ABET
Self-Study Report

for the

Bachelor of Science in Architectural Engineering

at the

University of Colorado Boulder

Boulder, Colorado

July 1 2017

CONFIDENTIAL

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Program Self-Study Report
for
EAC of ABET
Reaccreditation

BACKGROUND INFORMATION

A. Contact Information

Balaji Rajagopalan
Professor and Chair
Civil, Environmental, & Architectural Engineering (CEAE)
428 UCB
University of Colorado Boulder
Boulder, CO 80309-0428
Phone 303-492-5968, fax 303-492-7317
E-mail: balajir@colorado.edu
primary pre-visit contact person for the program

Sandra Vásconez
Senior Instructor
Phone 303-492-7614, fax 303-492-7317
E-mail: Sandra.Vasconez@colorado.edu
primary author of this self-study

B. Program History

The Bachelor of Science in Architectural Engineering (AREN) degree at the University of Colorado Boulder (CU) is offered through the Department of Civil, Environmental, and Architectural Engineering (CEAE), which resides within the College of Engineering and Applied Science (CEAS). The Architectural Engineering program was established in 1925, awarded its first degree in 1929, and has been continuously accredited since 1936. In the 2011-2012 general review by the Engineering Accreditation Commission of ABET, our program received a Next General Review with accreditation through Sept. 30, 2018.

Soon after the last AREN ABET accreditation in 2012, a revised curriculum was implemented for the 2012-2013 academic year. The 2012 AREN Joint Evaluation Committee (JEC) sanctioned the change indicating that the committee "takes no exception of the recommended AREN curriculum change for 2012-13". The JEC role and process is described in Criterion 2E.

There were significant changes to the curriculum. These were primarily driven by feedback from the JEC process, student surveys, and recent changes to the ABET EAC architectural engineering program criteria. Educational research on student autonomy and motivation (self-determination theory) was also taken in to account, which in our case meant adding flexibility to the curriculum. The four most significant change were:

1. AREN proficiency courses. In the pre-2012 AREN curriculum, all AREN students were required to take five proficiency courses (AREN 4550 Illumination II, CVEN 4545 or CVEN 4555 Structural Design, CVEN 3256 Construction Equipment & Methods, AREN 4110 HVAC Design, and AREN 4570 Electrical Systems for Buildings.) In the current curriculum students are required to take only two proficiency courses, one related to their concentration track, and one of their choosing.
2. Within their tracks, students are now required to take two concentration courses instead of one.
3. Dedicated lab courses were eliminated, but their content was distributed through various courses in the curriculum. In their place, a fourth technical elective was added. Additional information on lab content is provided on Criterion 4, Outcome 2b.
4. A free elective was added. Students can take a course of their choosing with minimal restriction.

Examples of other changes are:

1. AREN 1316 Introduction to Architectural Engineering (1 credit) was combined with Introduction to Civil and Environmental Engineering and changed to 2 credits."
2. GEEN 1400 Engineering Projects is required for all AREN first-year students.
3. AREN 2406 Intro to Building Construction was eliminated as a course but content was included in AREN 2050 Engineering Systems for Buildings. The new combined course is now called Building Materials and Systems.
4. ARCH 4010 Architectural Design changed from 3 credits to 5 credits. This course along with AREN 4317 Architectural Engineering Design form a 10-credit senior capstone experience.

The current block diagram that reflects the changes above can be found in Criterion 5A.

C. Options

Graduates of the AREN program are expected to acquire a broad education in architectural engineering as well as a specialization in one of four engineering disciplines—structural, mechanical, electrical/lighting, or construction. Each specialization is a separate option within the program, defined by 18 credit hours of upper division technical courses. Within the curriculum, students declare their concentration in one of these four areas, each of which has a separate set of required concentration courses (listed below) and suggested technical electives. Students must satisfy the requirements of one of these four options to graduate: Construction Engineering and Management, Electrical and Lighting Systems, Mechanical Systems and Structural Systems.

D. Program Delivery Modes

The bulk of the required Architectural Engineering curriculum is provided to students via courses offered between 8 am – 5 pm on weekdays on the Boulder campus as traditional lecture/laboratory/recitation courses. Humanities and social science electives may be taken as web-based or distance education courses through CU Continuing Education, but that is not common. Some technical electives could also potentially be taken as web-based or distance education courses. The program offers the opportunity for students to participate in a Cooperative Education ("Co-Op") program, but co-ops do not fulfill any of the curriculum requirements and few students participate.

E. Program Locations

The program is regularly offered at the University of Colorado Boulder main campus. Students may participate in Study Abroad programs offered by the University and transfer some of these credits into the major. Students also sometimes take summer courses from other institutions that can be transferred into the major, subject to the approval of the departmental transfer course evaluator.

F. Public Disclosure

The program education objectives and student outcomes are published in the catalog of the University of Colorado Boulder. These are also published on the website of the CEAE Department (http://www.colorado.edu/ceae/current-students/undergraduate-studies/educational-objectives-outcomes). The annual student enrollment and graduation data is posted on the College of Engineering & Applied Science (CEAS) website (http://www.colorado.edu/engineering/about/rankings-facts-figures?qt-funding_enrollment_degrees_quick=2#qt-funding_enrollment_degrees_quick - scroll down for the "Degrees" and "Enrollment" tabs).

G. Deficiencies, Weaknesses or Concerns from Previous Evaluation(s) and the Actions Taken to Address Them

The previous ABET Final Statement included three program concerns. These concerns are directly quoted below, followed with statements related to the program progress in these areas over the past six years.

Program Concerns

1. Criterion 4. Continuous Improvement This criterion requires the program to regularly use appropriate, documented processes for assessing and evaluating the extent to which the program educational objectives and student outcomes are being attained. The program has not clearly established the expected levels of attainment for student outcomes and relies heavily on student survey data, which may not be an effective measure of attainment, in its assessment and evaluation process. While it appears that the outcomes are being attained, the evaluation process may not consistently document the extent of attainment, which could result in future noncompliance with this criterion.

   Response: The Architectural Engineering program has various methods to determine levels of attainment for student outcomes. These are:

1. Fundamentals of Engineering (FE) exam results
2. AREN 4317 Architectural Engineering Design, the senior capstone class that provides a major design experience
3. Specific courses that contain assignments, projects, lab write-ups, and/or exams, which are used as embedded indicators of outcome attainment.
4. Joint Evaluation Committee (JEC) evaluation and feedback related to student outcomes. Their input is carefully evaluated by AREN faculty and suggestions are implemented wherever possible.
5. Faculty Course Questionnaires (FCQs), which provide valuable data related to how students perceive a particular course contributing to specific learning objectives.
6. Senior survey administered by the College of Engineering, where recent graduates rate their achievement of the 13 student outcomes.

Data collected using these various methods are shown in Criterion 4. Not all methods are used for all outcomes.

2. Criterion 6. Faculty: The criterion requires the faculty to be of sufficient number and competencies to cover all curricular areas. The Joint Evaluation Council has clearly noted a lack of strength in the building electrical systems area and the program has noted difficulty in hiring a lead design faculty member in this area. A class has been added, but without additional faculty it may be difficult to sustain the area.

Response: Since the last ABET review in 2012, the AREN group has conducted four faculty searches. All search descriptions included language such that a candidate with expertise in the area of building electrical systems would be welcome. The latest search (2017) was successful; the CEAE department will be adding an electrical engineer to its roster.

Since this new hire will join the AREN group in fall 2017, it is important to note:

1. The lighting instructor hired in 2012 had a degree in Architectural Engineering. He had sufficient fundamental knowledge and experience of electrical systems to cover the electrical building design portion in the senior capstone class while the professor who normally covers this topic was on sabbatical (AY 2014-15). In addition, an electrical engineer with extensive professional experience and PE licensure covered the Electrical Systems for Buildings course, also taught by the professor on leave.

2. The Lighting and Electrical Systems track requires students to take the following courses: ECEN 3030 Electrical Circuits, AREN 4570 Electrical Systems for Buildings, and AREN 4317 Architectural Engineering Design. In the latter, students have ample practical exposure designing an electrical system for a 15,000 to 30,000 square-foot building. They have access to one-on-one meetings with professional electrical engineers who act as their mentors.

Program Criteria. Program criteria for architectural engineering require the program to demonstrate that faculty teaching courses that are primarily engineering design in content are qualified to teach the subject matter by virtue of professional licensure or by education and design experience. Of the department's 46 faculty members, only 10 are licensed professionals, only six of those are licensed to practice in Colorado, and there are no licensed faculty members in the construction engineering area. The limited number of licensed professional engineers may reduce flexibility in assigning design courses and in the development of design depth within students' programs of study.

Response: As of spring 2017, of the department's 48 faculty members, 14 are licensed professionals and seven are licensed to practice in Colorado

Specifically, as it relates to the AREN program, nine faculty are licensed professionals and five of these are licensed to practice in Colorado:
- Two dedicated AREN faculty, one is CO licensed
- Two CEM faculty who teach in both AREN and CVEN programs, one is CO licensed
- One structures faculty who teaches in both AREN and CVEN programs is CO licensed.
- Four cover various AREN fundamental, proficiency and/or AREN technical elective courses, two are CO licensed.

Courses that are primarily design in content such as AREN 4110 HVAC Design, AREN 4570 Electrical Systems for Buildings, CVEN 4545 Steel Design, CVEN 4555 Reinforced Concrete Design, CVEN 3256 Construction Equipment & Methods are all taught by licensed professionals.

To learn more about faculty who teach other design courses but are not licensed professionals, refer to Program Criteria, section 2.1 (faculty qualifications to teach design). This section highlights the ample experience of non-PE faculty and instructors, who contribute to the teaching and development of design depth in the AREN curriculum.

Finally, since the 2012 ABET accreditation, the AREN faculty roster gained one faculty (growth) and lost one faculty (retirement). Since 2012, the AREN group has conducted four searches: AY 2012-2013 where a materials science and engineering faculty was hired; AY 2014-2015 and AY 2015-2016 were both unsuccessful, and AY 2016-2017 where an electrical engineering faculty was hired. The language of such searches has been consistent with the wider effort to increase the number of professionally licensed engineers who are faculty members in the CEAE department. Advertisements to hire CEAE faculty members have routinely included language that: "Professional registration or an ability to become registered as professional engineer is desired."

CRITERION 1. STUDENTS

A. Student Admissions

At the University of Colorado Boulder, students apply using an online application to a specific major. The campus-wide Office of Admissions in conjunction with the Engineering Director of Access and Recruiting handles the admission process and admission decisions for all engineering majors. While there are not set minimum requirements for admission, the College seeks to admit applicants with a high probability of successfully completing their undergraduate engineering degree program at the University of Colorado Boulder. The Office of Admissions and the College consider the following factors in making admission decisions:

- Evidence of scholastic ability and accomplishment as demonstrated by grade point averages, tests of scholastic aptitude and achievement (ACT or SAT), class rank, grades earned in courses directly applicable to an engineering academic program, and essays.

- Personal motivation and academic success as demonstrated by trends in the student's academic record, rigor and challenge of coursework, success in the academic community, ability to balance academic and personal interests, and letters of recommendation.

The College is committed to increasing the quality of its programs, in part by increasing the holistic diversity of its students (ethnic, gender, geographical, cultural, socio-economic, and first-generation students). This commitment is reflected in the admissions process and the special programs established to support these students.

The following mean average information is provided from prior first-year classes in this College:

Mean Averages, First-Year Classes

New Studs Entering in	High School Rank	HS GPA	ACT Math	ACT Engl.	SAT Math	SAT Crit. Read	# of New Studs
Fall 2016	88%	3.91	31	30	677	615	1032
Fall 2015	89%	3.91	30	30	679	625	900
Fall 2014	88%	3.90	30	30	673	617	909
Fall 2013	89%	3.88	30	29	677	615	838
Fall 2012	87%	3.87	30	29	673	613	778

For more information about first-year admissions, see http://www.colorado.edu/admissions

Due to large increases in the size of the incoming freshman classes, and heightened student interest in specific majors, the College has implemented several enrollment management policies over time. Currently, when students apply to the College of Engineering and Applied Science from high school, they may indicate to enter the College as "open option" (unsure of engineering major), or they may select a preliminary engineering major.

Sometime after completion of the first semester, and by the eighth week of the second semester, all students should finalize their choice of major in the College. Students wishing to make a major change within the College use the Change of Major Form to finalize their choice of major.

Students with a CU cumulative GPA of at least 2.250 after their first semester will receive immediate confirmation of their major choice. See http://www.colorado.edu/engineering-advising/get-your-degree/first-year-freshmen/confirming-your-major for details.

B. Evaluating Student Performance

Students are evaluated on a course-by-course basis. For each course, students earn grades A through F, A being the highest grade and F indicating failing. Depending on the course, students are evaluated on the basis of assignments, examinations, and projects.

The following grading system is standardized for all colleges and schools of the university. Each instructor is responsible for determining the requirements for a class and for assigning grades on the basis of those requirements.

Standard grade points per hour of credit:

A = superior/excellent, 4.0
A- = 3.7
B+ = 3.3
B = good/better than average, 3.0
B- = 2.7
C+ = 2.3
C = competent/average, 2.0
C- = 1.7
D+ = 1.3
D = 1.0
D- = minimum passing, 0.7
F = failing, 0.0

The average GPA of students graduating from the AREN program is approximately 3.1 (calculated from May 2013-December 2016 graduates). The course dossiers available during the ABET visit will contain information describing how individual courses are graded.

Students remain in good academic standing in the College if their semester and cumulative Grade Point Averages are at least a minimum of 2.250. These GPAs are reviewed by the College twice a year, following the fall semester and following the spring semester. Students are placed on academic alert, recovery, and/or suspension if they fail to maintain these levels. The AREN program faculty and staff do not have a role in determining the students who are placed on alert, recovery, or suspension. See the Academic Standing website at http://www.colorado.edu/engineering-advising/academic-standing for details.

Many courses have prerequisites, corequisites, or class standing requirements. It is program policy that all prerequisite and corequisite courses must be completed with a grade of C- or higher. Required prerequisites, corequisites, and other restrictions are coded into the CU student information system (CU-SIS). This system prevents students from registering for a course unless all requirements are either completed or in progress (in which case enrollment is conditional, pending successful completion of the requirements). Final authority over prerequisite and corequisite requirements rests with the faculty—any student requesting a waiver to these requirements must obtain permission from the course instructor. The CEAE Department requires students to obtain such permission in writing, either via e-mail or a hard copy petition form. Other departments may have different procedures for their own courses.

After final grades are posted each semester, departments can run reports in CU-SIS showing whether students successfully completed the prerequisites for the following semester's courses. Students who do not successfully complete a prerequisite may be administratively dropped from the course—the system then prevents the student from re-enrolling until they meet the requirements, or obtains a waiver from the instructor. Administrative drops are the purview of the department in charge of the course—the AREN undergraduate academic advisor handles this process for the CEAE Department, and has control over civil, environmental, and architectural engineering courses only.

In addition to prerequisite checks done by the department in charge of each course, the AREN undergraduate academic advisor tracks students' progress each semester. Each student has a copy of the AREN block diagram in their departmental file—the academic advisor updates this document after grades are posted every semester, indicating which courses have been completed, and which courses the student is enrolled in for the following semester. During this process, the academic advisor contacts students about prerequisites not fulfilled, courses which need to be retaken, courses that the student is missing to stay on track for graduation, or any other issues they may identify.

The staff advisor also conducts individual meetings with all students placed on academic alert or academic recovery. The purpose of these meetings is to make sure the student understands the requirements they must meet in order to return to good academic standing, discuss factors affecting the student's academic performance, and provide guidance, resources, and/or referrals to other academic support services.

Students can access an online degree audit via their online student portal, MyCUInfo. This online degree audit pulls the student's program information, grades, and course schedule directly from CU-SIS, and is updated in real time. Students can run a degree audit on their own from any computer and at any time. The AREN undergraduate academic advisor also checks the online degree audit every semester, and makes any necessary adjustments.

C. Transfer Students and Transfer Courses

External Transfers

External transfer students are admitted to the AREN program through the CU Boulder Admissions Office, based on criteria set by the College. Similar to the first-year freshman admission process, the College seeks to admit external and internal transfer applicants with a high probability of successfully completing their undergraduate engineering degree program at the University of Colorado Boulder.

To qualify for admission as a new transfer student, the applicant must have completed a minimum of two semesters of college-level calculus and two semesters of science (college chemistry and/or calculus-based physics). If the applicant has less than 24 semester credit hours, an ACT or SAT test score is also required.

To be most competitive, transfer applicants should have a minimum cumulative college GPA of 3.0. Grades of B or higher are expected in math, science, and engineering courses.

Additionally, The College of Engineering and Applied Science guarantees admission to any of its baccalaureate degree programs to students transferring from Colorado public institutions of higher education who meet the following requirements:

- At least two full-time semesters (or 24 semester credit hours) at a Colorado public institution must be satisfactorily completed immediately prior to the transfer
- A cumulative GPA of 3.3 or higher from a Colorado public institution
- Grades earned in individual mathematics, science, engineering and language arts courses must all be B or higher
- Completion, with final grades, of a minimum of two semesters of college-level calculus, along with two semesters of calculus-based physics and/or college-level chemistry, before an admission decision is rendered.
- Completion of admissions application and submission of all required documents by published deadlines

  CU Boulder and the Colorado Community College System have an articulation agreement for both admission, as well as general transfer equivalencies of certain engineering courses. The Guaranteed Admission Criteria is designed with the following parameters:

- At least two full-time semesters (or 24 credit hours) at a Colorado public institution must be satisfactorily completed immediately prior to the transfer
- Colorado public institution GPA of at least 3.30
- Grades in math, science, engineering, communications and writing courses must be B or better
- Must complete two semesters of college-level calculus and two semesters of calculus-based physics and/or college-level chemistry.

There are also a number of direct equivalent engineering courses that are part of the articulation agreement and allow community college students to transfer basic math, science and certain engineering courses to CU Boulder. The participating institutions agree to the agreement's policies governing the transfer of credit among Colorado public institutions for students pursuing baccalaureate majors in the College of Engineering and Applied Science. See http://highered.colorado.gov/Academics/Transfers/ for details. The University of Colorado Boulder Pre-Engineering Transfer Agreement for Community College Students is posted at http://highered.colorado.gov/Academics/Transfers/Agreements/UCB-Pre-Engineering-Transfer-Agreement.pdf. This agreement, and additional information posted at http://www.colorado.edu/engineering/future-students/transferring-cu/colorado-community-colleges, can be used by prospective transfer students to see which specific Colorado community college courses apply towards degree requirements for each of our undergraduate programs.

External transfer courses are reviewed by the CU Boulder department applicable to each subject. This process is coordinated by the CU Boulder Admissions Office transfer credit unit. Course equivalencies are entered into u.achieve, the university's degree audit and transfer credit system. This allows equivalent transfer courses to automatically populate the appropriate requirements in a student's online degree audit. In addition, prospective transfer students can use a free online service, Transferology, to look up transfer credit equivalencies, and run a degree audit showing how their current coursework will apply to the AREN curriculum.

Transferable courses that have not been deemed equivalent are up to the student's department to apply to degree requirements as they see fit. These courses are reviewed by the CEAE Department's Faculty Transfer Credit Evaluator. The AREN undergraduate academic advisor prepares a transfer credit evaluation for each transfer student, showing how all transfer coursework is being applied to degree requirements. This form is signed by the Faculty Transfer Credit Evaluator and kept in the student's file.

Current AREN students who want to take a transfer course (typically over the summer) can also use Transferology, or ask the AREN undergraduate academic advisor if the course has been reviewed for equivalence. If not, students are encouraged to have the course reviewed in advance to ensure that it will be accepted. Pre-approval for these courses is also handled by the CEAE Faculty Transfer Credit Evaluator.

Internal Transfers

Internal transfer applicants (degree-seeking students from another college/school at the CU Boulder campus) are admitted by the College, either via the Pre-Engineering Program or the Intra-University Transfer (IUT) process.

The IUT process allows CU Boulder students to transfer into the College if they complete a set of requirements which demonstrate their ability to be successful in an engineering curriculum. As with external transfers, IUT students must complete a minimum of two semesters of calculus and two semesters of science. CU cumulative and technical GPAs of at least 2.7 are required. The full set of IUT requirements is posted at http://www.colorado.edu/engineering-advising/transfer-within-cu.

The Pre-Engineering Program is a specialized IUT program serving qualified students who initially applied for direct admission to the College of Engineering and Applied Science, but were alternatively offered admission to the College of Arts and Sciences. The program is designed to facilitate the successful transition of qualified first-year students into the College. The program provides a structured pathway of CU Boulder coursework combined with academic advising support from both the College of Engineering and Applied Science and the College of Arts and Sciences.

Pre-Engineering students are generally required to complete the same IUT requirements to transfer into the College. The program requirements are posted at http://www.colorado.edu/pre-engineering/how-pre-engineering-works. However, Pre-Engineering students also have an accelerated transfer option, for students who earn cumulative and technical GPAs of 3.3 or higher in their first semester and meet the other requirements posted at http://www.colorado.edu/pre-engineering/how-pre-engineering-works/step-3-transferring-engineering/accelerated-transfer-option.

D. Advising and Career Guidance

The College of Engineering and Applied Science understands the importance of good advising in supporting student development and engagement. Undergraduate advisors meet regularly to share best practices and identify ways in which the College can support and improve advising. A collection of best practices and advising tools has been developed to support current advisors, and for use in training new advisors. The College annually recognizes exceptional advisors with an Outstanding Faculty Advisor Award and an Outstanding Staff Advisor Award.

Over the course of their AREN program, students are likely to receive academic and career guidance from both college and departmental faculty and staff. The First-Year Experience Director serves as advisor for the College's Open Option students (first-year freshmen who have not yet declared a specific engineering major). These students are typically expected to declare a major during their second semester in the College. The College also provides advising to Pre-Engineering and prospective IUT students, until they are admitted to an engineering major. Students who have been admitted to the College and have declared an engineering major receive academic advising within their department.

Academic Advising

All new AREN students are given an AREN Advising Guide including the current curriculum, graduation requirements, department policies and procedures, and information about curricular and extra-curricular opportunities. This information is also available on the department website at http://www.colorado.edu/ceae/current-students/undergraduate-studies/architectural-advising-curriculum. The AREN undergraduate advisor reviews the information in the advising guide at mandatory new student informational meetings each semester.

The College also maintains a comprehensive advising website at: http://www.colorado.edu/engineering-advising/, including policies, procedures, forms, etc. Examples of topics covered include:

1. Minimum Academic Preparation Standards (MAPS)
2. Humanities, Social Science, and Writing requirements
3. Four-year graduation guarantee
4. Academic standing and grading policies
5. Registration information

Within the CEAE Department, academic advising is performed by faculty and staff advisors.

The AREN undergraduate academic advisor is a full-time staff member who maintains all student files, each of which contains a complete record of the academic activity of the student. The files are updated every semester and are used during academic advising session each semester. The files contain the following:

1. Current transcript, listing course history, grades received and cumulative/semester GPAs.
2. Log of advising sessions held with student, including date, advisor signature, notes and date an advising hold was removed.
3. AREN block diagram. Schematic layout of all courses, showing which aspects of the curriculum have been satisfied.
4. Transfer Credit Evaluation Form (if applicable). Listing of courses taken at other institutions and how they are counted in the AREN curriculum, including the equivalent course number and credit hours counted.
5. Copy of all petitions, approved and disapproved, governing variances from the curriculum.
6. Copy of any Special Action Forms and/or Change of Record Forms: course withdrawal, change of grade and other administrative actions.
7. Graduation Certification Form. Completed by student and faculty advisor two semesters before anticipated graduation, and signed by both.
8. Graduation Check Form. Official degree audit with verification that all degree requirements are met, signed by CEAE Operations Committee.

In addition, the academic advisor maintains certain electronic records for each student. These include the online degree audit, and advising logs. The university online advising platform, MyCUHub, allows the academic advisor to log detailed notes after each appointment. This system allows for continuity in advising, as the advisor can save important e-mail conversations with students, and refer to notes from previous meetings. In addition, advisors in different departments can share information about students, which provides better service—for example, when meeting with a student who wants to change majors, the academic advisor can see what the other advisor has already discussed with them.

AREN students are required to have academic advising every semester, prior to registration for the next semester's courses. A hold on the student's electronic record prevents course registration until the hold is removed by the AREN undergraduate academic advisor.

During their first two years in the program, when most students are following the typical curriculum and do not require career guidance, students are advised by the AREN undergraduate academic advisor (staff advisor). The academic advisor holds 30-minute individual meetings with each student to discuss the student's academic progress and their planned courses for the following semester. In addition, the academic advisor provides guidance and referrals regarding academic support, extracurricular activities, study abroad, etc.
AREN underclassmen also have access to faculty advising if needed. If students have questions or need advice beyond the scope of the staff advisor, they will be referred to an appropriate faculty member. The AREN Faculty Director serves as the default faculty advisor for these

students, but students may be referred elsewhere if they have questions relating to a particular faculty member's area of expertise.

In their third year, students choose a faculty advisor at the same time as they declare their area of concentration within the AREN curriculum. The faculty advisor typically teaches in the same area as the student's concentration. From this point forward, the student meets with their faculty advisor for mandatory advising each semester. This meeting is scheduled by the student during a designated two-week advising period and is 20 minutes long. The advising program is such that faculty make extra time available during these two weeks, so that all students are accommodated. Students bring their departmental file to the advising session so that both student and faculty advisor have the most current information. Typically, the curriculum block diagram is annotated to show student progress and current status.

The advising sessions between student and faculty involve both academic and career guidance. The faculty member typically helps the student select relevant technical electives, establish contact with industry professionals, and identify internship opportunities.

AREN upperclassmen who meet with their faculty advisor for mandatory academic advising continue to meet with the staff advisor on an as-needed basis. These meetings are typically for graduation progress checks, study abroad planning, or administrative issues (petitions, independent study agreements, or other paperwork). In addition, the staff advisor conducts a final graduation meeting with each graduating senior, to review graduation processes and deadlines.

Academic Support
In addition to academic support programs offered by the campus (e.g., Student Academic Services Center, Department of Housing Academic Support Program, Office of Disability Services), the College of Engineering and Applied Science provides several substantial academic support programs. