring Improved Ductility and Health Monitoring Capabilities," Journal of Smart Materials and Structures, Vol. 10, No.3, June 2001, pp. 427-431.

## SYNERGISTIC ACTIVITIES
- Chairman of two national technical and educational committees and member of several others within the American Concrete Institute (ACI) and Transportation Research Board (TRB).
- Collaborator in the writing of several of state-of-the-art and other ACI documents.
- Research Investigator with UMR Intelligent Systems Center and coordinator of health monitoring of structural system research activities.

**<u>MINSU CHOI</u>**
Department of Electrical & Computer Engineering
University of Missouri - Rolla

**Current Position**
- Assistant Professor, 2002-Present, Department of Electrical & Computer Engineering, University of Missouri - Rolla (UMR).

**Education**
Oklahoma State University, Stillwater, OK.
- Ph.D. in Computer Science, 2002.
- M.S. in Computer Science, 2008.
- B.S. in Computer Science, 1995.

**Research Interests and Fields of Specialization**
- Computer Architecture and VLSI.
- Embedded Systems & Networks.
- Defect & Fault Tolerance.
- Testing, Quality Assurance and Reliability.
- Instrumentation and Measurement.
- Computational Nanotechnology.

**Systems Engineering Research Focus**
- Network Centric Systems, Systems Architecting, Distributed Systems Modeling, Network Centric Manufacturing and Control, Risk Modeling and Assessment, Modeling and Simulation.

**Research and Scholarly Production**
- Number of Archived Publications (Journals, Conference Proceedings, and Book Chapters): 42.
- Research funded by: NSF and UM Research Board.

**Five Recent Journal Publications**
1. Choi, M., Park, N., Lombardi, F. and Piuri, V., Reliability Measurement of Mass Storage System for Onboard Instrumentation, *IEEE Trans. on I&M.*, Vol. 54, No. 6, pp. 2297-2304, Dec 2005.
2. Park, N.-J., George, K.M., Park, N., Choi, M., Kim, Y.B. and Lombardi, F., Environmental-Based Characterization of SoC for Stratified Testing, *IEEE Trans. on I&M*, Vol. 54, No. 3, pp. 1241-1248, June 2005.
3. Choi, M., Park, N., Piuri, V., Kim, Y.B and Lombardi, F., Evaluating the Repair of System-on-Chip (SoC) Instrumentation using Connectivity, *IEEE Trans. on I&M*, Vol. 53, No. 6, pp. 1464-1472, Dec 2004.


4. Liu, B., Lombardi, F., Park, N. and Choi, M., Testing Layered Interconnection Networks, *IEEE Trans. on Computers*, Vol. 53, No. 6, pp. 710-722, June 2004.
5. Choi, M., Park, N., Piuri, V., Kim, Y.B. and Lombardi, F., Balanced Dual-Stage Repair for Dependable Embedded Memory Cores, *Journal of Systems Architecture*, Vol. 50, No. 5, pp. 281-285, April 2004.

**Miscellaneous (Professional Societies, Center Memberships, Fellowships, Awards, etc)**
- Program Committee Member of IEEE International Conference on Microelectronics Education.
- Program Committee Member of IEEE International Symposium on Defect and Fault Tolerance in VLSI Systems.
- Member of Sigma Xi, IEEE and Golden Key.
- Faculty Advisor of Korean Student Association of UMR.
- Chair, Vice Chair and Secretary/Treasurer of IEEE Rolla Subsection in 2005, 2004 and 2003, respectively.

## LOKESWARAPPA R. DHARANI
Department of Mechanical and Aerospace Engineering
University of Missouri-Rolla

**Current Position**
- Curators' Professor, Department of Mechanical and Aerospace Engineering.

**EDUCATION:**
- Ph.D., Engineering Mechanics, Clemson University of California, Clamson, SC, 1982.
- M.Sc., Aircraft Design, Cranfield Institute of Technology, Cranfield, U.K., 1975.
- M.Tech, Aerospace Engineering, Indian Institute of Technology, Kanpur, India, 1972.
- B.S.M.E., University of Mysore, Surathkal, India, 1970.

**PROFESSIONAL HISTORY:**
- 2004 – Present, Curators' Professor, University of Missouri-Rolla.
- 1992 – 2003 Professor, University of Missouri-Rolla.
- 1988 – Present, Senior Investigator, Materials Research Center, University of Missouri-Rolla.
- Associate Dean for Research & Graduate Affairs, University of Missouri-Rolla
- Associate Professor, University of Missouri-Rolla.
- Assistant Professor, University of Missouri-Rolla.
- Design Engineer, Stress and Fatigue Group, Hindustan Aeronautics Ltd., Bangalore India.

**SUMMARY OF RESEARCH GRANTS AND STUDENTS SUPERVISED:**
- Total research grants - $ 3,030,747 (total), $2,053,993 (Dharani's share).
- Students supervised - Ph.D. 16 completed, 3 in progress.
- M.S. - 31 completed, 2 in progress.
- Undergraduate Researchers - 22 completed.

**RESEARCH EXPERIENCE:**

- Development of a design methodology for laminated glazing subjected to low velocity impact.
- DEVELOPMENT OF A "COMPOSITE WOOD FLOOR" FOR TRUCK TRAILERS (US PATENTS 5,928,735 & 6,183,824 & MEXICAN PATENT 201793).
- Failure analysis of signal mast arms made of welded cold-formed steel elements. Development of failure predictive model for laminated glass subjected to missile impact.
- Development of hybrid ceramic matrix composites.
- Study of the effect of moisture and temperature on textile polymer matrix composites.
- Development of micromechanics models for sintering and failure of ceramic matrix composites.
- Study of the effect corners in FRP reinforced concrete structures.
- Development of non-asbestos friction materials for automotive brakes.

**Systems Engineering Research Focus:**
- Fracture Mechanics, Aerospace Structures, Fatigue and Failure Analysis, Composite Materials & Structures.

**Relevant List of Publications:**
1. Zhao Y, Dharani LR. 1994. Analysis of a Thin Film Sintering on a Rigid Substrate. Thin Solid Films. 245: 109-114.
2. Hong W, Dharani LR. 1994. Densification Rates of Ceramic Matrix Composites with Initial Matrix Inhomogeneity. Mater Manuf Proc. 9[5]: 869-883.
3. Hong W, Dharani LR. 1994. Analysis of Pressureless Sintering with Spherical, Ellipsoidal and Cylindrical Inclusions. J Mater Proc and Manuf Sci. 13[1]: 3-15.
4. Hong W, Dharani LR. 1995. Pressureless Sintering of a Ceramic Matrix with Multiple Rigid Inclusions: Finite Element Model. J Am Ceram Soc. 78[6]:1593-1600.
5. Dharani LR, Zhao, Hong W. 1995. Modeling of Constant Heating Rate Pressureless Sintering of Ceramic Matrix Composites. J Mater Proc Tech. 53[3-4]:617-629.

## XIAOPING DU
Department of Mechanical and Aerospace Engineering
University of Missouri – Rolla

**Research interest**
- Modeling and Simulation.
- Simulation based design under uncertainty.
- Nondeterministic design (reliability-based design, robust design, Design for Six Sigma, etc.).

- Multidisciplinary systems design.

**Professional Preparation**
- Shanghai Jiao Tong University, China, Mechanical Engineering, B. S., 07/1985.
- Chongqing University, China, Mechanical Engineering, M.S., 02/1992.
- University of Illinois at Chicago, Mechanical Engineering, Ph.D., 04/2002.

**Appointments**
- 11/2002–present, Assistant Professor, University of Missouri – Rolla.
- 04/2002–10/2002, Senior Design Engineer, Mechatronics, Michigan.
- 09/1998–08/2000, Visiting Scholar, University of Illinois at Chicago.
- 05/1998–08/1998, Visiting Scholar, University of Iowa.
- 07/1995–04/1998, Associate Professor, Southwest Petroleum University, China.
- 12/1986–09/1989, Instructor/Lecturer, Southwest Petroleum University, China.
- 07/1985–11/1986, Mechanical Engineer, Chengdu Construction Machinery Co, Ltd., China.

**Publications** (out of 55 papers)
1. Yu, X. and Du, X., "Reliability-Based Multidisciplinary Optimization for Aircraft Wing Design," in press, Structure and infrastructure Engineering, 2006.
2. Huang, B. and Du, X., "Uncertainty Analysis by Dimension Reduction Integration and Saddlepoint Approximations," ASME Journal of Mechanical Design, Vol. 128, No. 1, pp. 26-32, 2006.
3. Du, X., Sudjianto, A., and Huang, B., "Reliability-Based Design under the Mixture of Random and Interval Variables," ASME Journal of Mechanical Design, Vol. 127, No. 6, pp. 1068-1076, 2005.
4. Du, X. and Chen, W., "Collaborative Reliability Analysis under the Framework of Multidisciplinary Systems Design," Optimization and Engineering, Vol. 6, No.1, pp. 63-84, 2005.
5. Du, X., Sudjianto, A., and Chen, W., "An Integrated Framework for Optimization under Uncertainty Using Inverse Reliability Strategy," ASME Journal of Mechanical Design, Vol.126, No.4, pp. 561-764, 2004.
6. Du, X. and Sudjianto, A., "The First Order Saddlepoint Approximation for Reliability Analysis," AIAA Journal, Vol.42, No. 6, pp. 1199-1207, 2004.

**Grants**
- PI, Accounting for Reliability for Complex Engineering Systems Design, the National Science Foundation (NSF), $213,784, 06/01/2004-05/31/2007.
- PI, Integration of Probabilistic and Statistical Design Methods into Engineering Design Courses, NSF, $67,994, 02/15/2004-01/31/2007.

**Synergistic Activities**
- Investigator at UMR Intelligent Systems Center (since 2002).
- Reviewer: DMI, NSF (2003); Journal of Mechanical Design, AIAA Journal, etc.
- Member of Editorial Board of International Journal of Reliability and Safety.

- Member of ASME, AIAA, ASEE, and International Society for Structural and Multidisciplinary Optimization (ISSMO).
- Session chair for 5 professional conferences.

## KELVIN T. ERICKSON
Department of Electrical & Computer Engineering,
University of Missouri-Rolla

**PROFESSIONAL EXPERIENCE (Last Five Years):**
- 2003 – Present, Chairman, Department of Electrical & Computer Engineering.
- 2002 – 2003 Interim Chairman, Electrical & Computer Engineering.
- 2000 – Present, Professor, Electrical & Computer Engineering.
- 2000 – 2002 Assistant Chairman, Undergraduate Studies Electrical & Computer Engineering.
- 1992 – 2000 Assoc. Professor of Electrical Engineering, UMR.

**LAST DEGREE:**
- Ph.D.  1983, Iowa State University.

**RESEARCH INTERESTS**:
- Control system security, manufacturing automation, and plantwide process control.

**SYSTEMS ENGINEERING RESEARCH FOCUS:**
- Control Systems.

**TOTAL GRANTS GENERATED - $ 1,118,000.**

**NUMBER OF PUBLICATIONS – 37.**

**BOOK PUBLICATIONS:**
1. Erickson, K. T. and Hedrick, J. L., *Plantwide Process Control*, Wiley, 1999.
2. Erickson, K. T., *Progammable Logic Controllers: An Emphasis on Design and Application,* Dogwood Valley Press, 2005.

**BOOK CHAPTERS:**
1. Erickson, K. T, Stanek, E. Keith, Cetinkaya, E., Dunn-Norman, S., and Miller, A., "Reliability of SCADA Systems in Offshore Oil and Gas Platforms," *Stability and Control of Dynamical Systems with Applications*, Chapter 20, Birkhauser, Boston, MA, 2003, pp. 395-404.

**JOURNAL PUBLICATIONS:**
1. Bhaskar, Rajeev, Crow, M. L., Ludwig, E. M., Erickson, K. T., and Shan, K. S. "Nonlinear Parameter Estimation of Excitation Systems," *IEEE Transactions on Power Systems*, vol. 15, no. 4, Nov. 2000, pp. 1225-1231.

## KAKKATTUKUZHY M. ISAAC, PH. D.
Mechanical and Aerospace Engineering Department
University of Missouri-Rolla

**Professional Preparation**
- Indian Institute of Technology, Madras, India Aerospace Engineering B. Tech.
- Indian Institute of Technology, Madras, India Aerospace Engineering M.Tech.
- Virginia Polytechnic Institute and Aerospace Engineering Ph. D.

