Graduate Studies in Information Systems Engineering and Management (ISEM) for Digital Enterprises

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***Abstract*— Digital Enterprises of today and tomorrow need to be properly planned, architected, engineered, integrated and managed to meet the location and customer specific demands. There is a need for academic programs that concentrate on systems engineering practices with special attention to management and technology issues for a global market, including developing countries. A quick study of extant systems engineering academic programs has revealed that most do not consider information systems and engineering management topics. This paper describes an innovative graduate studies program that prepares well rounded systems engineers whose knowledge cuts across information systems, systems engineering, and engineering management for different populations. Highly flexible concentrations and capstone projects allow the students to gain knowledge in diverse sectors such as health, education, public safety, public welfare, energy, environment, agriculture and manufacturing. The steady growth in enrollments testifies to the appeal of this program.**

Keywords—Next Generation Enterprises, systems engineering, Enterprise2.0, Industry4.0, Digital Innovations

I. Introduction

We are living in an increasingly digital world that is dominated by the *Digital Enterprises (i.e., "the* organizations where nearly all significant business processes and relationships with customers, suppliers, and employees are digitally enabled and key corporate assets are managed through digital means" [4]). For example, in 2017, the top 5 companies on the Wall Street were high tech companies such as Google, Amazon, Apple, and General Electric. However, these digital enterprises are not one dimensional entities that are just exploiting mobile apps but in fact are *simultaneously* pushing the envelope in multiple dimensions that include Web, Outsourcing, Mobility, Security, Data, Globalization, AI, Analytics and several other technologies. Our objective is to address the following key questions:

- What are the next generation of digital enterprises and how do they look like in different parts of the world?
- What type of global challenges are posed to the academic programs by such enterprises?
- What is the conceptual model of a proposed graduate program that could addresses these challenges?
- Do the extant systems engineering programs meet these challenges?
- Has the proposed program been launched and what are the results so far?

II. Digital Enterprises

We have selected eight major digital technologies that define our reference multidimensional space shown in Figure1. This analysis proceeds by mapping various configurations of enterprises to regions in this space. With each technology, we associate a set of discrete values, {Low, Medium, High, Very High}, based on an informal, qualitative estimation shown in Figure1 – the center of the circle represents low reliance on digital technologies while the outermost circle represents high usage. In this model, traditional brick and mortar organizations represent the inner circle while *NGEs (Next Generation Enterprises)* represent the outermost circle because they fully exploit the following "mega trends" displayed in Figure1:

- *Web (W)* technologies for internal as well as external business activities on the Internet and Web technologies. Internet of Things and Web of Things show the high values of this dimension.
- *Mobility* (M) support for the mobile customers, workforce and operations over wireless networks that range from short range wireless sensor networks through Deep Space Communications.

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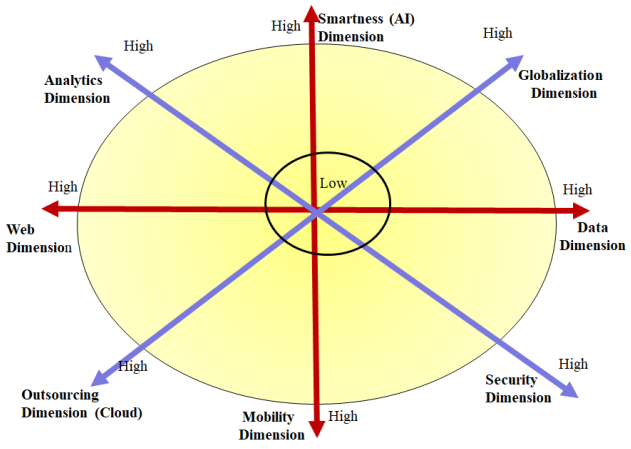

Figure 1: The Key "Mega Technologies" that are Driving Digital Enterprises (Source: [11]).

