An Agile Translation Process for Complex Innovations: an Industry/University Cooperative Research Center Case Study

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***Abstract*—The National Science Foundation Industry & University Cooperative Research Center (I/UCRC) program is intended to foster productive collaboration between industry organizations and academia. The focus of the I/UCRC research site herein is on the application of technology within the complex extended enterprise. The center's goal is to conduct research that is of interest to both the industry sponsor and the university partner, with the provision that the industry organization must provide major support to the center. In this paper, we describe the Agile Translation Process (ATP) for complex innovations that was developed at the center. The process meets the constraints of the academic calendar, the knowledge needs and the typical length of stay for a master's student, and the availability constraints of the students. At the same time, the process is designed to provide value to the industry sponsor. Specifically, it describes how the process meets the needs of technology consumers in industry seeking to derive tactical value through the funding of the center. In addition, we demonstrate how to derive research results for technology providers through subsequent activities. We also provide metrics from the center for a period of five years, which show, in particular, the benefit of using the ATP method over the last three years. These metrics provide insights on how to reconcile tactical industry needs with the long-term research and funding goals of academia, while understanding the innovations needed within complex contexts. This case study also provides insights on concurrently meeting the needs of all stakeholders – including industry clients, translational faculty members, adjunct faculty from partner companies, graduate students, and the center's affiliated research faculty – within the constraints of the academic calendar. By using an agile translation process and a set of expanded performance metrics, the center effectively applies research to bring innovation to its industry partners.**

Keywords—collaboration, design, innovation, performance metrics, services science, technology management

I. Innovations for Complex Enterprise Systems

Beginning in early 2004, we looked at hiring patterns within the Information Technology (IT) industry and noticed several emerging trends, including the fact that a significant portion of IT complexity began shifting from *technology development* to *technology use***.** These trends are shown through several factors. First, enterprise IT departments became brokers of cloud, social, mobile and information services [1]. Second, there was a significant interest in converting data from these services into actionable intelligence - the *big data opportunity* [2]. Third, hiring by the technology consuming industry overtook that of the technology producing industry. Fourth, budgets for IT maintenance were ballooning due to an increase in the number of technologies needed to manage complex IT service workflows. Thus, the overall focus of the Center's research became the growing gap between technology consumers (government, industry, etc.) and technology providers (including academia). Hence, the Center experimented with alternatives to make the translational process viable within academia.

In this paper, we describe what we term the Agile Translation Process. This process was developed to meet the needs of the student within the constraints of an academic program while meeting the needs of industry, by deriving tactical value through the utilization of the Center as a research partner. Furthermore, we show how to derive *research* results through subsequent activities. Lastly, we provide metrics from the Center for a period of five years. These metrics provide insights on reconciling tactical industry needs with the long-term research and funding goals of academia.

From an industry-university collaboration perspective, we can also ask related questions. How do we as academics and engineers help increase innovation, and diffusion of new ideas? How do we apply the rigor of the latest research to design solutions? How do we show that designed solutions provide value within the context of a complex enterprise? And, finally, how do we overcome any impediments to come up with a cost-effective industry-university capability to accomplish these goals? This case study provides approaches to these questions using the Agile Translation Process that concurrently meets industry-university stakeholder needs. These approaches include: the sharing, use, creation of knowledge and feedback; resourcing of translational projects related to complex systems; and protection of intellectual property while conducting projects.

The context of this study is a specific National Science Foundation Industry/University Cooperative Research Center (I/UCRC) for Experimental Research in Computer Systems (CERCS). This is a multi-university center with