**Present Position**
- Professor University of Missouri-Rolla.

**Research Interests and Fields of Specialization**
- Fluid Dynamics, Aerodynamics.

**Systems Engineering Research Focus**
- Modeling and simulation.

**Significant publications**
1. **Isaac, K. M.**, Colozza, T., and Rolwes, J., "Force Measurements on a Flapping and Pitching Wing at Low Reynolds Numbers," AIAA-2006-450, (accepted) AIAA Aerospace Sciences Meeting, Jan. 2006.
2. **Isaac, K. M**., Shivaram, P. and DalBello, T., "Low Re, High Aerodynamics with Controlled Wing Kinematics," AIAA 2003-4019, 33rd Fluid Dynamics Conference and Exhibit, Orlando, June 2003.
3. **Lunia, A.,** Isaac, K. M., **Chandrashekhara, K., and Watkins, S., "Wind Tunnel Testing of a Smart Composite Wing using Fiber Optic Strain Sensing and Neural Network," Smart Materials and Structures, 9, (2000), 767-773.**
4. Shi, Y.-J., Miles, J. R. and **Isaac, K. M**., "Computational Fluid Dynamic Simulation of Inviscid and Viscous Waverider Flow fields with Sideslip," AIAA Journal of Spacecraft and Rockets Vol. 34, No. 1, Jan.-Feb. 1997, pp. 76-82.
5. Liao, J. R., **Isaac, K. M**., Miles, J. B., and Tsai, B. J. "Navier-Stokes Simulation of Cone-Derived Waverider," AIAA Journal, Vol. 30, No. 6, June 1992, pp. 1521- 1528.
6. Banerjee, R. and **Isaac, K. M.,** "An Algorithm to determine the Mass Transfer Rate from a Pure Liquid Surface using the Volume of Fluid Multiphase Model," International Journal of Engine Research, Vol. 5, No. 1, 2004, pp. 23-37.
7. Pellett, G. L., **Isaac, K. M**., Humphreys, W. M., Gartrell, L. R., Roberts, W. L., Dancey, C. L. and Northam, G. B., "Velocity and Thermal Structure, and Strain-Induced Extinction of 14 to 100% Hydrogen-Air Counterflow Diffusion Flames," Combustion and Flame, Vol. 112, No. 4, March 1998, pp. 575-592.
8. Banerjee, R., Isaac, K. M., Oliver, L. R. and Breig, W. F., "Features of Automotive Gas Tank Filler Pipe Flow: Experiments and CFD Simulations," ASME Journal of Engineering for Gas Turbine and Power, vol. 124, April 2002.
9. Johnston, A. P. and Isaac, K. M., "Spray Evolution of a Coflowing Round Liquid Jet in High Speed Air Flow," Atomization and Sprays, Vol. 11, No. 4, Jul.-Aug. 2001, pp. 305-316.

**K. KRISHNAMURTHY**

101 School of Engineering
University of Missouri-Rolla

## CURRENT POSITION
- Professor of Mechanical Engineering, Department of Mechanical and Aerospace Engineering.
- Associate Dean for Research and Graduate Affairs, School of Engineering.

**EDUCATION**
- Bangalore University, B.E.M.E., 1980.
- Washington State University, M.S.M.E., 1982; Ph.D., 1986.
- Ph.D. Thesis Advisor: Thomas D. Burton.
- Ph.D. Thesis: "Dynamics and Control of Flexible Robotic Manipulators".

## CURRENT RESEARCH INTEREST
- Advanced Manufacturing Processes, Intelligent Control, MEMS, Nanotechnology, Robotics.

## SYSTEMS ENGINEERING RESEARCH FOCUS
- Network Centric Manufacturing and Control.

## RESEARCH AND SCHOLARLY PRODUCTION.
- Total Research Grants and Contracts - 3.1 million dollars.
- Total Publications - 50-refereed journal and conference papers.

## FIVE RECENT JOURNAL PUBLICATIONS.
1. Stone, R. and K. Krishnamurthy, "A Neural Network Thrust Force Controller to Minimize Delamination During Drilling of Graphite-Epoxy Laminates," *Int. J. of Machine Tools and Manufacture,* 36(9), pp. 985-1003, 1996.
2. Luo, T., W. Lu, K. Krishnamurthy and B. McMillin, "A Neural Network Approach for Force and Contour Error Control in Multi-Dimensional End Milling Operations," *Int. J. of Machine Tools and Manufacture,* 38 (10-11), pp. 1343-1359, 1998.
3. Menon, K. and K. Krishnamurthy, "Control of Low Velocity Friction and Gear Backlash in a Machine Tool Feed Drive System," *Mechatronics,* Vol. 9, pp. 33-52. 1999.
4. Kulkarni, A., K. Krishnamurthy, S. Deshmukh and R. Mishra, "Microstructural Optimization of Alloys Using a Genetic Algorithm," *Materials Science and Engineering: A*, Vol. 372, Nos. 1-2, pp. 213-220, 2004.
5. Kukarni, A., K. Krishnamurthy, S. Deshmukh and R. Mishra, "Effect of Particle Size Distribution on Strength of Precipitation-Hardened Alloys," *Journal of Materials Research*, Vol. 19, No. 9, pp. 2765-2773, September 2004.

**PROFESSIONAL HONORS**

- Outstanding Teacher Award, University of Missouri-Rolla, 1990-91, 1993-94, 1996-97, 1997-98.
- Letter of Commendation – Teaching Excellence, University of Missouri-Rolla, 1988-89, 1989-90, 1994-95, 1995-96.
- Boeing – A. D. Welliver Faculty Summer Fellowship, 1999.
- School of Engineering Teaching Excellence Award, University of Missouri-Rolla, 2005.

**ROBERT G. LANDERS**
Department of Mechanical and Aerospace Engineering
University of Missouri–Rolla;

**Latest Degree**

- Ph.D. in Mechanical Engineering, 1997, University of Michigan, Ann Arbor, MI.

**Current Appointments**

- Assistant Professor, University of Missouri at Rolla (2000–present).Research Investigator, Intelligent Systems Center, University of Missouri at Rolla (2001–present).Associate Member, Center for Technology Enhanced Learning, UMR (March 2004–present).

- Faculty Member, Manufacturing Engineering Ed. Program, UMR (2000–present).

- Faculty Member, Systems Engineering Program, University of Missouri at Rolla (2001–present).

**Research**

- Dr. Landers' research interests are in the areas of modeling, analysis, monitoring, and control of manufacturing processes (specifically metal cutting, parallel machining, friction stir, laser metal deposition, rapid freeze prototyping, and freeze extrusion fabrication), control of tribological systems, simulation of complex manufacturing processes, and digital control applications. He has over fifty technical publications in these areas, including three book chapters.

**Awards**

- Dr. Landers received the UMR Faculty Excellence and Outstanding Teaching Awards in 2005, UMR School of Engineering Innovative Teaching Award in 2004, Society of Manufacturing Engineer's M. Eugene Merchant Outstanding Young Manufacturing Engineer Award in 2004, the Outstanding Paper Award (Third Place with Jinming Liu) at the 38th ASEE Midwest Section Meeting in 2003, and the UMR Academy of Mechanical and Aerospace Engineers Faculty Teaching Excellence Award in 2002.

**Funding**
- Dr. Landers has received over $600,000 in funding (based on percent credit) from the following sources: National Science Foundation, Air Force Research Laboratory, Society of Manufacturing Engineers, Missouri Research Board, and various companies.

**Systems Engineering Research Focuses**
- Network Centric Manufacturing and Control; Modeling and Simulation

**Five Representative Journal Publications**
1. Pandurangan, B., Landers, R.G., and Balakrishnan, S.N., 2005, "Hierarchical Optimal Force–Position Control of a Turning Process," IEEE Trans. on Control System Technology, Vol. 13, No. 2, pp. 321–327.
2. Liu, J. and Landers, R.G., 2005, "Modular Control Laboratory System with Integrated Simulation, Animation, Emulation, and Experimental Components," International Journal of Engineering Education, Vol. 21, No. 6, pp. 1005–1016.
3. Yelma, S., Miller, B., and Landers, R.G., 2004, "Automatic Feedback Control of Mechanical Gas Face Seals via Clearance Control," Tribology Transactions, Vol. 47, No. 4, pp. 500–507.
4. Sudhakara, R. and Landers, R.G., 2004, "Design and Analysis of Output Feedback Force Control in Parallel Turning," Proceedings of the Institution of Mechanical Engineers Part I – Journal of Systems and Control Engineering, Vol. 218, No. 6, pp. 487–501.
5. Kim, S.I., Landers, R.G., and Ulsoy, A.G., 2003 "Robust Machining Force Control with Process Compensation," ASME Journal of Manufacturing Science and Engineering, Vol. 125, No. 3, pp. 423–430.

## JENNIFER LEOPOLD
Department of Computer Science
University of Missouri - Rolla

**Current Position**
- Assistant Professor, Department of Computer Science University of Missouri - Rolla (UMR).

**Education**
- University of Kansas, Lawrence, Kansas, 66045.
- Ph.D. in Computer Science, 1999.
- M.S. in Computer Science, 1986.
- B.S. in Mathematics, 1981.

**Research Interests and Fields of Specialization**
- Bioinformatics, Scientific Visualization, Data Mining, Database Design and Analysis

**Systems Engineering Research Focus**

- Systems Engineering Process and Design, Distributed Systems Modeling, Modeling and Simulation, Computational Intelligence.

**Research and Scholarly Production**
- Number of Archived Publications (Journals, Conference Proceedings, and Book Chapters) - 18
- Total Research Funding - $4,842,011

**Five Recent Publications**

1. Sea and J. Leopold, "The Use of a Learning Management System to Support Competition, Collaboration, and Cooperation in the Classroom", *Proceedings of World Conference on Educational Multimedia, Hypermedia, and Telecommunications (ED-MEDIA 2006)*, Orlando, Florida, June 2006.

2. T. Rupe, J. Leopold, A. Maglia, and D. Tauritz, "Evolutionary Optimization of Filter Parameters for Image Segmentation", *Proceedings of 6$^{th}$ International Workshop on Frontiers in Evolutionary Algorithms,* Salt Lake City, Utah, July 21-26, 2005.

3. J. Leopold and R. Harankhedkar, "Re-Engineering of a Distributed Object Infrastructure for Heterogeneous Enterprise Computation of Continual Queries", *Proceedings of IASTED International Conference on WWW/Internet 2004 (ICWI 2004)*, Madrid, Spain, Vol. 2, Pedro T. Isaias, Nitya Karmakar, Luís Rodrigues, Patrícia Barbosa (editors), IADIS 2004, ISBN 972-99353-0-0, 2004, pp. 927-931.

4. G. Arya, J. Leopold, S. Kapila, Q. Chen, W. Rouse, and E. Black, "A Game Engine Application to Visualize Obscurant Cloud Transport and Diffusion, and Robotic Obscurant", *Proceedings of Huntsville Simulation Conference 2004 (Sponsored by the International Society of Modeling and Simulation),* Huntsville, Alabama, October 2004, (8 pages).

5. Maglia J. Leopold, and V. Ghatti, "Identifying Character Non-Independence in Phylogenetic Data Using Data Mining Techniques", *Proceedings of 2$^{nd}$ Asia-Pacific Bioinformatics Conference (APBC2004)*, Dunedin, New Zealand, Conferences in Research and Practice in Information Technology, Vol. 29, Yi-Ping Chen (editor), Australian Computer Society, Inc., 2004, pp. 181-189.

**Miscellaneous (Professional Societies, Center Memberships, Fellowships, Awards, etc)**
- Memberships in ACM, IEEE, Sigma Xi
- UMR Teaching Awards (4), UMR Faculty Excellence Award, UMR Outstanding Graduate Faculty Award

**FRANK LIOU**
Mechanical and Aerospace Engineering Department
University of Missouri-Rolla

**PROFESSIONAL EXPERIENCE (Last Five Years):**

- 2000- Present, Director, Interdisciplinary Manufacturing Engineering Program, University of Missouri-Rolla, Rolla, Missouri.
- 1999- Present, Professor of Mechanical Engineering, Director of LAMP (Laser Aided Manufacturing Processes) Laboratory, University of Missouri-Rolla, Rolla, Missouri.

## LAST DEGREE:
- Ph.D. (M.E.)   University of Minnesota, Minneapolis, 1987.

## RESEARCH INTERESTS:
- CAD/CAM:   CAD/CAM Integration, Rapid Product Realization, Virtual Manufacturing, Rapid Prototyping, Concurrent Engineering.
- Manufacturing Automation: Flexible   Assembly/Manufacturing   Systems, Flexible Fixture, Manufacturing Workcell Development, System Optimization.

## SYSTEMS ENGINEERING RESEARCH FOCUS
- Network Centric Manufacturing and Control.
- Modeling and Simulation.

## TOTAL GRANTS GENERATED - over $7M

## NUMBER OF ACHIEVABLE PUBLICATIONS - over 100

## REPRESENTATIVE JOURNAL PAPERS:
1. C.P. Huang, S. Agarwal, F. W. Liou, "Calibration, Registration, and Preparation of an Augmented Reality Environment for Virtual Prototyping of Dynamic Systems," Journal of Advanced Manufacturing Systems.  Vol. 1 No. 1, pp. 19-36, 2002.
2.  Jun Zhang and F.W. Liou, "Adaptive Slicing for A Multi-axis Laser Aided Manufacturing Process," *ASME Journal of Mechanical Design, Vol. 126, pp 254-261, March 2004*.
3. Vinay Kadekar, Weiya Fang and Frank Liou, "Deposition Technologies for Micro-Manufacturing -A Review," ASME Journal of Manufacturing Science and Engineering, November 2004, Volume 126, Issue 4, pp. 787-795.
4. Heng Pan and Frank Liou, "Numerical Simulation of Metallic Powder Flow in a Coaxial Nozzle for the Laser Aided Deposition Process," Journal of Materials Processing Tech., Volume 168, Issue 2 , 30 September 2005, Pages 230-244
5. J. Ruan, K. Eiamsa-ard, and F. Liou, "Automatic Process Planning and Toolpath Generation of a Multi-Axis Hybrid Manufacturing System," SME Journal of Manufacturing Processes, Vol 7, No. 1, pp. 57-68, 2005.

