

**HEALTH CARE DELIVERY:
PROCESS IMPROVEMENT**

PROPOSALS FOR NEW INVESTMENT IN FACULTY HIRING

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1. BACKGROUND AND MOTIVATION

Faculty in the School of Nursing, Department of Mechanical and Industrial Engineering, and Department of Computer Science are proposing a set of cluster hires in the area of health care delivery focusing on process improvement. By filling four areas of critical need, this interdisciplinary team will have the full range of expertise necessary to identify, analyze, and improve complex health care processes - at both macro and micro levels. These areas of critical need include: a *macroergonomist* and a *software and systems engineer* to address the interaction between policies, individuals, processes and technology, a *behavioral decision maker* to predict how the various human agents in the health care system will respond to changes in policies and processes, and a *clinical teamwork and communication expert* to study the human network of clinical care providers and their interactions, on which the delivery of health care relies.

The United States spends more money on health care per capita than any other advanced industrialized nation (Reinhardt, Hussey, Anderson, 2004). Yet, it performs more poorly than most on key measures of health care quality (Blendon et al., 2004). The Centers for Disease Control and Prevention estimate that two million patients suffer hospital acquired infections each year. The Institute of Medicine (IOM) estimates that as many as 98,000 people die each year in US hospitals due to preventable medical injuries (Kohn, Corrigan, and Donaldson, 2000). A report jointly commissioned by the National Academy of Engineering and the IOM indicates that the ***great majority*** of the medical errors that harm patients ***can be traced back to poorly designed processes*** in the larger health care system (Kohn, Corrigan and Donaldson, 2000).

Not only do poorly designed processes impact quality and safety, but they radically affect the costs of health care delivery. Recent analyses have indicated wide variations in the amount spent to treat the same illness among Medicare patients (Fisher, Berwick and Davis, 2009). For example, the cost of providing health care to seniors is rising more than twice as fast in Dallas as in San Diego, and Medicare now spends nearly three times more to care for its enrollees in Miami than it does in Honolulu. Changes to the health care delivery system are clearly required. The IOM (Kohn, Corrigan and Donaldson, 2000) described four interrelated levels of health care quality that must be aligned for positive changes: (1) the aims to achieve better care, health, and costs, (2) the *design of the care processes* (at the micro- and macro-levels) that affect the patient, (3) the health care organizations that house almost all clinical microsystems and can ensure coordination among them, and (4) the environment which includes the payment, regulatory, legal and educational systems. These ***health care processes*** that are “famously unreliable, variable in costs, and often unsafe” (Fisher, Berwick and Davis, 2009), ***are at the heart of*** the disparity in the spending on Medicare patients, and are generally ***the cause of greatly inflated costs in the health care system***.

The nation must reduce health care costs and at the same time improve quality. These objectives require an approach that focuses on systematically and incrementally improving processes, from micro processes that include communication among caregivers and between caregivers and patients to the macro processes that include a system of policies, incentives, procedures, human capital, and equipment. The solutions to these problems will not come easily. There are hard and important questions about how to define, measure, analyze and model complex processes, how to generate less costly and better quality processes,

how to safely and effectively implement improvements based on these analyses and models, and how to validate process models against processes as actually practiced. The answers necessitate interdisciplinary and transdisciplinary knowledge of the science of nursing, operations research, systems engineering, human factors, information technology, and economics.

The cluster hire we are proposing in “Health Care Delivery: Process Improvement” builds on existing faculty expertise in the College of Engineering, School of Nursing and Department of Computer Science. This proposal brings together a uniquely qualified team with a broad and deep core of research competence in health care process improvement. This excellence is evidenced by the multiple grants from major funding agencies, such as the National Institutes of Health and the National Science Foundation, and by the stellar publication records of the faculty involved. Health care process improvement has caught the attention of the President, House and Senate and, as part of general health care delivery, should enjoy very healthy increases in research spending (New York Times, June 9). However, in order to take full advantage of the upcoming opportunities to meet this increasingly competitive challenge, the University needs to expand its core health care delivery faculty. In this proposal, we describe how the hiring of key individuals would give the health care delivery cluster a significantly fuller range of expertise that will enable it to address a still broader spectrum of the critical scientific problems whose answers will most certainly improve the processes that impact health care costs and quality.

2. PROVEN EXCELLENCE OF THE AMHERST CAMPUS IN THE GIVEN RESEARCH/TEACHING AREA

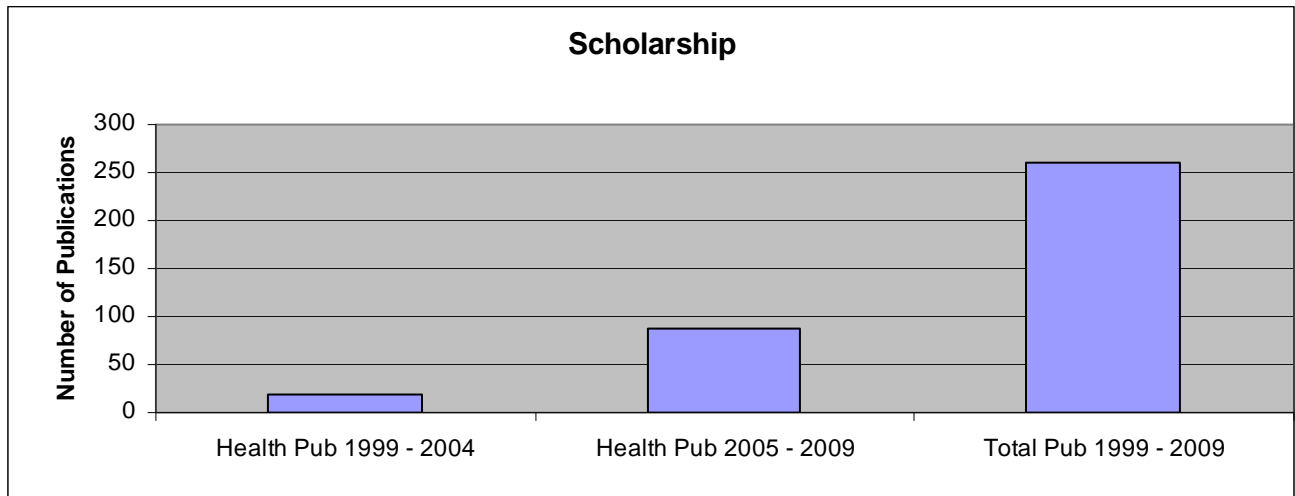
The cluster faculty have a strong record of scholarship and funding. The upward trajectory of funding in health care over just the past five years has been rapid. The cluster faculty have a longstanding record of interdisciplinary collaboration already (over 60 such interdisciplinary projects among various subsets of the core faculty in just the last 10 years, 15 in health care alone) and expect the trajectory of scholarship and funding to turn upwards even more rapidly. Core faculty in the cluster and their departments are listed below (Table 1):

Table 1. Core Faculty

IE	ME	Computer Science	Nursing
Baker	Krishnamurty	Clarke	Henneman
Balasubramanian		Gruppen	
Fisher		Osterweil	
Marquard			
Muriel			
Smith			

Scholarship. The core health care delivery faculty have published widely. They have a total of over 260 refereed publications and book chapters in the past 10 years (Figure 1, rightmost column). During the period between 1999 and 2004, there were a total of 19 publications specifically related to health care delivery. The number of health care related publications more than quadrupled in the last five years to 87.

Figure 1. Scholarship in Health Care and Total Scholarship



The particular areas in which the faculty have published include the entire span of the health care delivery process: prevention, entry into the health care system, stays in the hospital, and treatment after hospitalization. Briefly, some of the major published work includes the following:

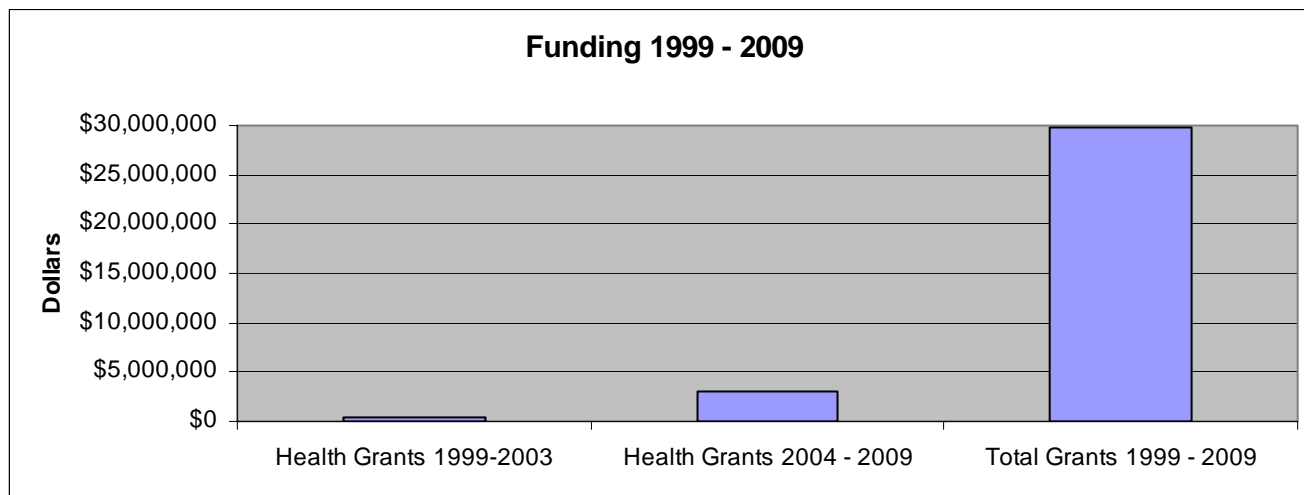
- (a) Prevention. Early on, before an individual even enters the health care system, one needs to implement processes that prevent illness and promote wellness. Core faculty have published papers on the prevention of diabetes, obesity and vehicle crashes among older and younger adults as well as the promotion of wellness measures.
- (b) Entry into the Health Care System. Published research includes papers on the best mix of physician panels and on the advantages of various screening procedures.
- (c) Hospitalization. The majority of research has been in the area of hospital operations, including studies designed to improve efficiency (emergency department flow, evacuation, colonoscopy suite flow, transfusion processes, and pedestrian/vehicle flow), to extend health information technologies (electronic medical records, computerized physician order entry, decision making heuristics, health information exchange, and consumer health information), and to increase patient safety (simulation, patient identification, medication reconciliation, IV infusion medication, recovery from medical errors).
- (d) Exiting the Hospital. Various studies have focused on what happens to patients after they leave the hospital, including studies of home care remote monitoring.

A selected list of health care publications is included in Appendix I

Funding. The core faculty involved in the cluster have a well established record of funding from the major federal agencies. Their total funding over the last ten years is almost 30 million dollars (Figure 2, rightmost column). During the period from 1999 to 2003 there was approximately \$500,000 funding in health care among faculty in the cluster. During the last five years, attention by most faculty in the cluster has been largely devoted to health care. They have won competitive awards from the major federal

agencies that are currently funding research on process improvement in the delivery of health care, including the National Institutes of Health, the National Science Foundation and the Centers for Disease Control. The total funding in health care is now over 3 million dollars (2004 – 2009). The complete list of relevant health care grants is included in Appendix II. The grants span the broad range of health care delivery and process improvement domains.

Figure 2. Funding in Health Care and Total Funding



Trajectory. The trajectory for research in this area is determined by a mix of applied and scientific needs, as well as the core competencies of the cluster and its history of research accomplishments. From an applied standpoint, health care delivery problems will be with us the unforeseeable future. Despite the startling statistics on the numbers of deaths due to medical error and a call to action by the IOM 10 years ago to improve healthcare processes, little to no progress has been made in improving patient outcomes. (AHRQ National Healthcare Quality Report, 2008). From a scientific standpoint, the complex systems engineering problems that confront process identification, modeling and optimization are only beginning to be addressed. As for predicting the trajectory based on the core competencies of the cluster, it is clear from Figure 2 and Figure 3 that scholarship and the support of that scholarship are rapidly increasing, more than quadrupling in both cases over the last five years. We expect an even more rapid trajectory in the future, assuming that the proposed cluster hires go forward.

3. INTERDISCIPLINARY/TRANSDISCIPLINARY NATURE OF THE PROJECT: CORE EXPERTISE AND PROJECTED HIRES

This section serves three purposes. First, we very briefly describe the processes and systems in which healthcare delivery takes place. Second, we describe our current expertise. Finally, we describe the positions in which we would like to hire and the synergistic ways in which these hires would build on our strengths.

3.1 Health Care Delivery: Processes and Systems

Health care *processes* are complex – or ‘messy’ - for various reasons: demand is uncertain, resources are constrained, human workers (e.g. physicians, nurses, clerks, etc.) with imperfect information must function seamlessly in teams, acting as autonomous decision-makers, while all focusing on improving patient outcomes. Yet, as we know from other industries, decision-makers must understand, measure,

evaluate, and make difficult decisions in order to improve these processes. The study of such processes inherently requires interdisciplinary and transdisciplinary input and expertise.

The process-improvement decisions that are part of these studies occur in the context of significant uncertainties, a heavily regulated environment, a large intertwined *system* of health care providers, and high stakes in the outcomes of decisions. Together, uncertainty and regulations shape a decision-making environment where the set of viable options is constrained by regulations and the potential impacts of these options are difficult to ascertain. In short, the US health care system faces core challenges on a variety of fronts, including challenges to safety, efficiency, effectiveness, patient-centeredness, equitability, and timeliness, which largely stem from deficiencies in the process-level design of the health care system – from federal and state policies to patient interactions with care providers.

Advances in science and engineering are needed to address these complex societal problems that are rooted in maladaptive micro and macro processes whose complexities are exacerbated by their interdisciplinary and transdisciplinary nature. In order to understand the multifaceted approach required to explore these scientific questions which must be answered to begin to solve the practical problems caused by the maladaptive processes, it is easiest to parse health care delivery into analyses of processes and analyses of the systems in which the processes are embedded. Process analysis includes process identification, process modeling and process development. As is clear from Table 2 below, any one of these types of analysis can apply to a single patient or provider (Level 1), to groups of patients or providers (Level 2), or to more complex procedures that involve individuals or teams of individuals, medical equipment, laboratory tests, and so on (Level 3). Furthermore, there is a flow of information between these different applications: The expertise needed to successfully understand and model health care procedures is informed by knowledge of how groups of health care patients and providers perform. At the same time, the performance of these teams is influenced by the incentives, policies and processes put in place. In turn, knowledge of how individual patients and providers function is required for a broader understanding of teams and procedures, and vice versa. This means that true problem solving, scientific or applied, cannot go on with inputs from just one discipline.

Table 2. Health Care Delivery: Process and System Analyses


Level	Process Identification	Process Modeling	Process Development	Socio-Technical Systems Identification	Systems Modeling
↓ Healthcare Patient/ Provider	Human Factors	Behavioral Decision Making	Informatics Product Design	Socio-Technical Sciences	Engineering Economics, Systems Engineering
↕ Groups of Healthcare Patients/ Providers	Social and Behavioral Sciences		Information Systems		
↑ Healthcare Procedures	Computer Science Operations Research, Probability and Statistics				

3.2 Current Core Expertise

The current multidisciplinary and transdisciplinary expertise of the core faculty overlaps most of the different functions required to understand and model processes (Table 3). This has allowed the team to respond aggressively to scientific and applied problems that focused on the individual or healthcare procedures involving the individual.

Table 3. Health Care Delivery: Core Expertise

	Process Identification	Process Modeling	Process Development	Socio-Technical Systems Identification	Systems Modeling
↓	Healthcare Patient/ Provider	Fisher, Henneman	Marquard Krishnamurthy		Baker
↕	Groups of Healthcare Patients/ Providers	Gruppen			
↑	Healthcare Procedures	Balasubramanian, Clarke, Muriel, Osterweil, Smith			




3.3 Enlarging Capacity: Future Cluster Hires

However, it is also clear that some areas are thin or missing expertise altogether (areas with gray shading, Table 3). Specifically, we need to augment our expertise in order to fully mine the potential of our existing strengths in process modeling and redesign. To control costs in the healthcare system much more needs to be known about the medical decision making process, all the way from the lowest level (predicting how individual caregivers make decisions) to the very highest level (determine the impact on the total health care system of a coordinated series of changes). To respond to this need, we are proposing to hire in three areas where currently we have no one expert (Table 4, additions underlined and in italics). (1) A *behavioral decision maker* would give us the expertise we need in order to understand better what decisions the individual care giver makes, what biases inform these decisions, and what steps can be put in place to overcome the limits of individual decision makers. This area (behavioral decision making) is receiving increasing scholarly emphasis (two of the most recent issues of the leading journals in operations research have been devoted solely to behavioral decision making) and a corresponding increase in federal funding. (2) Second, we believe that we need a *systems engineer* who would give us the expertise needed to address how the design of complex hardware and software systems is impacted by – and impacts – factors ranging from macro-level policies to micro-level human cognition. (3) Third, a *macroergonomist* would give us the expertise we need to measure and monitor a set of interacting factors that form current and future processes, specifically an individual completing tasks, using specific tools and technologies, and impacted by environmental and organizational factors. This faculty member will act as a bridge across system levels, assessing system interactions ranging from high-level factors (e.g.

policies) to individual-level decision making and processes (e.g. what processes and technologies allow individuals to identify errors). (4) Finally, we need to augment our strengths in *clinical teamwork and communication*. Teams are becoming increasingly important in any work environment, but more so in healthcare as a network of primary care physicians, specialists, nurses, lab technicians, pharmacists, etc, are typically involved in the process of caring for any single ailment, let alone the overall medical history of the patient. It is thus not enough to understand how any one individual interacts with the system process, but also to predict how system processes impact team dynamics and the fluid communication needed to achieve efficiency and safety.

Table 4. Health Care Delivery: Components and Core Expertise

	Process Identification	Process Modeling	Process Development	Socio-Technical Systems Identification	Systems Modeling
↓ Healthcare Patient/ Provider	Fisher, Henneman	<i>Behavioral Decision Maker</i>	Marquard Krishnamurthy	<i>Macroergonomist</i>	Baker, <i>Systems Engineer</i>
↕ Groups of Healthcare Patients/ Providers	<i>Clinical Teamwork and Communication</i>		Gruppen		
↑ Healthcare Procedures	Balasubramanian, Clarke, Muriel, Osterweil, Smith				



The full description of each of these positions is listed immediately below:

1. **Behavioral Decision-Making (possible homes, CS, MIE):** System redesign involving process measurement, analysis, and design efforts requires sensitivity and understanding to the factors influencing individuals' decisions, and their likely reactions to changes in processes and/or different incentive structures. There is a broad foundation in the decision sciences field which addresses the strategies and heuristics used by decision-makers. Yet, we have little information about how these decision-making strategies play out when individuals' decisions are embedded in a larger process. This faculty member will seek to better understand and predict these reactions, thereby improving the probability of successfully implementing process redesign changes. This faculty member is important because the outcomes of a new process design cannot be evaluated in absence of a deep understanding of how the various stakeholders will act under the new setting.
2. **Software and Systems Engineering (possible homes, CS, MIE):** The computational systems required to aid process measurement, design, and control are increasingly complex. These systems require a command regarding the design of, and interactions between, complex hardware and software. Additionally, the boundaries between these computational systems and end-users is varied, including precisely measuring processes, monitoring and automatically redirecting processes, or

providing decision-support to an end-user. This faculty member will address how the design of complex hardware and software systems is impacted by - and impacts – factors ranging from macro-level policies to micro-level human cognition.