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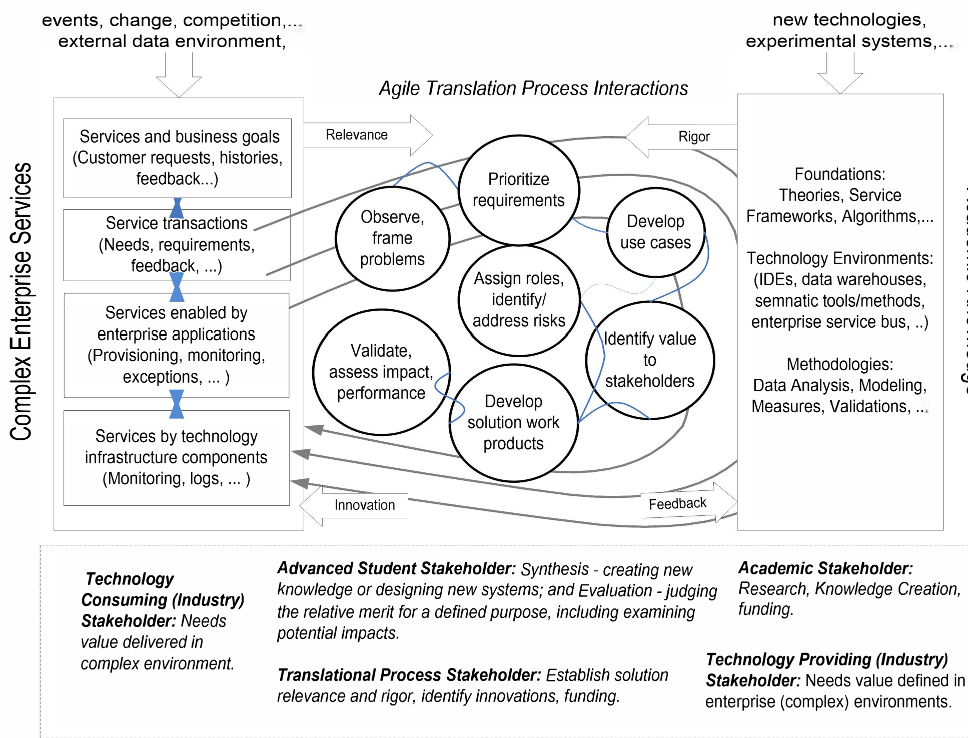

Fig. 1: The contexts of Complex Enterprise Services on the left and Academic Knowledge on the right. The Agile Translational Process (ATP) resources by advanced experiential learning, cycles between Descriptive and Normative research activities as illustrated.

CERCS at Georgia Tech researching technology: hardware, communications and system-level software, and applications. Complementary to this, the CERCS research site at The Ohio State University, the Center for Enterprise Transformation and Innovation (CETI) studies the applications of technology for innovation. The center's goal is to conduct research that is of interest to both the industry and the university, with the provision that the industry organization must provide major support to the center [3]. The simple center structure also provides for the protection and sharing of intellectual property through the Bayh–Dole Act. By emphasizing experimental methods, CERCS promotes the creation of knowledge through the design, implementation, and measurement of large-scale technology and systems.

The specific focus of this case study is the CETI research site and its application of technologies within the extended enterprise.

II. Design Related Concepts

Before presenting our case and performance data, we cover related concepts.

A. Context for Design

It is well established that engineering design requires an understanding of the context for the correct framing of the problem, as well as interdisciplinary approaches to solution development [4]. For example, architectural design is viewed as its own integrated field of study, and compared to other engineering disciplines; it is multi-disciplined since the field seeks integration of electrical, plumbing, lighting and other systems within an overall building design. Capture of contextual knowledge as *design patterns* was also first introduced by the architect Christopher Alexander [5, 6] as a way of making hitherto tacit knowledge explicit. Design patterns were adopted by software engineers, leading to many framework technologies that have improved the development of software. However, far less has been done in integrating interdisciplinary frameworks related to complex enterprise services within the graduate software and systems engineering curricula.

Recent NSF workshops have also looked at the process of introducing design thinking into the engineering curriculum [7, 8]. In addition, advocates of grounded theory provide a systematic methodology in the social sciences involving the discovery of theory through the analysis of data captured in the field [9]. It is mainly used in qualitative research, but is also applicable to quantitative data. These ideas and methods carry forward to bridging the gap between technology consumption (left of Fig. 1) and technology development (right of Fig. 1). Finally, related to technology, engineering research continues to focus primarily on normative theories related to technology while business, such as management information systems, and healthcare focus more on descriptive or operational aspects, leaving a gap to be bridged as described by Christensen [10]. To address this, *design science* [11] emphasizes the need for the information systems researcher to bridge the gap between existing knowledge and the context of use. This is captured in Fig. 1 as the Agile Translation Process (ATP) Interactions discussed later.

B. Complex Enterprise Service Systems

Complex enterprise service systems refer to intra- and inter-enterprise services that collectively enable a business goal. As in [12, 13], we view these as networks (a value chain, supply chain, service value networks) with nodes as agents (humans, organizations, software and hardware) creating, communicating, and consuming information.

C. Living Laboratory

A living laboratory, or sandbox, is an environment that replicates the complexity of real-world enterprise environments. Given the importance of field-based research in innovation, these environments allow problem framing and experimentation to occur as in the real world. This works well if this synthetic environment itself can be embedded in real-world organizations with safeguards in place for privacy and security concerns.

D. Translational Role

While there are many variations across universities, we have kept the role definitions below intentionally simple to make a point. Today the center acts in a translational role to conduct translational activities that are not explicitly identified within universities and their engineering colleges. This role is well recognized in medical schools; within engineering this is often filled in an ad-hoc fashion by appointments that do not fit the translational role and performance requirements. According to Duderstadt, "[t]he strong research focus of many engineering schools has led to a cadre of strong engineering scientists, quite capable of generating new knowledge but relatively inexperienced in applying this knowledge in professional practice" [14].

We illustrate this issue below using the term *role* to identify responsibilities. For a translational role, these responsibilities include: demonstrating the value of research in practice and developing descriptive theories; providing related experiential education in solution-driven contexts and applying research theories and methodological rigor where applicable; providing feedback and identifying intellectual property; developing industry relationships and making interpersonal connections needed for field research. It is insightful to contrast this with the typical academic roles at the other end of the spectrum: developing research theories; providing related education of principles, methods and tools; providing academic administrative services; and developing relationships with federal and industrial research and development labs. Because of the *applied research* component of the translational faculty role, we also distinguish the translational role from the roles of adjunct lecturer and clinical faculty typically filled by professionals from industry to augment teaching resources.

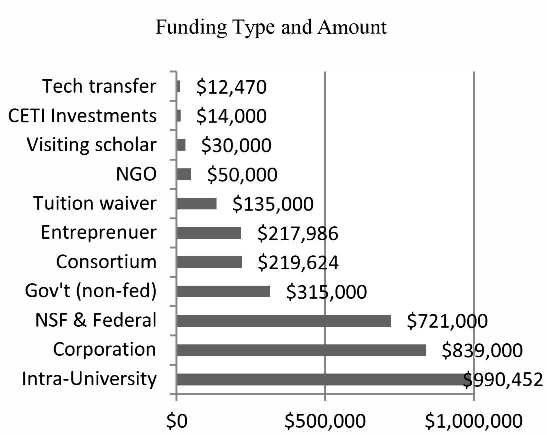

Fig. 2: Funding types and amounts. Total amount is approximately $3.25 million.

III. AGILE TRANSLATIONAL PROCESSES (ATP)

CETI uses the precise notion of an *Interaction* to bridge technology-consumer context and technology-provider knowledge as illustrated in Fig. 2.

A. Interaction-based Translation Methodology

For the purpose of measurement, we consider the unit of activity to be an Interaction that takes place between consumers and providers. Each Interaction is at the request of a consumer (e.g. a sponsor, student, or academic collaborator) and is provisioned with resources by the center to provide work products of value to the consumer. The request can ask for any type of Interaction, for example: requirements analysis, a project, experiential education, or thesis research. We take the average duration of an Interaction to be an academic term.

Also it is important to note that an Interaction may fall outside the primary I/UCRC mission and be a secondary Interaction. The variation in types of sponsors of Interactions is illustrated in Fig. 2. For example, a project Interaction with the Agriculture department to visualize the transmission of disease may be funded by another federal grant that is not counted as I/UCRC membership revenue for reporting, and is thus a secondary Interaction.