## MISCELLANEOUS:
-  Associate Editor (2001-Present), SME Journal of Manufacturing Systems
- Associate Editor (2000- Present), Mechanism and Machine Theory.

**XIAOQING (FRANK) LIU**
Department of Computer Science
University of Missouri – Rolla

## PROFESSIONAL PREPARATION

- Ph.D. in computer science, Texas A&M University, College Station, Texas, August 1995.
- M.S. in computer science, Southeast University, Nanjing, China, May 1985.
- B.S. in computer science, Changsha Institute of Technology, Changsha, China, August 1982.

## EMPLOYMENT RECORD

- 8/01 – Present, Associate Professor, Computer Science Department, University of Missouri-Rolla.
- 9/00 – 8/01: Associate Professor, Computer Science Department, Texas Tech University, I had been on leave from University of Missouri at Rolla.
- 8/95 – 8/01: Assistant Professor, Department of Computer Science, University of Missouri at Rolla, Rolla, Missouri.

## RESEARCH AREAS

- Systems Architecting, Systems Engineering Process and Design

## SELECTED PUBLICATIONS (OUT OF 54 PUBLICATIONS)

1. Xiaoqing (Frank) Liu, "A Quantitative Approach for Assessing the Priorities of Software Quality Requirements," Journal of Systems and Software, 42(8): 105-113, 1998.
2. Xiaoqing Frank Liu, Ruoqian Jia, and Ravi Viswanathan, "An Intelligent Tool for Analysis of Imprecise Software Quality Requirements from Different Perspectives," *International Journal of Concurrent Engineering: Research and Application (CERA)*, 6(3), 1998.
3. Hsin-Chi Chang, Xiaoqing Frank Liu, and Wen F. Lu, "A WWW Based Collaborative System for Integrated Design and Manufacturing," International Journal of Concurrent Engineering: Research and Application (CERA), 7 (4): 319-334, December 1999.
4. Liu, X. F., S. and S. Sigman, "A Computational Argumentation Methodology for Capturing and Analyzing Design Rationale Arising from Multiple Perspectives," International Journal of Information and Software Technology, 45(3), March 2003.
5. Xiaoqing (Frank) Liu, Chandra Sekhar Veera, Yan Sun, Kunio Noguchi, and Yuji Kyoya, "Priority Assessment of Software Requirements from Multiple Perspectives", Proc. of IEEE International Conference on Computer Software and Applications, Hongkong, Oct., 2004.
6. X. F. Liu, K. Noguchi, A. Dhungana, V. Sriranggam, and P. Inuganti, "Technical Target Setting based on Impact Analysis in Software Quality Function

Deployment", accepted for publication in the proc. of the 3rd World Congress on Software Quality, to be held in Munich, Germany, September 26-30, 2005.

## SYNERGISTIC ACTIVITIES

- Director of McDonnel Douglas Foundation Software Engineering Laboratory, Department of Computer Science, University of Missouri at Rolla, Rolla, Missouri.
- Have served as members of program committees of many international conferences, as a vice chairman of the program committee for the international conference on software engineering and knowledge engineering held in Chicago in 2000, will serve as a panelist for the 29th International Computer Software and Applications Conference in Edinburgh, Scotland in July.
- Have performed a number of sponsored projects. Here is a partial list of projects.
- Integrated Analysis of non-functional and functional requirements for requirements Transformation, $52,000, Toshiba Corporation, Sole Principal investigator, 7/1/2005-  3/31/2006, shared credit: 100%.
- Interconnected Laboratory Scale FACTS Devices, $1,270,391, Sandia National Laboratory, Co-Principal Investigator, PI: Mariesa Crow, 04/18/05-04/30/06, Shared credit 12%.
- MRI – Construction of a Laboratory to Study FACTS Device Interactions, $300,000, National Science Foundation, Co-Principal Investigator, PI: Bruce McMillin, 9/1/2004-8/30/2007, Shared credit 33%.
- Development of Software Volatility Metrics Risk Assessment, $42,620, Toshiba Corporation, 7/1/2004-3/30/2005, shared credit 100%.
- Advances in FACTS and Energy Storage, $303,363, Sandia National Laboratory, Co-Principal Investigator, PI: Mariesa Crow and Bruce McMillin, 5/1/2004-4/15/2005, shared credit: 33%.
- IGERT: Variable Speed Electromechanical Drive Systems, National Science Foundation, $2,698,626, Co-Principal Investigator, PI: Mariesa Crow, 8/1/1999-/7/30/2005.
- Development of a Virtual and Augmented Reality System for Research in Intelligent Design and Manufacturing, National Science Foundation, $441,401, Co-Principal Investigator, PI: Ming Lu, 9/1/2000-8/30/2003.
- Research and Development in Time-stamped Quality Function Deployment, $30,000, Toshiba Corporation and University of Missouri-Rolla, Sole Principal investigator, 8/1/2001-3/31/2002.
- Transformation and Analysis of Customer Requirements to Improve Customer Satisfaction, $44,030, Toshiba Corporation and Texas Tech University, Sole Principal investigator, 9/1/2000-3/31/2001.
- A Responsive Process Planning System in Agile Manufacturing Using Case-based Reasoning Approach, National Science Foundation and MRTC, $140,789, Co-principal investigator, (PI: Dr. Wen Lu), 9/1/1996-8/30/1998.

## SANJAY MADRIA
Department of Computer Science

University of Missouri - Rolla

**Current Position**
- Since 2000 - Assistant Professor, Department of Computer Science University of Missouri - Rolla (UMR)

**Education**
- Ph.D. Computer Science, Institute - Indian Institute of Technology, New Delhi, India

**Research Interests**
- Web Warehousing and XML, Web Mining, P2P Data Management, Mobile Databases, Sensor Networks and Security.

**Systems Engineering Research Focus**
- Network Centric and Distributed Computing.

**Research and Scholarly Production**
- Number of Archived Publications (Journals, Conference Proceedings, and Book Chapters): 100+.
- Total Research Funding Involved: $800K.

**Five Recent Journal Publications**
1. C. K. Lee, Wang-Chien Lee and Sanjay Madria, Pervasive Data Access in Wireless and Mobile Computing Environments, to appear in Wireless Communications & Mobile Computing (WCMC) Journal, 2006.
2. A. Rapaka, Sanjay Madria, Two Energy Efficient Algorithms for Tracking Objects in a Sensor Network, to appear in Wireless Communications & Mobile Computing (WCMC) Journal, 2006.
3. Q Zhao, Ling Chen, S S Bhowmick, S K Madria, XML Structural Delta Mining: Issues and Challenges, To appear in Data and Knowledge Engineering Journal (DKE), Elsevier Science, 2006.
4. Y. Chen, S. K. Madria, K. Passi, S. Bhowmick, Efficient Processing of XPath Queries using Indexes, Information Systems, 2006.
5. Deja Hepziba Francis, Sanjay Madria and Chaman Sabharwal, MODIS: A Moving Object Database Interface System, Journal of Networking and Information Systems, Vol.2, No.5, 2005.

**Miscellaneous (Professional Societies, Book, Awards, etc)**
- IEEE Senior Member.
- DEXA Achievement Award for Web and E-commerce Research Contributions.
- Outstanding Teaching Award by Dean, School of Distance Education, UMR.
- *Book* – Sourav Bhowmick, Sanjay Madria, and Wee Keong Ng**,** Web Data Management: A Warehouse Approach, Nov. 2003, Springer-Verlag.
- **Guest Editor:** Data and Knowledge Engineering, WWW Journal.

- Program Chair and C-chair, PC members and Editorial Board member in Journal and Conferences.
- External PhD thesis examiner of universities in Australia, Singapore, and India.
- Keynote and Invited speaker in many conferences and universities around the world.

## JOHN J. MYERS, PH.D., P.E.
Department of Civil, Architectural, and Environmental Engr.
University of Missouri-Rolla

### EDUCATION:
- The Pennsylvania State University; Univ. Park, PA Architectural Engineering.
- B.S. in 1987 University of Texas-Austin, Austin, Texas Structural Engineering.
- M.S. in 1994 University of Texas-Austin, Austin, Texas Structural Engineering Ph.D. in 1998

### PROFESSIONAL HISTORY:
- Sept. 2005 - present - University of Missouri-Rolla; Associate Professor.
- Mar. 1999 - Aug. 2005 - University of Missouri-Rolla; Assistant Professor.
- April 1994 – Mar. 1999 - Structural Project Engineer/Manager, José I. Guerra, Inc., Austin, TX.
- April 1991 - Aug. 1992 Structural Engineer, LPJ Inc., Baltimore, MD.
- June 1987 - April 1991 Structural Design & Project Engineer, RTKL Associates, Inc., Baltimore, MD.

### HONORS AND AWARDS (most recent awards):
- Honorable Mention of the 9NAMC Outstanding Paper Award, The Masonry Society, 2003.
- *One* Outstanding Student Advising Award, MSM-UMR Alumni Association (2004).
- *Four* Faculty Excellence Awards, University of Missouri-Rolla (2001-2004).
- *One* Outstanding Teaching Awards, University of Missouri-Rolla, (2005).
- *Three* Who's Who Among America's Teachers®, (2001, 2004,and 2005).
- Dwight D. Eisenhower Faculty Fellowship (2004).

### SUMMARY OF RESEARCH GRANTS AND THESIS SUPERVISED:
- Total research grants: $5,497,426 (total); $1,235,655 (Myers's credit).
- Thesis supervised: Ph.D.: 3 completed plus 1 in progress.
- M.S.: 13 completed plus 6 in progress.
- Visiting Scholars Hosted/Advised: 9 completed plus 1 in progress.

### RESEARCH INTERESTS:
- cementitious-based material development including high performance concrete (HPC) behavior and durability performance; microstructure analysis of cement-

based materials; use of FRP composites for repair / strengthening of RC, PC, and masonry structures including their durability performance.

**RECENT TECHNICAL PAPERS** (5 recent out of over 60 publications, with **two Award Papers**)

1. Carney, P., **Myers, J.J.,** *"Static and Blast Resistance of Unreinforced Masonry Wall Connections Strengthened with Fiber Reinforced Polymers,"* American Concrete Institute-Special Publication, In Press, to appear in print November 2005.
2. Ekenel, M., **Myers, J.J.,** *"Durability Performance of Bridge Concretes, Part I: High Performance Concrete (HPC),"* Journal of ASTM International (JAI), West Conshohocken, PA, Submitted September 2004, Volume 2, Issue 7, July/August 2005, 14 pages.
3. Ekenel, M., **Myers, J.J.,** *"Durability Performance of Bridge Concretes, Part II: High Strength Concrete (HSC),"* Journal of ASTM International (JAI), West Conshohocken, PA, Volume 2, Issue 7, July/August 2005, 12 pages.
4. Yang, Y., **Myers, J.J.,** *"Prestress Loss Measurements in Missouri's First Fully Instrumented HPC Bridge,"* National Research Council, 2005 TRB 84th Annual Meeting, Transportation Research Record – Journal of the Transportation Research Board, Washington D.C., Submitted August 2004, In Press to appear in print October 2005.
5. Akuthot, B., Hughes, D., Zoughi, R., **Myers, J.J.** Nanni, A., *"Near-Field Microwave Detection of Disbond in Fiber Reinforced Polymer Composites Used for Strengthening Concrete Structures and Disbond Repair Verification,"* American Society of Civil Engineering – Journal of Materials in Civil Engineering, November/December 2004, pp 540-546.

**SYNERGISTIC ACTIVITIES**

- Chairman of two & secretary of two national technical and educational committees, and member of several others within the American Concrete Institute (ACI) and Transportation Research Board (TRB).
- Collaborator in the writing of several of state-of-the-art and other ACI documents.
- Organizer/coordinator of UMR-ArchE Dept. introduction to engineering course for junior students in high school (3 weeks/summer).
- Advisor to UMR Concrete Canoe Team, UMR Architectural Engineering Institute and UMR-PCI Big Beam Competition Team.

## DR. ANTONIO NANNI
Department of Civil Engineering
University of Missouri—Rolla

### CURRENT POSITION

- Endowed Chair Professor, Department of Civil Engineering
- Founding Director, Center for Infrastructure Engineering Studies (CIES)
- University of Missouri—Rolla (UMR)

## EDUCATION
- Ph.D. in Civil Engineering, May 1985, Univ. of Miami, Coral Gables, FL.
- M.S. in Civil Engineering, Dec. 1980, Univ. of Witwatersrand, Johannesburg, South Africa.
- B.S. Magna cum laude in Civil Engineering, Minor in Construction of Transport Facilities, Dec. 1978, Univ. of Bologna, Bologna, Italy.

