The Goethals Infrastructure Challenge: A Proposal for a New Student Competition

Lt. Col. Steven D Hart, U.S. Military Academy

LTC Steve Hart is currently assigned as the ERDC Engineering Fellow and Director of Infrastructure Studies at West Point. He has taught numerous civil engineering courses including innovative courses on Infrastructure Engineering and Critical Infrastructure Protection and has authored numerous articles and a book chapter on these subjects. He is the developer and lead proponent of The Critical Infrastructure Symposium, now in its third year. He is active in The Infrastructure Security Partnership and the American Society of Civil Engineers including services on the Committee on Critical Infrastructure as well as the American Society of Engineering Education.

Johnette C. Shockley, U.S. Army Corps of Engineers, Engineer Research and Development Center

Johnnie Shockley is a Civil Engineer/Technology Transfer Officer with the US Army Corps of Engineers (USACE) Engineer Research and Development Center (ERDC), Office of Technology Transfer out of the ERDC's executive office located in Ft. Belvoir, Va. Johnnie currently works virtually as the Office of Research and Technology Applications (ORTA) for the ERDC Cold Regions Research Laboratory in Hanover, NH., and the Topographic Engineering Center, Research Division of the Army Geospatial Center. She is an ERDC liaison to the Army Educational Outreach Program where she is committed to inspiring the next generation of scientists, engineers, and technologists.

Mrs. Leah R Ellis, University of Nebraska, Peter Kiewit Institute
Major Berndt Spittka P.E., Unitee States Military Academy- Department of Civil and Mechanical Engineering

Major Berndt Spittka is currently an instructor in the Department of Civil and Mechanical Engineering at the United States Military Academy. Spittka's education includes a B.S. in Civil Engineering from USMA, a Master's of Engineering Management from University of Missouri Science and Technology and a Science Master's of Civil Engineering from Massachusetts Institute of Technology. MAJ Spittka is a Registered Professional Engineer in Missouri. Spittka's research interests are Design for future repair, Critical Infrastructure, Design for Sustainability and Engineering Education. He is an active member of the American Society for Engineering Education and the American Society of Civil Engineers.

The Goethals Infrastructure Challenge: A Proposal for a New Student Competition

Abstract

The American Institute of Steel Construction (AISC) and American Society of Civil Engineers (ASCE) Steel Bridge and ASCE's Concrete Canoe competitions are a staple of civil engineering education. These two competitions provide a technical design problem for students to solve under very tight performance requirements, solution envelopes, and evaluation standards which tend to drive competitors to similar, optimized solutions. In contrast to these highly structured problems, both the National Academy of Engineering (NAE) and the American Society of Civil Engineers (ASCE) report that the engineer of the 21st Century will also be called upon to solve extremely complex, daunting, and ill-structured problems. The authors and their institutions are currently developing the Goethals Infrastructure Challenge as a new student competition built around solving the social-technical, complex adaptive, and 'wicked' problems associated with designing, constructing, operating and maintaining the world's infrastructure. This paper explains the organization of the *Goethals Infrastructure Challenge*, the student learning objectives for participating in the challenge, the annual process used to formulate the challenge, required funding mechanism, submission procedures, judging and evaluation plans, and budgeting and funding. In addition to being educational, this competition is designed to inspire a new generation of engineers to address the challenges we face in "restoring and improving urban infrastructure" and "providing access to clean water" as suggested by the NAE, managing the $2.2 trillion necessary to improve our infrastructure, and defining what infrastructure should be and do when functioning optimally in the knowledge-based, global economy of the 21st Century. For this reason, the challenge is named for George Washington Goethals who, with the building of the Panama Canal, transformed 20th Century infrastructure in the hope that this event will inspire the participants and the engineering profession to transform the 21st Century infrastructure in a similar way.

Infrastructure in our National Discourse

Over the past ten years, our professional engineering societies have attempted to envision the future of the profession, to describe the engineer of the future, and to provide guidance for developing the profession that the society of the future will need. In one of the earliest of these works, The National Academy of Engineering (NAE) in *The Engineer of 2020* describes how engineers will have to solve technical problems in a social-political-economic context that includes issues of sustainability, changing demographics, security, emerging technologies, and increased urbanization. This is compounded by a professional context marked by increased business and operational complexity, multi-disciplinary teamwork, requirements for advanced technical knowledge, and a global market place. To operate within context, the NAE aspires to engineers who are creative and innovative in forming and leading interdisciplinary teams to solve complex problems at the intersection of engineering, business, policy, and social need. NAE further aspires to engineers moving beyond traditional technical fields and aspiring to "assum[ing] leadership positions from which they can serve as positive influences in the making of public policy and in the administration of government and industry" (1). Theory and calculations remain necessary for success as an engineer, but in 2020, they will no longer be sufficient.

Similarly, the American Society of Civil Engineers (ASCE) recognized that the infrastructure of the future will require a transformation in the role and development of engineering professionals. In *The Vision for Civil Engineering in 2025*, ASCE envisions "civil engineers will serve as master builders, environmental stewards, innovators and integrators, managers of risk and uncertainty, and leaders in shaping public policy." (2). The first of these is a traditional role of civil engineers and one at which the profession excels; the remainder are not. Although engineers are typically comfortable discussing technical matters with other engineers, we are generally underprepared for discussing complex ideas with the general public or engaging in the multi-disciplinary problem solving required for environmental stewardship, innovation, risk management, and public policy. To address this deficiency, ASCE included two new and three modified outcomes in the Second Edition of the *Civil Engineering Body of Knowledge for the 21st Century* (BOK2) (3):

Outcome 2 Natural Sciences (new)
Outcome 17 Public Policy (new)
Outcome 12 Risk and Uncertainty (separated for increased emphasis)
Outcome 18 Business and Public Administration (separated for increased emphasis)
Outcome 22 Attitudes (separated for increased emphasis)

ASCE further recognizes the need to develop new ways of thinking about emerging problems in *Guiding Principles for the Nation's Critical Infrastructure.* This document articulates four principles to inform the nation's approach to critical infrastructure issues:

Quantify, communicate, and manage risk
Employ an integrated systems approach
Exercise sound leadership, management, and stewardship in decision-making processes
Adapt critical infrastructure in response to dynamic conditions and practice

It is easy to map these principles to the outcomes of BOK2, especially the new and revised outcomes highlighted above; it is also easy to see they do not look like 'traditional' civil engineering. Instead, they are a further recognition that the engineers of the future must augment traditional engineering skills with a conceptual framework that includes and accounts for the social, economic, and policy aspects of the problems we will face.

As a topic of personal, professional ,and political discourse, infrastructure is in the news and the water cooler conversations. Since 1998, the American Society of Civil Engineers (ASCE) has continually reported that the infrastructure of the United States is exceeding its design capacity and is aging, accumulating an ever increasing requirement for maintenance and renovation (4). This condition directly affects the economic performance of the country. The Global Competiveness Report of the World Economic Forum (5) shows that between 2008 and 2011, the quality of the United States' infrastructure has fallen from 9th to 16th in the world, with a corresponding fall in overall economic competiveness from 1st to 5th. Fortunately and certainly due in part to efforts by the ASCE and WEF, infrastructure has become more prominent in public discourse (Figure 1) (6). This discourse is not limited to the national level with local newspapers arguing also for improvements not only in local and regional infrastructure, but also in national infrastructures which have direct impacts on local economies (7).

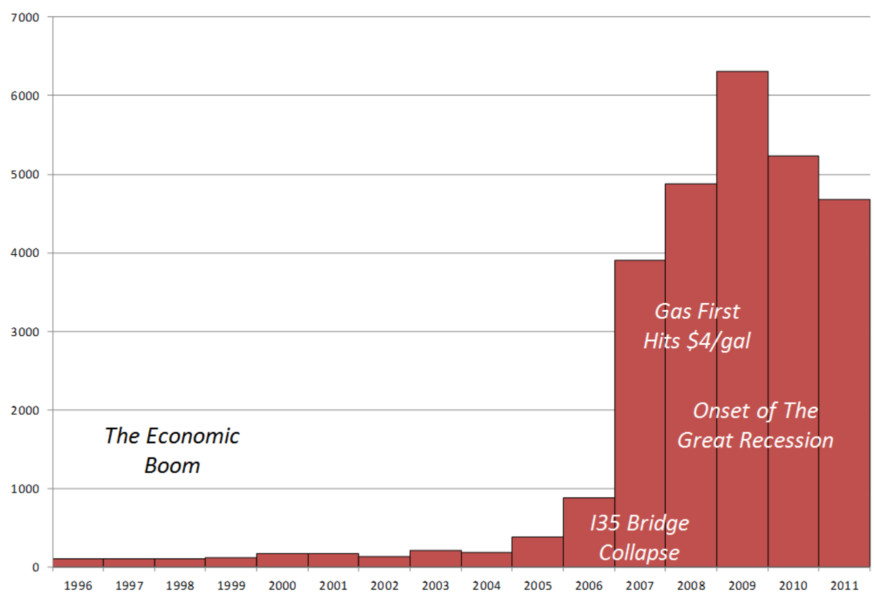

Figure 1: Appearances of the word Infrastructure in U.S. Newspapers

Academic interest in infrastructure has grown in response to the political and social demand for action on aging and emerging infrastructures. Since the events of September 11, 2001 and the hurricane season of 2005, critical infrastructure protection has been an essential topic in homeland security academic programs. The Critical Infrastructure Symposium (CIS), which began at West Point in 2010 as a student conference attracting 60 participants drew 150 participants from the United States, Canada, and Europe in 2012. Attendance in 2013 is expected to be over 200. One aspect of The CIS is a 3 hour seminar on infrastructure education. At the first seminar in 2011, organizers were expecting 12 participants; over 60 attended with similar attendance in 2012. The University of Wisconsin-Platteville and West Point have submitted an NSF proposal to expand their existing infrastructure engineering courses to ten partner institutions that have committed to teach new undergraduate infrastructure engineering courses if the proposal is funded. Infrastructure topics have grown in prominence in engineering programs as evidenced by an NSF to Clemson University for the establishment of a master of science program in Sustainable and Resilient Infrastructure (8) and the Sustainable and Resilient Infrastructures Program launched in 2012 at Illinois University (9).

If asked over dinner or at the water cooler, a civil engineer is very likely to say, "Civil engineers have been building infrastructure for 2,000 years." Even though this is true, the use, understanding, and interest in all things infrastructure has grown in the mind of the public in the past ten years to the point that is a common element of public and private discourse. Academic, professional, and government programs have responded accordingly and the competition proposed in this paper furthers that response.

The Nature of Problems

One inescapable conclusion of studying infrastructure problem is that they are 'different.' This difference tends to appear when someone asks a question like, "We replaced the I-35 bridge in Minneapolis is about a year; why did it take us ten years to replace this local bridge?" The speaker inherently grasps the idea that there must be more to bridge building than technical requirements. This difference can be articulated in different problem classes found in literature. Technical problems are characterized by a consensus on the nature of the problem, an ability to use metrics to evaluate options leading to an optimal solution, and a general agreement when the solution has been achieved (10). During the scientific and industrial revolutions, the engineering profession came into its own through our skill in solving the technical problems associated with those eras.

In the 20th century, many technical solutions began to detract from the quality of life they were intended to support. Toxic chemicals resulting from industrial production of consumer goods people wanted resulted in toxic waste dumps people did not want. This conflict of a social good like a clean environment with at technological good like an aluminum can gave rise to the idea of social-technical problems which, as the name implies, have a strong technological component with significant societal implications. These problems are characterized by layered networks where the immediate problem at hand requires a network representation and this problem as a whole is also a node in a higher level problem (11). These problems are so different in their nature that Professor Joseph Sussman of MIT argued a new field of study in Sociotechnical Systems (12). Infrastructure problems are clearly social-technical problems: the problems and solutions are based in technology but are only undertaken in the service of society.

Infrastructure problems can also be characterized as *wicked* after the concept of Rittel and Webber (1973). Rittel and Webber listed ten characteristics of *wicked* problems yet offered no formal definition of the term. Wicked problems can generally be characterized by a lack of agreement on what the problem is, a lack of agreement on the evaluation metrics, a lack of agreement on potential acceptable solutions, and the inability to optimize to achieve the best solution. These externalities to the problem are compounded by the fact that every attempt to solve the wicked problem irreversibly changes the system in question and the problem itself—there are no Mulligans when it comes to *wicked* problems. Unlike technical problems, *wicked* problems are never solved; they are merely temporarily resolved.

As we look into the future, technical problems have not gone away, but they have been joined by social-technical, wicked, complex-adaptive, complex-evolving, and other yet-to-be-determined problem characterizations. It is this recognition that has led the NAE and ASCE to challenge the engineering profession to take a leadership position in these problems spaces. When one also considers that the solution to many technical problems can be commoditize and outsourced (13), it is imperative that our students are able to solve not only technical problems but also ones of the social-technical, complex adaptive, and *wicked* varieties.

A Brief Assessment of Existing Competitions

Many competitions exist for engineering students. This section will summarize some of these competitions classify them according to the students they focus on and the types of problems they address.

Many, if not most civil engineers are familiar with the Steel Bridge and Concrete Canoe competitions. The first national level steel bridge competition was held in 1992 and continues through today. It is sponsored by the American Institute of Steel Construction and the American Society of Civil Engineers and its mission is "to supplement the education of civil engineering students with a comprehensive, student-driven project experience from conception and design through fabrication, erection, and testing, culminating in a steel structure that meets client specifications and optimizes performance and economy" (14). In this competition, the all bridge dimensions are set and the ability to innovate is tightly constrained. Since an optimal result is sought, designs that perform well tend to be very similar. The problems addressed in this competition are all technical in nature.

The Concrete Canoe Competition grew from individual competitions in the 1960s to regional competitions in the 1970s to a national completion in 1988. The competition is sponsored by the American Society of Civil Engineers and competitions are now held internationally. According to the competition website, the competition provides a practical application of engineering principles learned in the classroom and application of leadership and management skills. The basic profile of the canoe is proved by ASCE, but this can be modified by student teams. The principle area for student innovation is in the mix design which each team must formulate within the given requirements (15). Like the Steel Bridge, the Concrete Canoe Competition is a technical problem. There is a fixed, common understanding of the problem, the solution can be optimized, and there are no substantive differences in the winners and near winners.

In contrast to these two leading civil engineering competitions focused on technical problems with tightly defined parameters, other competitions offer open-ended challenges which often include opportunities for the participant to define the problem. For example, The Institute for Soldier Nanotechnologies (ISN) at the Massachusetts Institute of Technology (MIT) is in the tenth year of sponsoring the Soldier Design Competition. The competition typically lists four to six challenges faced by soldiers in a deployed environment and always includes an 'Open Design Challenge' where the participants can identify a need and propose a solution (16). The submissions in the open category are often the most innovative and perform highly in the competitions. Representatives from industry are present at the final presentations and several competition submissions have progressed to industrial trials. (17)

In another competition, The National Homeland Defense Foundations annually sponsors the National Security Innovation Competition that challenges college students to address critical needs in any area directly related to national security and homeland defense. Leading submissions are presented to an audience of industry, academic, and government leaders. Industry technical scouts are also present giving the potential for further funding opportunities, development, patents, or even production of submitted projects. Beyond saying the projects meet a national security need, the contest does not specify requirements or guidelines. Participants must determine the need and the solution. The open ended nature of the completion has resulted in submission including on-demand thermal protection for vehicle crew members, a pathogen detection device, and a hybrid engine for an un-manned aerial vehicle (18).

The Mathematical Contest in Modeling (MCM) sponsored by COMAP, the Consortium for Mathematics and Its Applications, is enjoying its thirtieth year of success. This contest offers contests students the opportunity to answer one of two challenge questions in mathematical modeling in a 96 hour contest. The challenge questions are typically posted on Thursday evening with submissions required by Monday evening. The challenge questions are designed to be open ended are unlikely to have unique solutions. Participants may use any available inanimate resources. From the institutional perspective, this contest has minimal overhead. Registration cost is $100 and students perform all work at a convenient location of their choice (19). The long success of this contest demonstrates that student will respond and participate to intense, time compressed, open ended challenges.

Both of these competitions have been successful in allowing participants to define the problems at hand and propose solutions. They function with minimal rules and guidelines and submitted solutions all look different, even if addressing the same challenge. Perhaps the most important aspect of both competitions is the presence of technical scouts from industry which indicated that the problems addressed are real world problems and the solutions proposed have economic potential.

The preceding information all points to an opportunity for a new engineering, strike that, a new multi-disciplinary completion opportunity. The topic of infrastructure is clearly prevalent in our national discourse and challenges for the 21st century as envisioned by our professional societies. Many elements of the ASCE BOK2 are related to infrastructure and academic interest in solving infrastructure problems in growing. The focus of our current national engineering contests in solving technical problems is not in consistent with the social-technical, complex-adaptive, and 'wicked' problems associated with infrastructure issues. The success of the Soldier Design Competition and the National Security Innovation Competition shows that a competition can be based on participant defined complex problems. This paper proposes the Goethals Infrastructure Challenge as an inter-disciplinary student competition to address the challenge of 21st century infrastructure and develop participants as wicked problem solvers.