- *Data* (D) for internal as well as external business decisions. Low values indicate use of Excel spreadsheets on small files but high values represent heavy use of Big Data to make business decisions.
- *Smartness (*S) to quickly detect and respond to changing business conditions and learn from them to do a better job in the next round. Extensive use of Artificial Intelligence and Deep Learning represent the high values of this dimension.
- *Analytics (A*) dimension represents the use of statistical and optimization techniques to analyze, forecast and optimize business operations. High reliance on analytics techniques represent the high values of this dimension.
- *Outsourcing* (O) of operations to widely dispersed sites and partners is a common business practice at present. Cloud providers offer extensive capabilities for very high levels of outsourcing.
- *Security* (S) technologies are essential for most modern digital enterprises. Extremely high levels of security measures are needed for financial institutions, government agencies and defense organizations.
- Globalization (G) of operations to widely dispersed sites by using the broadband digital networks supported by satellite communication systems. Global enterprises conduct business operations that are dispersed across multiple locations in different countries and continents.

The eight dimensional model seems to capture a very large number of digital enterprises commonly discussed in the literature [2, 3, 5, 6, 7, 9]. While more dimensions can be always added, we feel that the 6 to 8 dimensions are good enough for our purpose, i.e., to represent a large number of digital enterprises in a simple yet elegant manner in diverse settings. For example, the large number of Smart Cities initiatives such as the United Nations New Urban Agenda [12] are heavily relying on the aforementioned technologies to address urgent issues for least developed countries (LDCs). The focus is on health, education, public safety, public welfare, transportation, agriculture, energy and the environment. On the other extreme, this model can also represent the emerging Industry4.0 smart factories based on IIoTs (Industrial Internet of Things) and industrial robotics [8]. In addition to large centralized corporations, this model can also be used to represent a smart global village consisting of widely distributed smart hubs, located in developed as well as developing countries, that collaborate with each other to address regional and global needs [16].

III. Requirements for Graduate Studies

There is an urgent need to educate the leaders who can plan, engineer/re-engineer, and manage the next generation of digital enterprises in a world where roughly half of the world population is being left out due to the digital divide [15]. For example, developments in Smart Health, Smart Agriculture, Smart Energy Grids and other NGE models offer unprecedented opportunities for modern organizations to make strategic decisions based on latest business and strategic intelligence. However, these opportunities also raise serious technical, business and social challenges due to the digital divide. Specifically, the future educational programs must consider the widening digital divide where almost half of the world population is being ignored and is not benefiting from the digital innovations.

To develop a suitable educational approach it is important to clearly understand how the digital technologies cut across and support multiple sectors, as illustrated in Figure 2. It is also important to consider the coordination and integration of services between multiple sectors in B2B (business to Business) scenarios. Specific examples include disaster recovery, healthcare exchanges, international food supply chains, telemedicine in developing countries, the impact of smart factories on economic development, and the implications of smart cities for public health and safety. In addition, the concept of smart global villages based on widely distributed smart collaborating hubs needs considerable research. We propose that the graduate studies in the digital age should satisfy the following requirements:

- The education must be based on flexible interdisciplinary programs that are especially suitable for *career change and/or career enrichment*.
- The program should be customizable for students with different backgrounds, educational/professional needs, and personal goals.
- Students should be able to enter the program with the following portfolios: a) IS/IT background who seek management training; b) Non-IS/IT background who want to develop more IS/IT expertise, and c) Mixture who want more depth in technology or technology management.
- *Bridge* courses should be available for students with insufficient IT backgrounds but with solid knowledge of vertical sectors such as health, pharmaceuticals, manufacturing, financials, agriculture, etc.
- Many free electives should be provided so that the students can study more management, more technologies or a mixture based on their interest. In addition, the student should be able to take electives to specialize in digital health, entrepreneurship, digital government, project management, information security, biotechnologies or a mixture of the above.

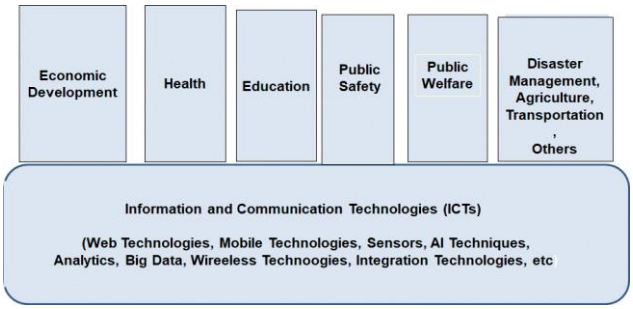

Figure2: How the Digital Technologies are Enabling Multiple Public and Private Sectors

IV. The Proposed Solution

We propose that the aforementioned challenges can be addressed through a highly flexible graduate program in *Information Systems Engineering and Management (ISEM)* that cuts across the following three active areas of work:

- *Information Systems*: latest digital technologies and innovations as represented by the eight dimensions (e.g., web-based components, mobile computing and wireless communications, IoTs, security technologies, data analytics, and artificial intelligence).
- *Systems Engineering*: systems thinking and emphasis on systems instead of individual components so that the interactions and tradeoffs between people, processes and technologies are fully leveraged to build smart solutions in diverse regions of the world [14]. The emphasis on systems engineering for engineering and managing complex information systems is of key importance.
- *Management:* innovative business strategies, entrepreneurship, planning, integration, security, governance and project management to assure that the NGEs are well aligned to the user needs and well managed for long range growth.

Figure 3 shows conceptual view of such a flexible and interdisciplinary program that emphasizes the entire Learn, Plan, Do, Check (LPDC) cycle instead of one narrow area of work. Digital enterprises and the digital technologies that enable such enterprises are at the center of the program. The core and recommended courses of the program allow the student to *Learn* about digital enterprises and technologies, *Plan* (i.e., translate their knowledge into working solutions), *Do* (i.e., architect, engineer and integrate the solutions), and *Check* (i.e., secure and manage the solutions). The student can then take elective courses in topics that span project management, analytics, multimedia management, entrepreneurships, digital health, enterprise management, leadership, financial aspects of systems, learning technologies, business intelligence, Internet technologies, information security and governance, mobile computing, and others. Specializations and "bridge courses" to other programs, displayed as the outermost circle should be also available to the students.

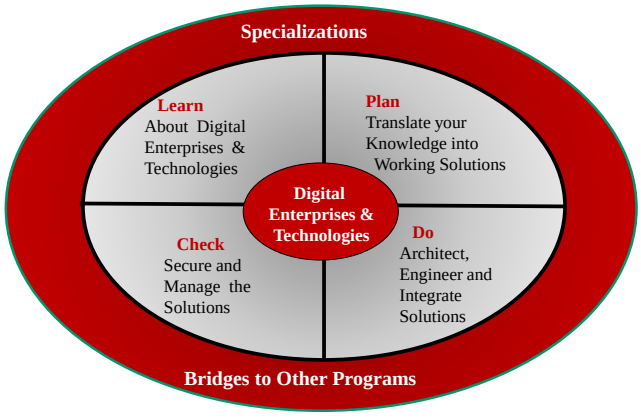

Figure 3: Conceptual View of ISEM

V. Status of The Extant Programs

A quick survey of the extant graduate programs has indicated that the proposed ISEM program does not exist at present (the ISEM acronym is being used by the International Society for Ecological Modelling). An extensive literature survey cannot be presented here due to space limitations but we have made the following observations based on our study of related programs:

- Most systems engineering programs largely ignore information systems while few ISE (Information Systems Engineering) programs such as the one at John Hopkins [14] ignore management considerations.
- Most academic programs in IT/IS focus either on IT (the horizontal layer) without much discussion of the vertical sectors or different vertical sectors (e.g., health, banking, agriculture, etc) without any attention to the horizontal enabling digital technologies.
- The MIS (management information system) programs reside in business schools and have business and strategy focus with no engineering aspects.

There appears to be a shortage of ISEM programs that cut across information systems, systems engineering, and engineering management.

