ENGEEERING IN THE AMERICAS BEFORE COLUMBUS:
WONDERS OF THE INCAS, MAYAS AND AZTECS

**Discipline:** Engineering Elective: 3 credits  
**Semester:** Summer of 2015  
**Course Number:** Engr. 1256  
**Faculty Name:** Luis E. Vallejo, Professor of Civil and Environmental Engineering, University of Pittsburgh

**Qualifications of the Instructor:** The director of the course is Dr. Luis E. Vallejo, Professor in the Department of Civil and Environmental Engineering. Professor Vallejo has taught a course similar to the one being proposed for the Semester at Sea Program during the Summer of 2007. He has also taught a similar course for the civil and environmental engineering students of the Universidad de los Andes in Bogotá, Colombia. (Dr. Vallejo’s country of origin is Colombia.) In addition, Dr. Vallejo is conducting research on the methods of engineering construction by the Incas and Mayas. Thus, the instructor is very well qualified to teach and direct the field component of the course.

**Contact Hours for the Course:** The course will be composed of 45 contact hours. Of these contact hours, 36 hours will comprise the field component of the course (6 days of 6 hours per day), and 9 contact hours of classroom instruction. The classroom instruction will be conducted during the month of April (three Sessions of 2 hours per Session for a total of 6 hours). One post-field trip session of 3 hours, during which the students will present their projects, discuss their findings, and reflect upon their experiences, is also included. The post-session will be held at a date to be determined in September or October.

**Prerequisites for the Course:** This course is open to engineering students with a basic knowledge of algebra, geometry, trigonometry, introductory physics, and calculus. We will analyze the design of pre-Columbian structures in Central and South America from a civil engineering perspective.

**Course Description:** Traveling throughout Latin America we encounter stunning examples of engineering expertise, from the Aztec and Mayan pyramids and cities such as Tenochtitlan, Palenque and Tikal, to the lost city of the Inca, Machu Picchu, to name just a few. This course is designed to introduce students to the methods employed in the design and construction of these and other major pre-Columbian structures, and to analyze why these structures have remained stable in the face of time and natural hazards. Factors which made pre-Columbian engineers so effective will be analyzed using basic principles of civil engineering. The class will consist of preparatory lectures, discussion, and exercises, a site visit to Cuzco and Machu Picchu (Peru), and debriefings subsequent to the site visit. Students will keep a journal recording relevant information collected during the site visit, and prepare a final report detailing and analyzing civil engineering features found at the sites included in the required field trips. The final report will be prepared by students, working individually or in small groups of 3 to 5, presenting an in-
depth investigation of a topic of particular interest, documenting their findings using a variety of media. The students will share, in written and oral formats, the results of their special report after the conclusion of the field trip.

**Course Objectives:** By the end of the course the students will:

1. Have a basic understanding of fundamental principles of analysis and design of civil engineering structures;
2. Be able to use these principles to understand the design and construction of pre-Columbian architectural and civil engineering structures;
3. Develop an appreciation of the engineering skills of pre-Columbian peoples; and
4. Gain experience in collecting, analyzing and presenting data in a variety of formats.

**SYLLABUS OF THE COURSE (PRE-FIELD TRIP)**

**Sessions 1 and 2 (4 hours, including Orientation: Spring Semester 2015)**

1. *Inca Civilization*  
   (a) Inca heritage: cultural background  
   (b) Geology and environment of the Inca Region  
   (c) Mathematics of the Incas: The Quipu and the Abacus  
   (d) Construction materials, methods, and tools used by the Incas  
   (e) Inca roads, the area covered by these roads, their method of construction, and the political importance of the roads for the Inca Empire  
   (f) Introduction to Machu Picchu and Cuzco, the capital of the Inca Empire  
   (g) Engineering planning and importance of Machu Picchu and Cuzco  
   (h) Building foundations, retaining walls, and suspension bridges built by the Incas.  
   (i) Comparison of structures that the Incas built that operated under tensile stresses and those built by the Europeans that worked under compressive stresses  
   (j) Hydrology and hydraulic engineering in the Inca Empire  
   (k) Drainage infrastructure of Machu Picchu  
   (l) Assessing the accomplishments of Inca engineers and architects

**Assigned Reading:** Complete *Machu Picchu a Civil Engineering Marvel*, by Wright and Valencia-Zegarra by the end of Session 2.  
Read book: *The Incas: New Perspectives* by G.F. McEwan  
Read Part 1 of *1491: New Revelations of the Americas before Columbus* by Mann.  
Read: *Moray*, by Wright and others.
Session 3 (1 hour: Spring Semester 2015)

2. Maya Civilization
   (a) Maya heritage: cultural background
   (b) Geology and environment of the Maya region
   (c) Mathematics of the Mayas
   (d) Engineering and Architectural planning of Mayan cities
   (e) Materials of construction, development of cement and methods and tools for
      construction
   (f) The building and stability of the great pyramids and the astronomical observatory,
      roads, and bridges
   (g) Architectural elements: floors and stairs
   (h) Architectural elements: retaining walls, columns, and windows
   (i) The origin of the Mayan Arch
   (j) Stability analysis of the Mayan Arch
   (k) Architectural elements: vaults, roofs, and roof crests
   (l) Assessing the accomplishments of Maya engineers and architects

Assigned Reading: Mann, Part 2.

