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Strategic Project Management to Use the Grand Challenge Scholars Program to Address Urban Infrastructure

Abstract Throughout the world, infrastructure to support cities is critical to support sustainable and responsible economic development. This can include new infrastructure projects in the case of growing areas. It can also include the renewal and upgrading of existing infrastructure in areas that have been inhabited and already developed. Infrastructure includes roads, bridges and transportation systems; power grids and energy service; internet and telecommunications; and water and sewer services. This development can be part of a system of systems, in which government, industries, and universities can contribute knowledge, skills, and abilities. This paper will investigate the strategic project management taken by one university to provide an academic experience that will prepare engineering students to address several of the Grand Engineering Challenges of the 21st Century, as identified by the US National Academy of Engineering. The challenges relating to energy, water, information, and urban infrastructure can be approached using the functions of teaching, research, and service. By approaching the challenges strategically, resources of faculty time, student effort and laboratory facilities can be leveraged to achieve greater results. This case study will describe the efforts and results to date and identify opportunities for future growth.

Keywords: Grand Challenges, urban infrastructure development, engineering management, system of systems, strategic management, engineering management case study

1 Introduction

Human civilization has developed rapidly over the last 10,000 years. We have evolved from local tribes of hunter-gathers to be globally interconnected. This development has been accelerating and many of the systems we have developed are no longer capable of meeting the demands of today's world, let alone tomorrow's world. This growth has put an incredible strain on the earth's resources as well, as evidenced by extinctions of species and societal impacts of climate change.

Infrastructure is a critical aspect of providing services to people, allowing for trade, transportation, and economic development. Development of infrastructure requires an integration of technology, design for sustaining the environment, and understanding societal needs. Planning, designing, implementing, operating, and maintaining infrastructure systems is very complex and requires a structured and systematic approach.

To approach large problems that are extremely complex, system of systems engineering can be useful. The SoSE approach facilitates the incorporation of many perspectives and allows for effective integration of numerous systems. Keating, Rogers, and Unal (2003) describe SoSE, compare it to traditional systems engineering, describe its use, and provide insights for practitioners and academics for its use and development.

In 2008, the US National Academy of Engineers announced the 14 "Grand Challenges of the 21st Century." Of the 14, two rely heavily on the contributions of the civil engineering discipline.

This paper will review these grand challenges and describe the approach taken by West Virginia University to approach them in a strategic manner using the Grand Challenge Scholars Program. The case study will describe the activities to date and suggested future activity will be made.

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2 Grand engineering challenges of the 21st century

The National Academy of Engineers assembled a panel of more than 50 subject matter experts from around the world to identify the greatest challenges facing humanity that

would improve how humans live, if met. Over the course of two years, the panel grouped challenges into four main groups, dealing with sustainability, health, reducing vulnerability, and joy of living. The fourteen grand engineering challenges are grouped in Table 1 (NAE, 2008).

The grand engineering challenges have become recognized and relevant around the world. Since 2013, there has been a Global Grand Challenges Summit every two years. The first was held in London and the 2015 Summit was held in Beijing (NAE, 2016a). Three West Virginia University students attended the Beijing Summit and were much energized from the experience.

Of the fourteen grand challenges, two, access to clean water and restoring and improving urban infrastructure will rely heavily on the civil engineering discipline. Providing access to clean water will require hydrology, pipelines, treatment, environmental protection, and other aspects of engineering. Restoring and improving urban infrastructure will require planning, transportation, construction, and environmental engineering, among other aspects. Both require protection of the natural environment, protection of cultural heritage and artifacts, recognition of political and social factors, and consideration of many other factors. Because of the complexity of each of these challenges, a system of systems engineering approach would be reasonable.

Table 1

Grand Engineering Challenges of the 21st Century

Challenges	Content
Sustainability	Make solar energy affordable
	Provide energy from fusion
	Develop carbon sequestration methods
	Manage the nitrogen cycle
Health	Provide access to clean water
	Restore and improve urban infrastructure
	Advance health informatics
	Engineer better medicines
	Reverse-engineer the brain
Reduce vulnerability	Prevent nuclear terror
	Secure cyberspace
Improve joy of living	Enhance virtual reality
	Advance personalized learning
	Engineer the tools for scientific discovery

3 An SoS case study for the Grand Challenges

The introduction of the Grand Engineering Challenges in 2008 stirred considerable interest. Duke University, Olin College, and the University of Southern California proposed a "new education model to prepare engineers to be world changers" (NAE, 2016b). The Grand Challenge Scholars Program, or GCSP, consists of five components: a hands-on project or research experience related to a Grand Challenge, an interdisciplinary curriculum to help frame the Grand Challenge from different perspectives, entrepreneurship to develop a sense of how to identify and act on opportunity, a global dimension to develop a multicultural and international perspective, and service learning to comprehend the impact of working with people and society.