3. **Macroergonomics (possible homes, MIE):** Process redesign requires measuring and monitoring a set of interacting factors that form current and future processes, specifically an *individual* completing *tasks*, using specific *tools and technologies*, and impacted by *environmental* and *organizational* factors. At a broad system-level, this new hire will interact with the **Systems Engineering Faculty** member, as well as with much of the faculty team, focusing on how policy-level decisions (e.g., Medicare and Medicaid reimbursements) are likely to impact processes and resulting outcomes such as safety and efficiency. At a more focused level, this individual will interact with the **Behavioral Decision-Making Faculty** member, addressing how individual's decisions are likely to affect processes and outcomes. Additionally, this faculty member will act as a bridge across system levels, assessing system interactions ranging from high-level factors (e.g. policies) to individual-level decision making and processes (e.g., what processes and technologies allow individuals to identify errors).
4. **Clinical Teamwork and Communication (possible home, Nursing):** System redesign must support multiple stakeholders (e.g., nurses, physicians, etc.) with imperfect information functioning seamlessly in teams and acting as autonomous decision-makers, while all focusing on improving patient outcomes. This faculty member will address the measurement and improvement of teamwork and communication in the clinical setting, an approach likely to support all six aims of the IOM, including process efficiency, effectiveness, timeliness, and patient safety.

4. WILLINGNESS OF DEPARTMENTS/SCHOOLS/COLLEGES TO SUPPORT THIS DIRECTION WITH THEIR OWN RESOURCES

College of Engineering. The College of Engineering has heavily committed to research and teaching in the area of health care delivery and is committed to continuing to support the area. Two of the hires in the past two years have included new faculty with research interests and competencies in the area of health care delivery: one focusing on operations research and health care delivery, and one focusing on informatics and health care delivery. Development has secured funding from private donors which has enabled the support of graduate students over the last several years doing research on health care delivery. The Dean has provided substantial funding for the development of a systems engineering graduate degree program and that program is ready to launch this coming fall.

School of Nursing. The School of Nursing has three core research and teaching foci, one of which is health care systems and informatics. Our two newest graduate programs are the Clinical Nurse Leader and the Doctorate of Nursing Practice. The University of Massachusetts was one of the early adopters of these innovative educational programs that address health care systems issues. Both of these programs are taught by nurse leaders with clinical, research and organizational expertise in individual and/or population-based health care delivery. Additional faculty will allow us to continue to expand the school's influence nationally and internationally as leaders in the advancement of health care outcomes such as patient safety.

Department of Computer Science. The Department of Computer Science has recognized the importance of health care delivery and has several faculty and projects looking into ways in which computer technology can improve health care delivery. In addition to process improvement, these projects include patient safety and privacy, medical device security, and robotic support for assisted living.

5. ESTABLISHED LEADERSHIP FOR INITIATIVE ON CAMPUS

The entire set of core faculty are listed above in **Error! Reference source not found.** Overall leadership of the cluster will be assumed by Don Fisher. He has led a number of interdisciplinary efforts in the past, including being director of the Human Performance Laboratory, an interdisciplinary laboratory with funding since 1982 which includes primary faculty and students from Mechanical and Industrial Engineering, Civil and Environmental Engineering, Psychology and Nursing and continuing relations with faculty and students in Communications Disorders, Computer Science, Kinesiology and the School of Management. In addition, he has been a PI or Co-PI on over 30 interdisciplinary grants, a number funded by federal agencies over the past 10 years. For the cluster hire governance, one faculty from each of the three areas will be assigned as a primary liaison: Jenna Marquard in MIE, Beth Henneman in SON and Lee Osterweil in CS. As evidenced by their vitas, these faculty members have extensive depth and breadth of expertise in their respective areas of health care delivery.

At the outset, this group will be responsible for prioritizing the hires, writing the job position announcements, and coordinating the searches. After the hires join the University, this group will take continuing responsibility for integrating the new hires into opportunities for health care research on campus, meeting at least twice a semester over the first two-three years with the individuals hired as well as informally whenever the need arises. Additionally, this group is committed to writing an NSF IGERT in the area of health care delivery. Currently there are no IGERTS in health care delivery. We will be ideally placed for such an effort. Successful coordination of the current expertise on campus with the complementary and discipline-bridging areas of the cluster hires is essential to achieving our funding and publication goals, as well as the desired impact on widespread health care policies and processes. Under the overarching leadership of Don Fisher and the disciplinary governance of Jenna Marquard, Beth Henneman and Lee Osterweil, the team is well poised to achieve its full potential.

The cluster faculty will hold two day-long retreats per year. During these retreats, faculty will discuss and coordinate their efforts in several areas: 1) refining and developing health care delivery-related courses, 2) ensuring students' are able to engage in interdisciplinary and transdisciplinary coursework and research, 3) coordinating research agendas and funding proposals, and 4) outlining strategic publication venues. Additionally, every two years, the health services cluster leader and three area liaisons will be voted upon.

6. ABILITY TO ATTRACT FUNDING FROM FEDERAL, STATE AND PRIVATE SOURCES

While the current research team has a proven collaborative track record in health care delivery research, as demonstrated through publications and grant funding, we feel this trajectory will not only continue but will accelerate with the proposed hires. Only in the past ten years has health care delivery captured broad attention, starting a relatively new stream of research requiring systematic analysis. Building trust and reciprocity among faculty from different disciplines can be a long and arduous process. Yet, the collaborative track record of the existing faculty demonstrates that proposed hires will be easily integrated

into these already strong relationships. With the proposed hires, we have a set of faculty who together are poised to take advantage of a variety of funding opportunities.

There are multiple levels and types of funding opportunities available through the Agency for Health care Research and Quality's (AHRQ's) patient safety and health information technology portfolios. The patient safety funding is aimed at identifying processes that lead to medical errors and researching strategies for improving those processes – thus lowering errors. AHRQ's health information technology portfolio supports research that helps hospitals, clinicians, and patients successfully incorporate new health information technology into their work practices.

Within the National Institutes of Health, the National Library of Medicine (NLM) also supports a broad array of health care delivery research. NLM's "Health Services Research" program is aimed at funding proposals that specifically study health care access, costs, and quality.

The Centers for Disease Control (CDC) provide funding for proposals that "protect health and promote quality of life through the prevention and control of disease, injury, and disability". The CDC would be an ideal funding course for the cluster's focus on the connections between micro (e.g., patient or provider behavior) and macro health care delivery processes (public health preparedness).

Another major source of federal funding is from the National Science Foundation's (NSF's) Service Enterprise Systems (SES) program. SES supports "research on strategic decision making, design, planning and operation of commercial, nonprofit, and institutional service enterprises with the goal of improving their overall effectiveness and cost reduction. The program has a particular focus on health care and other similar public service institutions, and emphasizes research topics leading to more effective systems modeling and analysis as a means to improved planning, resource allocation, and policy development".

As previously mentioned, our team is committed to writing, and we believe is well-positioned to get, an NSF-IGERT in health care delivery that would provide stable support for graduate students in this area.

In addition to federal funding sources, foundations such as the Robert Wood Johnson Foundation (RWJF) fund primarily health care delivery research. RWJF has funding initiatives aimed at developing a new set of health care workers (Building Human Capital), preventing childhood obesity, expanding health care coverage, pioneering bold ideas (e.g. using virtual reality to train health care workers, something with which the core faculty have extensive direct and indirect experience), improving public health, ensuring health care quality and equity, and improving the health of vulnerable populations.

These prominent funding sources are obvious fits for the health care delivery cluster, and our ability to attract funding from these sources will be strengthened through the specific skill sets of the proposed hires, detailed above (Section 3.3).

7. PROSPECTS THAT THE PROJECT WILL ESTABLISH OR CONFIRM UMASS AMHERST AS THE LEADER IN THE PROPOSED AREA OF SCHOLARSHIP, RESEARCH OR TEACHING

The interdisciplinary and transdisciplinary nature of the current health care delivery faculty, coupled with the proposed positions, will uniquely position UMass Amherst as a leader in the health care delivery

research and scholarship domains. While other universities recognize the need to study and improve health care processes systematically, these efforts consist largely of pair wise partnerships – industrial engineers working in concert with a practicing physician, for instance. Our faculty in nursing, engineering, and computer science, working jointly to address the aforementioned problems, provide a more comprehensive perspective and approach to health care process improvement. Nursing colleagues bring domain expertise, knowledge of evidence-based and non evidence-based clinical practices, and insight into relevant research questions. Engineering faculty bring tools to analyze, model, and improve processes, while addressing the fit between the processes and individuals’ cognition and behavior. Computer science colleagues contribute a rigorous analytical approach and set of computational tools for precisely studying and modeling these processes. In this way, our research team can identify real problems in the domain, rigorously study and improve those processes, and successfully implement changes within and across organizations.

The proposed hires will solidify the impact of this research team by filling gaps in current faculty expertise. Our nursing faculty bring a wealth of clinical care domain knowledge. A new faculty hire in nursing who can broaden our understanding and analysis of health care processes from a single provider acting alone to multiple providers acting in concert would strengthen our team immensely. In our technical areas of expertise – namely engineering and computer science – we currently have researchers with strong depth of knowledge in their respective fields. As a team, we would benefit by having a researcher in each domain who can link the respective skill sets of these faculty with broader system-level problems, and who can work together to bridge our engineering and computer science approaches. Finally, our team would benefit from a faculty member who studies individual decision-making behavior and can predict how individuals are likely to respond to process-related interventions.

By continuing to integrate faculty across disciplines, UMass students will significantly benefit. Our students now require an understanding of, and experience working in, multidisciplinary teams. We envision opportunities for interdisciplinary collaboration in our undergraduate and graduate coursework, through jointly sponsored undergraduate research opportunities, and by engaging graduate students in the research problems that result from this expanded network of health care delivery faculty.

8. BUSINESS CASE

Given the current budget constraints the University faces, an important advantage of the proposed cluster hire is the relatively low setup cost associated with research on health care delivery processes, mainly requiring computing capability and access to existing University resources. Our hires will require moderate start-up packages that departments, colleges and schools can more likely afford in these challenging budget times, while still being poised to attract significant funding. As an example, for someone in behavioral decision making, aside from the salary and benefits, start up costs would likely include a laboratory with up to four subject data collection stations (each outfitted with a basic desktop PC), an eye tracker, and associated software. This cost is in the neighborhood of \$50,000. Based on past experience, one can estimate that approximately 100 square feet would suffice for the four subject running stations. Space on this order of magnitude is available in several of the core departments; some key equipment, such as eye trackers and PCs, can potentially be purchased with grant money already in place and shared more broadly (something we now do with all of the equipment in the Human Performance Laboratory). Additionally, it is conceivable that fellowship funds would be available from several sources for first year funding of a graduate student for the new hire. For example, the New

England University Transportation Center regularly funds doctoral student fellowships. Several such fellowships over the years have been given to students in the Department of Mechanical and Industrial Engineering who have an interest in behavioral decision making. The worth of a fellowship is about \$40,000. So if the total start up package were \$150,000, instead of needing to spread that entire amount over the Department, College and University, we might only need \$60,000 - \$80,000 after we consider existing resources and fellowships.

9. TEACHING CASE

The Department of Mechanical and Industrial Engineering has some of the highest enrollment numbers in the College of Engineering. Multiple classes have over 100 students. Two of the positions could potentially be located in the Department and greatly reduce the student to faculty ratio in several of the largest courses. First, an individual hired in behavioral decision making would have an extensive background in probability and statistics and could easily teach MIE 273 (Probability and Statistics). The individual could assist with the teaching of MIE 302 (the load is especially heavy here). And the individual could assist in the joint program between the College of Engineering and the Eisenberg School of Management. This would free up other faculty to teach courses where the demand continues to be very heavy. This individual could teach as well an elective undergraduate/graduate course in decision making. There are only one or two such courses and the demand for more electives increases every year as the faculty grows smaller. Second, an individual hired in systems engineering could teach the first semester MIE engineering seminar (MIE 113), could potentially teach MIE 315 (Mechanical Systems), and could offer a new undergraduate/graduate course in systems engineering that would provide our students with the knowledge that is becoming increasingly important to function as engineers in their future professional careers.

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11. APPENDIX I. SELECTED HEALTH CARE PUBLICATIONS

1. Prevention (Public Health)
 - 1.1. Automobile Crashes
 - 1.1.1. Younger Adults (Don¹)
 - 1.1.2. Older Adults (Don)
 - 1.2. Obesity
 - 1.3. Diabetes
2. Entry to the Health Care Delivery System
 - 2.1. Assignment
 - 2.1.1. Physician Panels (Hari²)
 - 2.2. Screening
 - 2.2.1. Prostate
 - 2.3. Primary Care (Hari, Ana)
3. Hospital Operations
 - 3.1. Efficiency
 - 3.1.1. Process Flow Analysis
 - 3.1.1.1. Emergency Department Flow (Hari³, Ana, Lori, Lee, Phil)
 - 3.1.1.2. Colonoscopy Suites (Hari⁴)
 - 3.1.1.3. Transfusion (Beth⁵)
 - 3.1.2. Pedestrian/Vehicular Flow (Jim⁶)
 - 3.2. Health Information Technologies
 - 3.2.1. Electronic Medical Records
 - 3.2.2. Computerized Physician Order Entry (Don, Phil)
 - 3.2.3. Decision Making Heuristics (Jenna^{7,8,9})
 - 3.2.4. Health Information Exchange (Jenna^{10,11,12,13,14,15,16,17})
 - 3.2.5. Consumer Health Information (Jenna^{18,19})
 - 3.3. Patient Safety
 - 3.3.1. Simulation (Beth, Don, Phil, Jenna)
 - 3.3.1.1. Training (Beth²⁰)
 - 3.3.1.2. Identifying Errors (Jenna²¹)
 - 3.3.2. Patient Identification (Don, Beth²², Phil^{23,24})
 - 3.3.3. Medication Reconciliation
 - 3.3.4. IV Infusion Medication (Beth²⁵)
 - 3.3.5. Recovery of Medical Error (Beth²⁶)
 - 3.4. Evacuation
 - 3.4.1. ICU (Jim²⁷)
4. Ambulatory Operations
5. Exiting the Health Care Delivery System
 - 5.1. Postoperative Care
 - 5.2. Home Care Remote Monitoring (Jenna²⁸)

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12. APPENDIX II. HEALTH CARE GRANTS

1. Prevention (Public Health)
 - 1.1. Automobile Crashes
 - 1.1.1. Younger Adults (Don^{1,2,3})
 - 1.1.2. Older Adults (Don)
 - 1.2. Obesity
 - 1.3. Cancer (Jenna⁴)
 - 1.4. Diabetes (Jenna⁵)
2. Entry to the Health Care Delivery System
 - 2.1. Assignment
 - 2.1.1. Physician Panels
 - 2.2. Screening
 - 2.2.1. Prostate
 - 2.3. Primary Care (Hari⁶, Ana)
3. Hospital Operations
 - 3.1. Efficiency
 - 3.1.1. Process Flow Analysis
 - 3.1.1.1. General Methodology (Lori, Lee, Beth^{7,8})
 - 3.1.1.2. Emergency Department Flow
 - 3.1.1.3. Colonoscopy Suites
 - 3.1.1.4. Transfusion
 - 3.1.2. Lean Six Sigma
 - 3.2. Health Information Technologies
 - 3.2.1. Electronic Medical Records
 - 3.2.2. Computerized Physician Order Entry
 - 3.2.3. Decision Making Heuristics
 - 3.3. Patient Safety
 - 3.3.1. Simulation (Beth⁹)
 - 3.3.2. Patient Identification
 - 3.3.3. Medication Reconciliation (Beth^{10,11,12})
4. Ambulatory Operations
5. Exiting the Health Care Delivery System
 - 5.1. Postoperative

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¹ Fisher, D. L. (Principal Investigator) and Pollatsek, A. “Newly-licensed Driver Crashes: Causes and Remediation”. National Institutes of Health (1R01HD057153-01). \$913,000. October 2007 – September 2012.

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³ Blomberg, R. D., Thomas, F. D. and Fisher, D. L. (Consultant). National Highway Traffic Safety Administration (Contract No. DTNH22-05-D-350433-0007, Traffic Injury Control Evaluation and Behavioral Technology Research). “Safety Outcomes for Older Drivers of Licensing Procedures”. \$393,269. October 2007 – April 2010.

⁴ Pending: Marquard, J. (Principal Investigator), Puleo, E., Peckinpaugh, D. & Freedson, P. “Promoting Activity, Training, and Health using Information Technology (Path-IT)”. National Institutes of Health. \$817,917. Project Period: October 2009 – September 2011.

⁵ Pending: Saver, B. (Principal Investigator), Marquard, J. (UMass Amherst Principal Investigator). “CONtrolling Disease Using Inexpensive IT – Hypertension in Diabetes: CONDUIT-HID”. Agency for Health care Research and Quality. UMass Amherst Subcontract of \$384,430. Project Period: October 2009 – September 2013.

⁶ Balasubramanian, H., Muriel, A. and Stahl, J. (Submitted February 2009). National Science Foundation. "Flexibility in Primary Care." \$462,155 for 8/1/09-7/31/12.

⁷ Clarke L, Henneman PL, Avrunin G, Henneman EA (Co-PI) Osterweil,L. Process-centered, analysis driven, system development applied to human intensive medical processes. National Science Foundation. Award Number 0820198. Project period: 7/08-6/11. \$500,000.

⁸ Clarke L, Henneman EA (Co-PI), Osterweil, L. Avrunin G, Henneman PL. Improving the safety and efficiency of medical processes. National Science Foundation. Project period: 10/04-8/08. \$1,448,242.

⁹ Cunningham, H (PI), Henneman EA, Reilly CA. Use of simulation technology in nursing education. Massachusetts Board of Higher Education 4/05-6/06. The aim of this project is to expand the patient safety-focused clinical experiences of nursing students at the University of Massachusetts, School of Nursing by providing simulation technology at an acute care hospital setting, Baystate Medical Center. Project period: 4/06-6/06. \$59,975

¹⁰ Henneman EA and Tessier, E. An Evaluation of Collaborative Nurse-Pharmacist Intervention for Improving the Medication Reconciliation Process: Impact on Patient Safety. The American Society of Health-System Pharmacists Research and Education Foundation. Project period: 9/06-8/08. \$40,000

¹¹ Ritter G, Henneman EA (Co-investigator), McGirr J, Morsi J, Kerr G. Medication reconciliation to improve safety in patients undergoing joint replacement surgery. Baystate Health Systems Insurance Company. Project period: 9/04-8/05. \$21,000.

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