Session 4 (1 hour: Spring Semester 2015)

3. Mexico- The Aztec Civilization
   (a) Aztec heritage: cultural background
   (b) Geology and environment of the Aztec region
   (c) Aztec mathematics
   (d) Aztec engineering: the building and stability of the great pyramids, bridge
      construction, irrigation channels, chinampas
   (e) From Tenochtitlan to modern Mexico City: engineering challenges

Assigned Reading: Mann, Part 3 and Coda.

Session 5 (3 hours)

4. Summary of the Course and Project Presentations

FIELD COMPONENT OF THE COURSE (36 hours: Summer Semester 2015)
Students will travel to Cuzco and Machu Picchu for the field component of the course. The amount of time programmed for the field trip is 10 days (May 1st to May 11th). The students will dedicate 6 days of the trip to the field component of the course. Each day of field work will be about 6 hours per day of work for a total of 36 hours. During field trips students will concentrate on collecting data relevant to their particular special project related to Cuzco, Machu Picchu and the Sacred Valley near Cuzco. They will take measurements, produce technical drawings, take notes and photos throughout their site visits. The data collected will be recorded in a journal documenting all visits. The students will work individually or in small groups to produce a final engineering report
related to a special topic related to the sites visited. This final report will be shared with the other students during a project presentation session that will be held after the trip (in September or October, Session 5).

**Field Schedule (Summer Semester 2015)**

Day 1: Tour of Cuzco with emphasis on engineering and architectural features of the city (i.e., the palace of Hatunrumiyuc, and the temple of Koricancha).
Day 2: Visit to the Inka Museum of Cuzco and lecture by Fernando Astete, Instituto Nacional de Cultura, Cuzco, Peru
Day 3: Visit to the fort of Sacsayhuaman. Analysis of the history and engineering construction of this massive structure.
Day 4: Visit to engineering structures in the Sacred Valley at Pisac, Moray, Urubamba, and Ollantaytambo.
Day 6: Visit to Tipon

**METHODS OF EVALUATION**

In addition to attending and participating actively in all classes, which involves engaging in discussions, responding to questions, and sharing observations and documentation from field trip work, students are required to complete the following:

a) A journal documenting each site visit. This can include written information, observational drawings, and photographs relevant to class topics. Each entry should be a minimum of 2 to 3 pages in length. Journals will be collected at the end of the term for grading purposes.

b) Final report of a special investigation. Each student will choose a topic of special interest to investigate throughout the course of the field trip, working alone or as part of a small group. Before departing for the field trip, students will submit their proposed ideas for review by the professor. The student should conduct library and internet research pertaining to the topic, collect data from the field trips relevant to the topic, and analyze the ideas involved based on the principles being learned in class. For example, a group of students might choose to study retaining walls built by the Incas. The students would then use field trip time to investigate the characteristics and uses of retaining walls encountered. Finally, they would prepare a report including an analysis of the stability of these walls using the civil engineering principles learned in class. **The final report will be due at the end of September or the beginning of October, 2015.** It should be approximately 15 pages in length (including pictures and drawings). It will be shared by each group or individual with classmates as a short presentation (20 minutes) as well as submitted to the instructor. Students are encouraged to use a variety of media.
**GRADING:**

Class attendance and participation 25%
Journal: 20 %
Final special report: 55%

**REQUIRED TEXTBOOKS**

(1) **AUTHOR:** Kenneth R. Wright and Alfredo Valencia Zegarra  
**TITLE:** Machu Picchu a Civil Engineering Marvel  
**PUBLISHER:** ASCE Press (American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, Virginia 20191-4400)  
**ISBN #:** 0-7844-0444-5  
**DATE/EDITION:** 2000/First  
**COST:** $35.75

(2) **AUTHOR:** Gordon F. McEwan  
**TITLE:** The Incas: New Perspectives  
**PUBLISHER:** W.W. Norton & Company  
New York  
www.wwnorton.com  
**DATE EDITION:** 2006

(3) **Author:** Keneth R. Wright, Ruth M. Wright, A. Valencia Zegarra, and G. McEwan.  
**TITLE:** Moray: Inca Engineering Mystery  
**PUBLISHER:** ASCE Press  
ISBN: 978-0-7844-1079-0  
**DATE EDITION:** 2011

The Following Texts is Recommended:

(4) **AUTHOR:** Charles C. Mann  
**TITLE:** 1491: New Revelations of the Americas before Columbus  
**PUBLISHER:** Alfred A. Knopf, New York  
**ISBN #:** 1-4000-4006-X  
**DATE/EDITION:** 2005/First  
**COST:** $30.00

(5) In addition (of time permits) the instructor will provide the students with Notes relevant to the course and present the following films:
(1) Secrets of Lost Empires: The Incas
(2) Modern Marvels - Machu Picchu
(3) Engineering an Empire (The Mayas)
(4) Engineering an Empire (The Aztecs)