## RESEARCH INTERESTS
- Civil infrastructure renewal including construction materials, their structural performance, and field application.

## SYSTEMS ENGINEERING RESEARCH FOCUS
- Structures

## RESEARCH AND SCHOLARLY PRODUCTION
- Articles published in refereed journals - 131.
- Articles published in refereed proceedings – 209.
- Total Research Funding: $26,570,362.

## FIVE RECENT JOURNAL PUBLICATIONS
1. Lopez, A. and A. Nanni, "Composite Technology Evaluation," Concrete International: Design and Construction, Vol. 28, No. 1, Jan. 2006, pp. 74-80.
2. Galati, N., A. Nanni, L.R. Dharani, F. Focacci and M.A. Aiello "Thermal Effects on Bond between FRP Rears and Concrete," Composites Part A: Applied Science and Manufacturing, Vol. ?, No. ?, Nov. 2005 (available online).
3. Barton, B., E. Wobbe, L. R. Dharani, P. Silva, V. Birman, A. Nanni, T. Alkhrdaji, J. Thomas, and G. Tunis, "Characterization of RC Beams Strengthened by Steel Reinforced Polymer and Grout (SRP & SRG) Composites," Materials Science and Engineering A, Vol. ?, No. ?, Nov. 2005, (available online).
4. Li, T., N. Galati, J.G., Tumialan, and A. Nanni, "FRP Strengthening of URM Walls with Openings - Experimental Results," TMS Journal, Vol. 23, No. 1, December 2005, pp. 47-57.
5. Li, T., N. Galati, J.G., Tumialan, and A. Nanni, "FRP Strengthening of URM Walls with Openings - Numerical Analysis and Design," TMS Journal, Vol. 23, No. 1, December 2005, pp. 59-72.

## MISCELLANEOUS
- Member, Advisory Board, International Institute for FRP in Construction (IIFC) Newsletter, 2004-present.
- Member, Editorial Board, Advances in Structural Engineering – An International Journal, 2003-present.
- Editor-in-Chief, Journal of Materials in Civil Engineering, ASCE, June 1999-present.
- Recipient, 2005 ACI Chapter Activity Award, American Concrete Institute.
- Recipient, 2005 President's Award for Research and Creativity, University of Missouri – System.

- Founding Member, International Institute for FRP in Construction (IIFC) (No. M04018), 2003-present.
- Fellow, American Society of Civil Engineers, 1985-present.

## VON L. RICHARDS
Department of Materials Science and Engineering
University of Missouri-Rolla

**Current Position**
- Associate Professor, Metallurgical Engineering.
- Wolf Professor of Metals Casting.

**Education**
- Ph.D. in Engineering Materials from University of Michigan Ann Arbor, 1982.
- M.S. degree in Metallurgical Engineering from University of Wisconsin, Madison in 1971.
- B.S. Degree from General Motors Institute in 1969.

**Research Interests and Fields of Specialization**
- Metals casting, materials processing, physical metallurgy of casting alloys, interactions of metals and other materials during melting and casting.

**Systems Engineering Research Focus**
- Network Centric Manufacturing and Control; Structures

**Research and Scholarly Production**
- Number of Archived Publications (Journals, Conference Proceedings, and Book Chapters): 56.
- Total Research Funding: $1,560,000.

**Five Recent Journal Publications**
1. Composition Effects on Age Strengthening of Gray Iron, Von L Richards, Thottathil V. Anish, Simon Lekakh, Wayne, Nicola, and David C. Van Aken, Accepted by Transactions of AFS.
2. An Investigation of the Causes that Lead to Burn-in/Burn-on in Heavy Section Steel Castings, B.L. Kruse, V.L. Richards, P. D. Jackson, Accepted for Publication in AFS Transactions, paper number **06-035.**
3. Curing Kinetics of Ceramic Slurries Used in Investment Casting With Ice Patterns, Qingbin Liu, Von L. Richards, Kevin P. Daut and Ming C. Leu, accepted for publication by International Journal of Cast Metals Research.
4. Design of a Foundry Size Ladle Metallurgy Vessel: Ferromanganese Dissolution Kinetics, V. Richards, D. Weber, and K. Peaslee, AFS Transactions 2005.
5. Age Strengthening of Gray Cast Iron, Von L. Richards, D.C. Van Aken, and Wayne Nicola, International Journal of Cast Metals Research, 2003, Vol. 16, Nos. 1-3, p. 275-280.

**Miscellaneous Awards**
- 2005 AFS Cast Iron Division Best Paper Award for 2004 Casting Congress.
- 2004 SOMEER Award for Most Improved Laboratory Teaching.
- 2004 "Boots" Clayton Award for teachers who are most concerned about students – UMR Metallurgical Engineering Department Seniors.
- 2002 AFS Howard Taylor Award for the technical paper with the greatest long term technical impact on the metals casting industry.
- 2001 AFS/FEF Board Award for FEF Key Professors.
- 2001 Tri-State University Barrenbrugge Award for Faculty Excellence.
- 1999 Tri-State University Senior Class teaching award.

## R. JOE STANLEY
Department of Electrical and Computer Engineering
University of Missouri - Rolla

**Current Position**
- Associate Professor, Department of Electrical and Computer Engineering University of Missouri - Rolla (UMR)

**Education**
University of Missouri - Columbia (UMC), Columbia, MO
- Ph.D. in Computer Engineering and Computer Science, 1994-1998, National Cancer Institute Predoctoral Fellow
- M.S. in Electrical Engineering, 1993-1994, National Library of Medicine Predoctoral Fellow
- B.S. in Electrical Engineering, 1987-1992, Summa Cum Laude

**Research Interests and Fields of Specialization**
- Image and signal processing (Medical imaging, Non-destructive evaluation, Humanitarian demining, Medical Informatics, Bioinformatics)
- Pattern recognition (Data fusion, Distributed system security)

**Systems Engineering Research Focus**
- Computational Intelligence, Network Centric Systems

**Research and Scholarly Production**
- Number of Archived Publications (Journals, Conference Proceedings, and Book Chapters): 39.
- Total Research Funding: - $2,025,628.

**Five Recent Journal Publications**
1. W.V. Stoecker, K. Gupta, R.J. Stanley, R.H. Moss, B. Shrestha, "Detection of asymmetric blotches (asymmetric structureless areas) in dermoscopy images of malignant melanoma using relative color," Skin Research and Technology, vol. 11, 179-184, 2005.