However this type of secondary Interaction would not have happened without the existence of the center and its relevance to sustainability. We therefore list secondary Interactions here to identify the full benefit of the I/UCRC, which is often outside the main / measured intent. We also list secondary Interactions here to identify potential opportunities to establish a sustainable translational center beyond the duration of the I/UCRC. Also, it is important to note that the concept of an Interaction is similar to the previous I/UCRC evaluation methodology followed using *critical events or incidents* in the life of the center from the perspective of the director [15]. The goal of that study was to study management relationships *across* centers. On the other hand, the goal of this study is to analyze events and resulting Interactions *within* a single center.

Agile software engineering bridges customer needs and provider tasks, especially when requirements are uncertain.

From the center perspective, the benefits of combining *agile* and *translation* include: a prescriptive process that is responsive to industry sponsors; an expanded set of internal performance measures across industry engagements; and collaborative resourcing for experiential learning. Thus, by focusing on the details with ATP at the boundary of industry and university, we begin to examine opportunities for increasing the rate of bidirectional idea diffusion.

The ATP is illustrated in the center of Fig. 1. Each Interaction is aligned to academic increments. It consists of the following steps, based on [16]:

1. *Process satisfaction:* Measured by rapid delivery of useful work products, in the midst of changing requirements, even late in development. Work products (see center of Fig. 1) delivered frequently.
2. *Project work products:* Acceptance by the sponsor is the principal measure of progress towards an innovation. This means the sponsor reviews the work products based on value to organization.
3. *Self-organizing teams:* Small teams of one to five students are asked to be responsive to the sponsor. There is regular adaptation to changing circumstances.
4. *Standup presentations:* Made to the sponsor; reviewed by translational faculty.
5. *Sustain development at a constant pace:* For graduate research associates and interns this starts at 20 hours per week, less so for capstone students. Close, weekly cooperation between sponsors and student developers with face-to-face conversations is expected.

Some unique aspects of ATP are important to note here. Industry sponsors approve all work products based on achieving a translational goal; thus the work products are of value to an industry process or product. Each work product contributes incrementally to a final innovation.

A typical master's student is available *only* for four increments; during their first semester, they are taking their mandated core courses. Useful value must result as below:

- Increment 1 (Spring) consists of on boarding in the field with mentoring by professionals, with instruction delivered as an advanced project-oriented course using an enterprise context and curriculum assets. Here, second year group members mentor the first year group members in each team. The course serves to provide needed background on different sponsor companies.
- Increment 2 (Summer) is where students are embedded as industry interns in the enterprise. Enterprise data gathering, model development, and initial problem formulation are the foci of this increment.
- Increment 3 (Fall) sees problem abstraction and solution synthesis along with project deliverables. Thesis research and hypothesis development begin.
- Increment 4 (Spring) consists of analysis and thesis writing for the student, who must defense their research and hypothesis at the end of the increment.

B. *Project environment*

The environment includes weekly activity tracking, which is kept private to the student and faculty advisor, and a project environment with blogging for team collaboration.

IV. Center Performance and Stakeholder Benefits

The following data are both for primary and secondary Interactions from April, 2007 to March, 2013. These data provide insights into: the primary and secondary Interaction outcomes that are measured from an engineering research perspective in academia; the need for additional translational measures to address translation; and ways the I/UCRC-type structure could provide sustainable translational research.

Over the five-year period CETI has had 85 Sponsors ranging from Fortune 500 companies to small- and medium-sized enterprises. These industry organizations are both technology-using and technology-providing companies, as well as both local and international. Included in the sponsors are other departments across the university and Capstone sponsors. Capstone course projects do not initially involve significant dollar amounts. The center has over fifty master's and doctoral students at any given time. In addition, over five years the center has provided 3,000 students at the undergraduate and graduate levels with experiential learning that generated tuition revenue.

A. *Interaction Performance and Related Stakeholder Benefits*

The Interaction framework and standard ATP structure presented above allows us now to explicitly state CETI performance, which is discussed next.

1) Interaction Outcomes: As mentioned, all center execution is measured in a standard way as increment-long Interactions. A primary or secondary Interaction can be of different types, can have different types of consumers, providers, sponsors, or resourcing, and can have different outcomes. Outcome types are classified as follows: Academic outcomes and innovation outcomes.

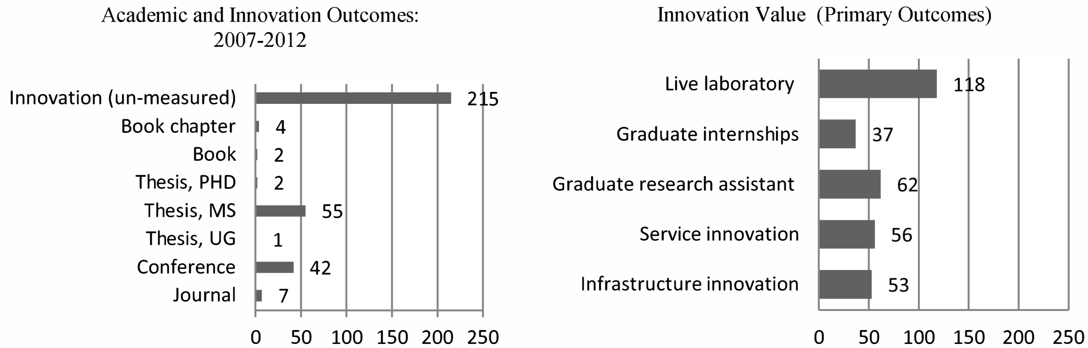

Fig. 3: Overall Interaction outcomes: (a) academic and (b) translational.

Academic outcomes, which are measured for individual researchers, include: journal and conference publications, undergraduate, Masters, and doctoral theses, books, and book chapters. Innovation outcomes, which are typically unmeasured for individual researchers, include: workforce impact, project reports, curriculum assets, software assets, and data assets. As shown in Fig. 3, there were both academic and translational Interactions. There were 113 academic outcomes and 215 innovation outcomes related to projects which are identified in greater detail in Fig. 3(b)Fig. 3. All reported work products were sponsored by consumer or provider stakeholders (see related graphs in Fig. 4).

The center's technology consumers and providers have specific innovation value tied to one or more of the following: Technology Infrastructure, Service Delivery, or Workforce. The rationale related to Workforce innovation is that, through graduate research assistantships and graduate internships, the live laboratory curriculum assets are indirectly used to achieve skills that will diffuse results to industry.

2) Interaction Funding Types: This refers to any organization type that provides funds, including: industry, the government, academic or non-governmental organizations, the university (in terms of fee waivers), visiting scholars, technology transfers, internal CETI funding, intra-university (i.e. other departments within the university). Note that the funds for an Interaction might be from a source that is different from the problem sponsor for an Interaction. For example, a capstone class may provision an Interaction for an entrepreneur, but funds are by tuition. Incidentally, this is the only type of funds not counted in the overall number in Fig. 2. Also, the university support in terms of fee waivers was instrumental in making this program successful.

The overall funds directed to the center are given in Fig. 2. From an NSF perspective, note that the funding from other departments, labeled Intra-OSU, is the highest due to the high level of interdisciplinary collaboration in the center. Also, an I/UCRC brand has far greater impact in fostering and resourcing collaboration than the amount reported as direct I/UCRC funding which is less than a third of the total amount.

3) Interaction Domains: Described in Fig. 4, the sponsor's domain could be a Technology Consumer (in government, finance & insurance etc.), or as a Technology Provider interested in complex system aspects classified as one of: service delivery (e.g. applications of mobile, sensor technologies); technology infrastructure improvement (e.g. applications of cloud computing, Hadoop, etc.); or semantic enterprise architectures and services.