VI. The Present ISEM Program

The MS in ISEM (Information Systems Engineering and Management) Program was launched at Harrisburg University of Science and Technology (HU) in 2010 to address the aforementioned needs. MS in ISEM, displayed in Fig 4, is a 36 credit hours (12 courses) program that is structured as follows:

- The five core required courses that provide a mixture of technical and management topics with global awareness
- The five electives that can be chosen from a large pool of courses in diverse topic areas. The students may select five electives from any of these topic areas to build their own specialization or choose to specialize in predetermined topic areas
- The two capstone courses that allow the students to synthesize their knowledge into an experiential project or a research thesis

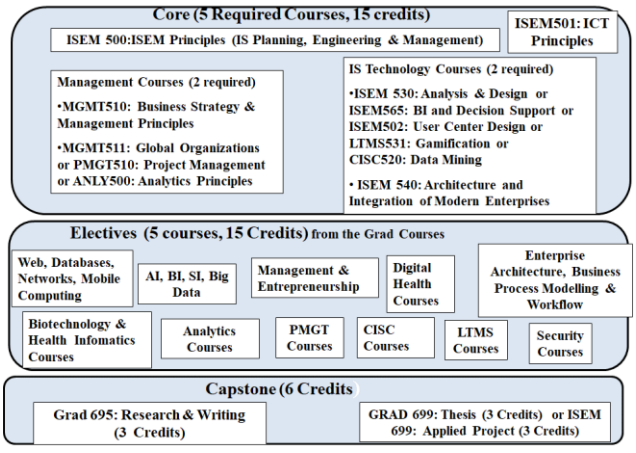

Figure 4: More Detailed View of ISEM Program

We expect that the students enter the program with basic knowledge of vertical sectors and/or horizontal layers. We make the program flexible enough so that they can detect and fill the gaps. The core courses and capstone projects emphasize planning, engineering and management of any digital enterprise anywhere in the world. The students are encouraged to exploit the latest digital innovations to help the underserved populations around the globe by using the resources made available by the United Nations and others.

Exhibit 1 shows a list of all ISEM Courses and other related courses. The most significant aspect of ISEM program is that the students may build their own specialization by taking 5 electives from *any* programs at HU such as Analytics, Biotechnologies, Computer Science, Cyber Security, Digital Health, Enterprise Engineering, Interactive Media, Learning Technologies, Project Management and Techpreneurship. Courses in Research and Writing and a master's thesis or applied project serve as the required capstone of the program. Basically, an ISEM student can take any 5 courses from any graduate program at HU as electives, totaling 15 semester hours. This option allows the ISEM students to focus on areas such as the following:

- Analytics by taking at least 9 semester hours in Analytics and using Analytics concepts in Capstone.
- Business Intelligence (BI) by taking at least 9 BI related courses and using BI concepts in Capstone.
- Digital Enterprises by taking at least 9 semester hours in Digital Enterprises and using Digital Enterprise trends in Capstone.
- Digital Health by taking at least 9 semester hours in Healthcare and using Healthcare concepts in Capstone.
- Digital Technologies by taking at least 9 semester hours in Digital Technologies and using Digital Technology trends in Capstone.
- Entrepreneurship by taking at least 9 semester hours in Entrepreneurship and using Entrepreneurship concepts in Capstone.
- Information Security by taking at least 9 semester hours in Security and using Security concepts in Capstone.
- Project Management by taking at least 9 semester hours in Project Management and using Project Management concepts in Capstone.
- An almost unlimited number of highly creative areas of focus by combining any graduate course work in ISEM with other HU courses to meet the changing needs of modern digital enterprises. For example, a student interested in forming a healthcare startup that specialized in security and privacy issues took one course in entrepreneurship, 2 courses in healthcare, 2 courses in security, and used his capstone to develop a business proposal for his startup company.

The MS in ISEM program was launched with modest enrollments but has gained significant ground since 2014. At the time of this writing, almost 1200 students are enrolled in the MS ISEM program. Buoyed by the success of MS in ISEM, we have launched a new Ph.D. in ISEM program to emphasize a strong foundation in information systems engineering and management with innovative applied research. Figure 5 displays an overall flow of the Ph.D program in ISEM. The program requires 36 credits of advanced work beyond MS in ISEM and consists of rigorous checkpoints and gateways after admission (e.g., qualifying examination and comprehensive examination). External deliverables such as conference and journal level publications are required in addition to a Ph.D dissertation, The students completing this program should be able to:

- Serve as thought leaders and visionaries in planning, engineering/re-engineering and management of the next generation of digital enterprises.
- Conduct original research on the impact of digital innovations on the enterprises and the work force.
- Push the envelope of *interdisciplinary knowledge* in three active areas of work (information systems, systems engineering, and management) towards a globally sustainable environment for all.