Development

The Goethals Infrastructure Challenge is organized around six fundamental concepts. First, the challenge is to inspire participants. We currently live in and with an infrastructure that was designed for an industrial age economy when we have passed through the service based economy and currently have a knowledge based economy. Our society needs a new generation of engineers, planners, politicians, and leaders to shape and build 21st century infrastructure in the same way that 20th century infrastructure was shaped by the Panama Canal, rural electrification, and the Eisenhower Interstate Highway System. We must inspire the world renowned engineers of the 21st century. This inspiration is achieved in name, scope, and organization of the challenge. The event is named for George Washington Goethals who was responsible for transforming 20th century infrastructure in the Panama Canal and the scope will challenge participants to transform 21st century infrastructure in a like manner. It is intended that the scope may appear nearly impossible because this is the nature of infrastructure problems. Besides, there is no inspiration is solving an easy problem. The presence of leading infrastructure engineers, policy experts, and employers on the evaluation committee serves as an inspiration to participants and communicates the seriousness of the work being undertaken for the future of the nation.

Second, real world infrastructure issues are inherently wicked to use the term and characteristics proposed by Rittel and Webber (1973). See Figure 2. Therefore, the Goethals Infrastructure Challenge must prepare participants to solve wicked problems by presenting them a wicked problem to solve which drives the characterization of the challenge. The problems proposed must be consistent with characteristics of Figure 2.

1. There is no definitive formulation of a wicked problem.

2. Wicked problems have no stopping rule.

3. Solutions to wicked problems are not true or false, but good or bad.

4. There is no immediate and no ultimate test of a solution to a wicked problem.

5. Every solution to a wicked problem is a "one-shot" operation; because there is no opportunity to learn by trial and error, every attempt counts significantly.

6. Wicked problems do not have an exhaustively describable set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.

7. Every wicked problem is essentially unique.

8. Every wicked problem can be considered to be a symptom of another problem.

9. The existence of a discrepancy representing a wicked problem can be explained in numerous ways.

10. The planner has no right to be wrong.

Figure 2 Characteristics of Wicked Problems by Rittel and Webber

Third, the challenge posed must address an actual societal need and problem formulation associated with the need must come from the participants. It must be done this way because when considering wicked problems, problem definition and solution conception are concurrent and interdependent activities. Every effort in defining the problem shapes the potential solutions and the conception of an innovative solution changes the perception of the problem (20). The second and third characteristics are satisfied through the formulation of the challenge statement. Infrastructure meets a societal need so the challenge statement will be formulated in terms of a societal need, for example: reduce urban roadway congestion or increase the resilience of the greater New York City metropolitan area to hurricanes. The method of challenge formulation is explained below.

Fourth, as participation in the Challenge will require a substantial input of student and faculty time, it is expected than most participants will be awarded course credit for participation. This means the Challenge must support a programs outcomes and objectives. Therefore outcomes and objectives will be established for the Challenge which will allow participation to be included in course and program evaluation. Consistent with the ABET definitions (21), the Challenge Educational Objectives (CEO) are broad statements that describe what participants are expected to do a few years after participating in the challenge. Participant Outcomes (PO) describe what students are expected to know and be able to do upon completing the challenge. The initial proposed CEOs and POs are:

Challenge Educational Objectives:

1. Lead in the discussion, understanding, and making of public infrastructure policy.
2. Employ creative and critical thinking in the resolution of 'wicked' problems.

Participant Outcomes:

1. Solve interdisciplinary problems as a member of a team.
2. Formulate problem and solutions sets to 'wicked' problems.
3. Present and defend a proposed infrastructure solution in a public forum.
4. Integrate social, political, economic, sustainability, resilience, and technical factors in solving infrastructure problems.

Fifth, infrastructure challenges are inherently interdisciplinary which means an interdisciplinary approach is required. Note that it is the approach, not the team organization, which must be interdisciplinary. Should a sociological approach be required for a particular submission but a sociologist is not available, someone on the team must fulfill this role.

Sixth, since infrastructure solutions make long term changes to a society, participants must address the sustainability and resilience of the proposed solution. It is not sufficient for a solution to meet the needs of today; it must meet these needs without mortgaging the future or failing under the inevitable duress. Compliance with the fifth and sixth characteristics is achieved through the proposal evaluation. Challenge proposal that properly identify and integrate social, political, economic, sustainability, resilience, and technical factors will score better than those that do not. Participants will be encouraged to use LEED, Envision, and other recognized frameworks to assist in the evaluation of these factors.

Continuing Development of the Challenge

The authors recognize that this is a concept in development, but it has advanced beyond the 'good idea' stage and this paper and presentation is an effort to continue that development in consort with institutions which may elect to participate. We anticipate executing the first challenge competition in April, 2014.

As introduced above, the Challenge for each competition will be stated as a societal need. The organizers are actively soliciting input of proposed needs from professional and government organization engaged in infrastructure such as, America 2050, ASCE, the US Army Engineer Research and Development Center (ERDC), The Infrastructure Security Partnership (TISP), and the Bay Area Center for Regional Disaster Resilience. National, regional, and local perspective will be sought and draft challenges will be presented and discussed at The 2013 Critical

Infrastructure Symposium to support a broad based consensus. The call for participation will list three to five needs with the final need always being a participant defined need. Participants will be allowed to compete based on a self-determine need, subject to the approval of the organizing committee to insure it meets the intent of the challenge.

Two challenge formats are currently being considered: Year long and 96 hour. Under the year long concept, the challenge would be distributed in August and participants would have through April of the following year to complete and submit the challenge. This format has the advantage of allowing participants to conduct new and in-depth research to support their proposals and the disadvantage of requiring a substantial time commitment. The 96 hour format follows the concept of the MCM described above. The challenges would be posted on a Thursday evening with solutions submitted via email by Monday evening. This format has the advantage of minimal time commitment on the part of participants but limits research and new learning that could occur during the contest. The authors plan on selected the final format in consultation with professors and students that might be interested in participating.

Regardless of the format selected, the challenge submission will nable participants to present their work in three formats. First, participants will submit a written report limited to 7,500 words plus graphics thus making is suitable for potential journal publication. Second, participants will submit a 500 word OP-ED style piece presenting and arguing for their idea in a format suitable for including in a newspaper or magazine. Third, participants will present 'in person' either to the evaluation committee or with a short video clip. Exact details of the submission requirements will be appropriately calibrated for the format selected.

The winner will be determined by an evaluation committee including representatives of the organizing committee and of the organizations which provided the challenge topics. Participants will be evaluated on the quality of written and oral communications, their ability to effectively scope and describe the issue, the effectiveness of the proposed solution in resolving the issue, and inclusion of all appropriate factors impacting both the problem definition and problem resolution.

Consistent with appropriate legal restrictions, the organizing committee will seek sponsors able to provide monetary rewards for the winners. Our goal is to be able to provide $10,000 for first place, $6,000 for second place, and $4,000 for third place. To minimize overhead costs, we will conduct the challenge at an existing event such as The Critical Infrastructure Symposium or at one of the sponsoring institutions in conjunction with a Projects Day, Research Symposium, Capstone Presentation, or similar event.

The authors recognize that school and donated resources for student participation in contests and competitions are limited and scarce. Accordingly, every effort is being made to limited the resources required for participation. Under the 96 hour format, the only required resources would be the entry fee, if any, a computer lab, and a long weekend. Under the year-long format, we envision offering the opportunity for participants and the evaluation team to attend the final presentations either in-person or by video teleconference. In either case, every effort will be made to minimize required resources and barriers to participation.

The leadership team for the Goethals Infrastructure Challenge consists of the US Army Engineer Research and Development Center (ERDC), West Point's Department of Civil and Mechanical Engineering, and the Peter Kiewit Institute at the University of Nebraska-Omaha.

Conclusion

There is an old saying that goes, "Never do anything you haven't done before" which recognizes that training, education, practice, and rehearsal are essential to success in the actual event. Built on this idea, the Goethals Infrastructure Challenge provides students with the opportunity to solve wicked infrastructure problems in an inspirational, interdisciplinary, environment as students before being required to do it as professionals. The academic nature of the competition does not make it less 'real'. The challenges posed are real; the academic nature simply allows participants to explore the social, political, technical, financial, sustainability, and other dimensions of the problems in a consequence free environment. This has two benefits. First, the participants hone their wicked problem solving skills before they must employ these skills on 'real' problems where society must live with the consequences. Second, real-world constraints and consequences serve to make a solution practical, but can also severely limit innovation. Challenge participants have to consider the real world, but are much freer to propose innovations and changes to that world. When the answer to a problem is not required to be implemented, innovation can run wild. The supposition, "What if…?" is no longer just daydreaming, but may now be a path to the futur~~e a~~future with sustainable, resilience, economically viable, technically innovative infrastructure serving 21st century society.

Bibliography

1. **NAE.** *The Engineer of 2020: Visions of Engineering in the New Century.* Washington, DC : National Academy of Sciences, 2004.

2. **ASCE.** *The Vision for Civil Engineering in 2025.* Reston, VA : American Society of Civil Engineers, 2007.

3. **ASCE**. *Civil Enigneering Body of Knowledge for the 21st Century, Second Edition.* Reston : American Society of Civil Engineers, 2008.

4. **American Society of Civil Engineers.** *2009 Report Card for America's Infrastructure.* Reston, VA : ASCE, 2009.

5. **World Economic Forum.** *The Global Competativeness Report, 2011-2012.* Geneva, Switzerland : World Economic Forum, 2011.

6. **Parker, Phillip.** Private communication between authors and Dr. Phillip Parker. 2012.

7. **Austin, Harry.** Editorials, Crisis: US Infrastructure. *Chattanooga Times.* October 29, 2012, p. B6.

8. **Engineering, Clemson University Department of Civil.** Department of Civil Engineering Sicned Master's Program in Sustainable and Resilient Infrastructure. [Online] November 7, 2012. [Cited: November 7, 2012.] http://www.clemson.edu/ce/NSF_SMP/.

9. **Engineering, Illinois University Department of Civil and Environmental.** Civil and Environmental Engineering. [Online] November 7, 2012. [Cited: November 7, 2012.] http://cee.illinois.edu/SRIS.

10. *Dilemmas in a General Theory of Planning.* **Rittel, Horst W.J. and Webber, Melvin M.** 1973, Policy Sciences, pp. 155-169.

11. **Sussman, Joseph M.** [Online] November 4, 2009. [Cited: November 15, 2012.] http://esd.mit.edu/wps/2010/esd-wp-2010-02.pdf.

12. **Sussman, Joseph M.** Complex Socialtechnical Systems--The case for a New Field of Study. *Charles L. Miller Lecture.* Boston : MIT, May 22, 2012.

13. **Friedman, Thomas L.** *The World Is Flat: A Brief History of the Twenty-First Century.* New York : Farrar, Straus, and Giroux, 2006.

14. **ASCE & AISC.** Student Steel Bridge Competition. [Online] November 19, 2012. [Cited: November 19, 2012.] http://nssbc.info/.

15. **ASCE.** ASCE National Concrete Canoe Competition. [Online] 2012. [Cited: November 19, 2012.] http://www.asce.org/concretecanoe/about/.

16. **ISN.** Institute for Soldier Nanotechnologies Soldier Design Competition. [Online] November 26, 2012. [Cited: November 26, 2012.] http://web.mit.edu/isn/newsandevents/designcomp/index.html.

17. **Floerscheim, LTC Bruce.** *Director, Center for Innovation and Engineering.* [interv.] LTC Steven D. Hart. November 26, 2012.

18. **NHDF.** National Homeland Defense Foundation Innovation Competition. [Online] November 26, 2012. [Cited: November 26, 2012.] http://www.nhdf.org/8-innovation-competition/nsic-history.

19. **COMAP.** MCM/ICM Home. [Online] March 26, 2013. [Cited: March 26, 2013.] http://www.comap.com/undergraduate/contests/mcm/.

20. *War Planning for Wicked Problems.* **Greenwood, T.C. and Hammes, T.X.** 2010, Armed Forces Journal, pp. 18-37.

21. **ABET.** Assessment Planning. [Online] December 3, 2012. [Cited: December 3, 2012.] http://www.abet.org/assessment-planning/.

22. **ASCE.** *Guiding Principles for the Nation's Critical Infrastructure*. Reston, VA : American Society of Civil Engineering, 2009.