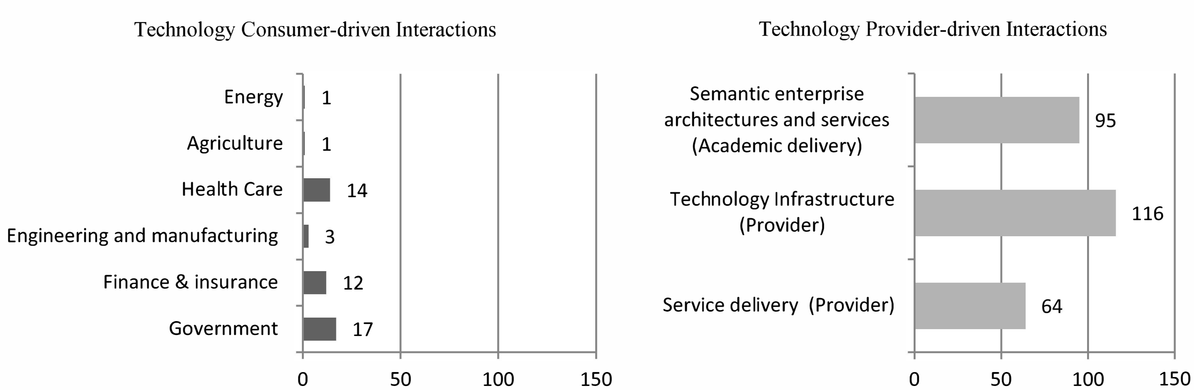

Fig. 4: Interactions and domains of technology providers and technology consumers.

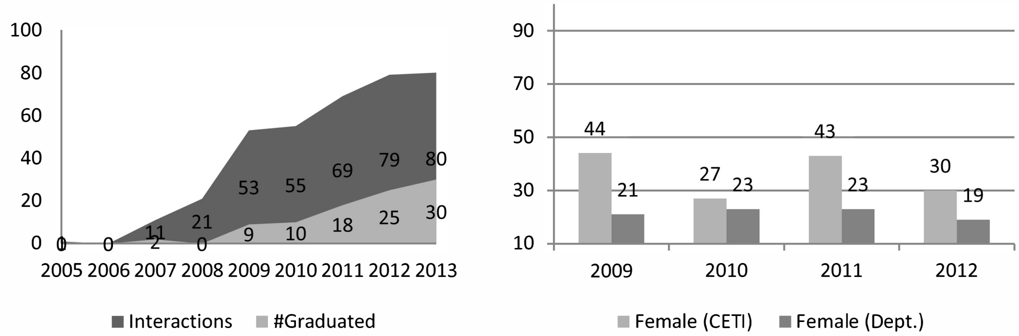

Fig. 5: (a) Advanced student beneficiary numbers (the number of graduate students) and related Interactions. (b) Female students within the CETI sub-population vs. female students within the at-large departmental population.

4) Interaction Resourcing to Achieve Translation Outcomes: Graduate students implement the Interactions using the ATP steps of problem framing, synthesis, and analysis. These are measured as the final project report and work products accepted by the sponsor, a published research paper or thesis, and usable living laboratory curriculum assets, such as case studies that introduce the contextual challenges of problem solving. In addition, the ATP conforms to the students' availability and academic interests and addresses their knowledge gaps. The students also get two to three increments of funding. The knowledge applied is often interdisciplinary. They learn that research ideas may or may not provide value within a complex system whose improvement depends on many factors. The students also learn that the most critical aspects must be identified first, meaning that they must be agile.

5) Interactions versus Graduates: The number of graduate student beneficiaries is related to the Interactions needed to achieve this number in Fig. 5. This provides an idea of the resource intensive nature of advanced experiential learning and the demands on the translational role. While projects were sponsored by industry from the very inception of CETI, we began to link projects and industry sponsorships to the academic increments (e.g. a semester or quarter) and the students' own availabilities and skills only in the third year. Coincidentally, in 2008, the Center's home Department started accepting master's students, thus providing a pool of industry-headed talent with an interest in innovation (see the large increase in Fig. 5. CETI graduates were a fifth of all Masters level graduates over the period. We also note that significant number of female students joined CETI (see in Fig. 5(b)).