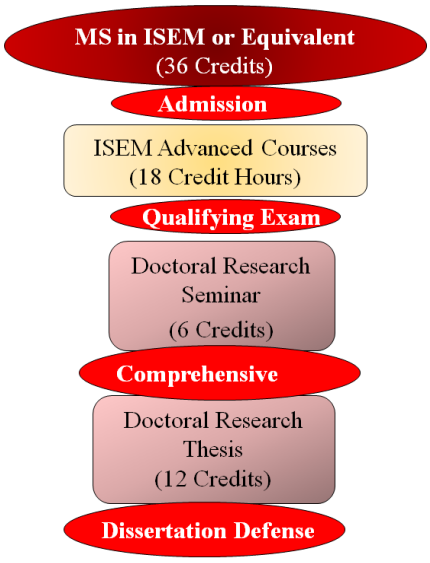

Figure 5: Doctoral Studies in ISEM

Doctoral candidates are required to complete six doctoral-level courses (700-level, 18 semester hours); six semester hours in a formal research seminar; and 12 semester hours of dissertation work. A total of 72 semester hours of coursework and research is required beyond the baccalaureate degree, including 36 semester hours at the master's level. The main courses are listed in Exhibit2. As can be seen, the core courses cove practical topics such as smart enterprises and strategic intelligence, advanced business process modeling and simulation, advanced systems engineering, and advances in operations management and entrepreneurship. One of the active areas of research is the use of latest digital innovations to support the United Nations Sustainable Development Goals for the underserved populations [15]. Other topics are being explored at present.

Exhibit1: MS in ISEM -- Courses and Other Related Courses at a Glance

Core Courses for MS in ISEM (15 semester hours)

- ISEM 500: IS Planning, Engg & Management
- MGMT 510: Business Strategy & Management Principles
- ISEM 540: Architecture and Integration of Modern Enterprises
- ISEM 502 User Centered Design or ISEM530 or ISEM565 or CISC510 or LTMS531
- MGMT 511 Digital and Global Enterprises or PMGT510 or ANLY500

ISEM Capstone (6 Semester Hours)

- GRAD 695: Research Methods & Writing
- GRAD699/ISEM 699: Applied Project or Research Thesis

ISEM Elective Courses

Digital Technology Courses

- ISEM 501: Information & Communication Technologies
- ISEM 534: Database Design and Management
- ISEM 536: IT Infrastructure & the Internet
- ISEM 551: Web-based Software Engg
- ISEM555: Mobile Computing and Wireless Communications
- ISEM 558: IoTs and Embedded Systems
- ISEM570: IT Quality Assurance

Business Intelligence (BI) Related Courses

- ISEM 503: Artificial Intelligence Principles and Applications
- ISEM564: Big Data Applications
- ISEM 565: Business Intelligence and Decision Support
- ISEM572: Smart Enterprises and Strategic Intelligence

ISEM Courses (Cont)

Enterprise Engineering Courses

- ISEM 530: Analysis & Design of Information Systems
- ISEM 550: Information Security Management
- ISEM 525: Business Process Modeling and Workflow
- ISEM539: Enterprise Architectures Frameworks
- ISEM 560: eGovernment and eCommerce
- ISEM 568: Aligning Business Strategy with IT Strategy
- ISEM 574: Block Chains and Bit Coins

Enterprise Management and Entrepreneurship Courses

- ISEM 547: IT Management
- MGMT 512: Marketing in the Digital Age
- MGMT 513: Financial and Managerial Accounting
- ISEM 520 Service Science, Management and Engineering
- MGMT 531: Business Entrepreneurship Principles
- MGMT 532: Business Entrepreneurship Management
- MGMT 533. Business and Entrepreneurial Financing
- ISEM 561 Public Administration
- ISEM 562: Public Policy

Digital Health and Life Sciences Courses

- ISEM 521: Life Science for IT Professionals
- ISEM 541: Healthcare Systems
- ISEM 542: Health Informatics and Information Systems
- ISEM 543: Digital Health
- ISEM 544: Social, Technical and Organizational Issues in Digital Health
- ISEM545: Healthcare Data

Exhibit2: Ph.D in ISEM at a Glance

ISEM PhD students are required to complete six (6) courses from the following upper-level courses – 18 semester hours:

- ISEM 700: Smart Enterprises and Strategic Intelligence
- ISEM 725: Advanced Business Process Modeling and Simulation
- ISEM 730: Advanced Systems Engineering
- ISEM 760: Advances in Operations Management or a 700 level course in Analytics
- MGMT 731: Advances in Entrepreneurship and Innovation or a 700 level course in Analytics
- ISEM 770: Advanced Topics in ISEM

Students then complete six hours in the Doctoral Research Seminar:

- ISEM 780 Doctoral Research SeminarI
- ISEM 781 Doctoral Research SeminarII

Students must also complete the dissertation process by taking 12 semester hours of:

- ISEM 799 Doctoral Studies

VII. Program Outcomes

The ISEM program has grown rapidly from 10 students to 1200 students in last 5 years. Most of the ISEM graduate students are on F1 visa and are finding employment opportunities in diverse industries such as agriculture, banking, healthcare, information technologies, manufacturing, pharmaceuticals, retail stores, telecommunication providers, and government services. Many students have become entrepreneurs who have launched their own successful companies in developing countries.

The experience of launching and running a highly flexible interdisciplinary program at Harrisburg University of Science and Technology (HU) has given us many insights about the possible difficulties encountered in running such programs in large traditional universities. HU is a small entrepreneurial STEM (Science, Technology, Engineering and Mathematics) school that can adjust quickly to meet market needs. Incorporated in the Commonwealth of Pennsylvania in 2001, HU addresses the local and global need for increased educational opportunities in STEM careers. The HU Graduate School offers MS degrees in Biotechnology, Computer Science, Data Analytics, ISEM, Health Informatics, Learning Technologies, Project Management, and others. We have started offering Ph.D. degrees in Data Analytics and ISEM, more will follow. The unique features of STEM education at HU are:

- It is a relatively flat organization with no rigid departments. Academic degrees are offered by programs that can be quickly combined with other programs to launch new programs.
- Instead of individual interdisciplinary programs, the entire graduate school is interdisciplinary with courses and faculty shared between different programs.
- All graduate courses are considered a pool of courses that can be taken by students from any program as free electives. This makes it very easy to launch highly flexible programs such as ISEM.
- As new programs are introduced, the pool of available courses gets larger which benefits all programs.

We have found that the entrepreneurial spirit is best suited for education in the 21st century and is the primary reason for the rapid growth of HU from 450 students to over 5000 students in last 5 years.

VIII. Conclusions

Modern digital enterprises are *simultaneously* exploiting the web, cloud computing, mobility, security, big data, AI, analytics and a multitude of other technologies to compete and succeed in the marketplace at a global level. The enterprises need to be properly planned, architected, engineered, integrated and managed to meet the location and customer specific demands. There is a need for academic programs that concentrate on systems engineering practices with special attention to management and technology issues for a global market, including developing countries.

This paper has presented a flexible interdisciplinary graduate studies program that prepares well rounded systems engineers and managers whose knowledge cuts across information systems, systems engineering, and engineering management to meet the challenges faced by developing as well as developed countries. Highly flexible concentrations and capstone projects allow the students to gain knowledge in diverse sectors such as health, education, public safety, public welfare, energy, environment, agriculture and manufacturing. The students are encouraged to exploit the latest digital innovations to help the underserved populations around the globe by using the extensive resources made available by the United Nations, the World Bank, the World Health Organization, the World Economic Forum, and others.

Acknowledgements: The dedication, hard work and friendship of the Harrisburg University students, faculty, administration and staff is greatly appreciated.

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