2. B. Erkol, R.H. Moss, R.J. Stanley, W.V. Stoecker, E. Hvatum, "Automatic lesion boundary detection in dermoscopy images using gradient vector flow snakes," Skin Research and Technology, vol. 11, no. 1, pp. 17-26, 2005.
3. P. Chamarthy, R.J. Stanley, R. Long, S. Antani, G. Thoma, "Image analysis techniques for characterizing disc space narrowing in cervical vertebrae interfaces," Computerized Medical Imaging and Graphics, vol. 28, pp. 39-50, 2004.
4. D. Beetner, R.J. Stanley, S. Agarwal, D.R. Somasundaram, K. Nema, B. Mantha, "Landmine detection and discrimination using high-pressure waterjets," EURASIP Journal of Applied Signal Processing, vol. 13, pp. 1973-1984, 2004.
5. R.J. Stanley, S.E. Watkins, A. Gopal, R.H. Moss, "A web-sharable real-world imaging problem for enhancing an image processing curriculum," IEEE Transactions on Education, vol. 47, no. 2, pp. 211-219, 2004.

**Miscellaneous (Professional Societies, Center Memberships, Fellowships, Awards, etc)**
- Member of Four Professional Societies.
- Two UMR School of Engineering Teaching Excellence Awards, One UMR Outstanding Teaching Award.
- Co-Coordinator, Students Ethics Competition, 2003 ASEE Conference, Rolla, MO.
- Local Arrangements Chairman, The International Conference on Fuzzy Systems (FUZZ-IEEE), St. Louis, MO, May 2003.

## GANESH KUMAR VENAYAGAMOORTHY
Department of Electrical and Computer
University of Missouri-Rolla

**Current Position**
- Assistant Professor of Department of Electrical and Computer Engineering & Dir*ector* of Real-Time Power and Intelligent Systems Laboratory

**Education**
- PhD in Electrical Engineering, February 2002, University of Natal, Durban, South Africa.
- MScEng in Electrical Engineering, April 1999, University of Natal, Durban, South Africa.
- BEng (First Class Honors) in Electrical and Electronics Engineering March 1994, Abubakar Tafawa Balewa University, Bauchi, Nigeria.

**Research Interests**
- Computational Intelligence.
- Intelligent Control Systems.
- Power Systems.
- Evolvable Hardware.
- Signal Processing.

**Systems Engineering Research Focus**
- Computational Intelligence, Modeling and Simulation

**Research and Scholarly Production**
- Number of Archived Publications (Journals, Conference Proceedings, Edited Books and Book Chapters)- **149**.
- Total Research Funding - **$1.8 M.**

**Five Recent Journal Publications**
1. Cai X, Zhang N, **Venayagamoorthy GK**, Wunsch DC, "Time Series Prediction with Recurrent Neural Networks Trained by a Hybrid PSO-EA Algorithm", *Neurocomputing*, in press.
2. Park Jung-Wook, Harley RG, **Venayagamoorthy GK**, "MLP/RBF Neural Networks Based On-Line Global Model Identification of Synchronous Generator", *IEEE Transactions on Industrial Electronics*, vol. 52, Issue 6, December 2005, pp. 1685 - 1695.
3. **Venayagamoorthy GK**, Singhal G, "Comparison of Quantum-Inspired Evolutionary Algorithms and Binary Particle Swarm Optimization for Training MLP and SRN Neural Networks, *Journal of Computational and Theoretical Nanoscience*, vol. 2, no. 4., pp. 561 - 568.
4. Liu W, **Venayagamoorthy GK**, Wunsch DC, "A Heuristic Dynamic Programming based Power System Stabilizer for a Turbogenerator in a Single Machine Power System", *IEEE Transactions in Industry Applications*, vol. 41, no.5, September 2005, pp. 1377 - 1385.
5. **Venayagamoorthy GK**, Harley RG, Wunsch DC, "Implementation of Adaptive Critic Based Neurocontrollers for Turbogenerators in a Multimachine Power System", *IEEE Transactions on Neural Networks*, vol. 14, no. 5, September 2003, pp. 1047 - 1064.

**Miscellaneous (Professional Societies, Center Memberships, Fellowships, Awards, etc)**
- Senior Member (from August 2002) - Institute of Electrical and Electronics Engineering (IEEE) USA – Member of 4 societies.
- Senior Member - South African Institute of Electrical Engineers (SAIEE).
- MIEE, Member of Institute of Electrical Engineers (UK).
- Member - International Neural Network Society (INNS).
- Member - American Society for Engineering Education (ASEE).
- Associate Editor, IEEE Transactions on Neural Networks.
- Chair - IEEE Computational Intelligence Society & IEEE Industry Applications Society St. Louis Chapters.
- Secretary - IEEE PES PSACE Intelligent Systems subcommittee & Chair - IEEE PES Intelligent Control Systems Task Force.
- Investigator, Intelligent Systems Center, University of Missouri-Rolla, USA.

**YING ZHAO**

Department of Computer Science

University of Missouri-Rolla

**Current Position**
- Assistant professor, Department of Computer Science University of Missouri-Rolla

**Education**
- University of Minnesota, Minneapolis, Minnesota Ph.D**.** in Computer Science and Bioinformatics, 2005
- Peking University, Beijing, China B.S. in Computer Science, 1999

**Research Interests**
- Data mining (high-dimensional data clustering, semi-supervised learning)
- Bioinformatics (computational biology, protein structure prediction, modif prediction)
- Information Retrieval (term-weighting scheme, information abstraction)

**Systems Engineering Research Focus**
- Computational Intelligence

**Research and Scholarly Production**
- Number of Archived Publications (Journals, Conference Proceedings, and Book Chapters): 17.

**Five Recent Journal Publications**
1. "*Data Clustering in Life Sciences*".  Ying Zhao and George Karypis. Molecular Biotechnology, 31(1): 055-080, September, 2005.
2. "*Prediction of Contact Maps Using Support Vector Machines".*  Ying Zhao and George Karypis.  International Journal of Artificial Intelligence Tools (IJAIT), 14(5): 849-865, October, 2005.
3. "*Hierarchical Clustering Algorithms for Document Datasets*".  Ying Zhao and George Karypis.  Data Mining and Knowledge Discovery, 10 (2): 141-168, March 2005.
4. "*Empirical and Theoretical Comparisons of Selected Criterion Functions for Document Clustering*".  Ying Zhao and George Karypis.  Machine Learning, **55** (3): 311-331, 2004.
5. "*An Approximation Scheme for the Rectilinear Steiner Minimum Tree in Presence of Obstructions*".  Manki Min, Scott C.-H.  Huang, Jian Liu, Eugene Shragowitz, Weili Wu, Yiyuan Zhao and Ying Zhao.  Novel Approaches to Hard Discrete Optimization, Fields Institute Communications Series, 37: 155-163, 2003.