6) Interdisciplinary collaboration: As noted earlier, the greatest funding type (Fig. 2) is intra-university funding. This represents over forty faculty from fifteen departments – including public policy, medicine, business, and design – across the university that were actively involved in supervising specific Interactions. Often faculty members started with sponsoring a capstone project, then moved the project to an externally funded grant.

V. CONCLUSIONS

The presented case is related to an Agile Translation Process implemented specifically in the CETI I/UCRC research site. The data show that it is possible to impact innovation and research and advance experiential learning in a way that is concurrently beneficial to all stakeholders. We show here how to build a translational structure at the boundary of industry and university through alignment of existing resources. This includes provisioning work through experiential learning courses and funding advanced graduate students. These students, under the guidance of translational faculty, learn how to correctly frame problems, synthesize solutions, and evaluate results in the context of complex enterprise service systems. Such problem-based experience can be time consuming and resource intensive. To overcome the challenges and make this possible, we draw upon agile development principles to address: the translational processes at the boundary of industry and university; the academic calendar constraints; and the needs of stakeholders and challenges.

ACKNOWLEDGMENT

This work was done under the aegis of the Center for Experimental Research in Computer Science at Georgia Tech and The Ohio State University, funded by the National Science Foundation's I/UCRC program (NSF IIP 0753710). Funding was also provided by The Ohio Board of Regents Computer Science Graduate Education program and by NSF CCLI Grant No. 0837555. We wish to acknowledge helpful ideas by CETI students, particularly Andee Peabody, colleagues, members, and sponsors.

REFERENCES

[1] J. McKendrick, "Line-of-business tech budgets may soon top IT department budgets: Gartner,". ZDNet, December, 2011.

[2] Gartner, "Big data," Retrieved March 30, 2013, from http://www.gartner.com/technology/topics/big-data.jsp.

[3] National Science Foundation, “NSF I/UCRC,” Retrieved March 30, 2013, from http://www.nsf.gov/eng/iip/iucrc.

[4] National Academy of Engineering, The Engineer Of 2020: Visions Of Engineering In The New Century. Washington, DC: National Academies Press, 2004.

[5] Wikipedia. “Christopher Alexander - Wikipedia, The Free Encyclopedia,” Retrieved March 30, 2013, from http://en.wikipedia.org/wiki/Christopher_Alexander.

[6] G. Bryant, “The Oregon Experiment after twenty years,” RAIN Magazine, vol. XIV, no. 1, 1991.

[7] W. Chen, E. Colgate, D. Norman, A. McKenna, E. Gerber, “NSF workshop on driving innovation through design: Engineering in the 21st century,” NSF Directorate for Engineering, 2010-2011.

[8] IDEO, “A design and innovation consulting firm,” Retrieved March 30, 2013, from http://www.ideo.com.

[9] B. Glaser and A. Straus, The Discovery of Grounded Theory: Strategies of Qualitative Research. London, UK: Wiedenfeld and Nicholson, 1967.

[10] C. Christensen, S. Anthony, and E. Roth, Seeing What's Next: Using the Theories of Innovation to Predict Industry Change. Boston, MA: Harvard Business School Press, 2004.

[11] A. R. Hevner, J. Park, S. T. March, and S. Ram, “Design science in information systems research,” MIS Quarterly, vol. 28, no. 1, pp. 75–105, March 2004.

[12] R. C. Basole and W. B. Rouse, “Complexity of service value networks: Conceptualization and empirical investigation.” IBM Systems Journal, vol. 47, no. 1, pp. 53–70, 2008.

[13] J. Ramanathan, “Fractal architecture for the adaptive complex enterprise,” Communications of the ACM, vol. 48 no. 5, pp. 51–57, May 2005.

[14] J. J. Duderstadt, “Engineering for a changing world: A roadmap to the future of engineering practice, research, and education,” The Millennium Project the University of Michigan, pp. 131–156.

[15] C. Boardman, D. O. Gray, and D. Rivers (Eds.), Cooperative research centers and technical innovation. New York, NY: Springer New York, 2012.

[16] K. Beck, and C. Andres, Extreme Programming Explained: Embrace Change. Boston, MA: Addison-Wesley, 2004.