In March 2015, Gene Cilento, the Glen H. Hiner Dean of the Benjamin M. Statler College of Engineering and Mineral Resources at WVU, signed a letter with 122 engineering deans in the US addressed to President Obama pledging to graduate a minimum of 20 students per year who are able to address the Grand Challenges (NAE, 2015). This letter has set into motion plans to initiate a GCSP at West Virginia University.

A university must propose to become an official member of the GCSP community. The 2015 letter was simply a letter of intent. The proposal requires a vision and goals statement, a description of the steering committee and organization structure, a recruiting strategy, a description of how students can apply and be selected, recruitment and selection of faculty mentors, the funding and support to be provided, a description of the unique aspects of this particular program compared to other programs, details of the five curricular elements, a description of how students will be mentored and supported through the program, details of how program graduates will be recognized, and a plan for continuous improvement of the program.

System of Systems Engineering has been used to study the interaction of industry, government, and higher education in the Dallas-Fort Worth metropolis of Texas, USA (Ilseng, 2015). That work studied the performance measures that could be used in a system of systems. Using this philosophical framework that universities work in a complex system that relates to government (society) and industry, we intend to develop a Grand Challenge Scholars Program that is symbiotic and virtuous.

The Guide to the Engineering Management Body of Knowledge, published by the American Society for Engineering Management (ASEM, 2010), includes domains of strategic planning and project management. This information is very useful in designing a program and implementing it to achieve a distinctive program.

The WVU proposal is titled the Mountaineer Grand Challenge Scholars Program. At the time of writing of this paper, the proposal is undergoing editing and is expected to be submitted for NAE review by August 2016.

It is envisioned that the graduates from the Mountaineer GCSP will be sought for their demonstrated ability to identify significant opportunities and bring their solutions to reality, recognizing the societal and global impacts of the issues and working effectively in a wide variety of settings

with many different people.

The curriculum is designed to initially be satisfied by a minor of 15 semester credit hours. It will consist of courses within and outside the Statler College. We expect that at least 60% of the GCSP students will complete some of their coursework at international partner universities that can provide courses and/or research opportunities that support the student's selected grand challenge. As an example, civil engineering students addressing a grand challenge in urban infrastructure may elect to take a semester of courses in Bahrain in a joint development with the Royal University for Women. Students may satisfy some of the curricular components by participating in non-coursework activities; a student may satisfy the entrepreneurship aspect by participating in one or more of the many available business plan competitions; similarly, a student may satisfy the global component by being an active member of Engineers Without Borders; in any case, the students will still be required to have a minimum of 15 hours of identified coursework for the minor.

As a result of the need to develop appropriate study abroad opportunities for GCSP students, the various engineering departments within the Statler College will be identifying strategic international partner universities. The departments will develop options for students to study at these schools so that their courses can be integrated into their major degree program as well as accepted for GCSP credit.

Resistance to change is a major challenge to many initiatives. Fortunately, the department chairs have expressed their strong support for the Mountaineer GCSP program. This support will be invaluable as students develop their plans of study for the program.

4 Summary and conclusions to date

This paper has reviewed the 14 "Grand Challenges of the 21st Century." Providing clean water and restoring and improving urban infrastructure are two of these challenges. System of Systems Engineering provides a framework to address complex problems, and is an appropriate model for addressing these challenges.

The Grand Challenge Scholars Program is intended to encourage universities to develop new educational approaches to prepare graduates to be able to address large problems holistically. The case of West Virginia University's GCSP proposal development was presented.

Significant resources may need to be invested to support a GCSP. Many curricular requirements can satisfied with existing on-campus course offerings or service opportunities. Projects and research require staff and faculty support and lab resources. Study abroad may require additional scholarship support to assist with travel and additional expenses. Administrative oversight and faculty mentoring will require time and potential reallocation of resources. The rewards of the program and the potential breakthrough contributions of the GCSP scholars to society make this investment worthwhile.

Effectiveness of the program will be assessed and evaluated using the accreditation framework used in ABET reviews. Minors are not accredited, but the process used for ABET incorporates significant quality assurance for continuous improvement.

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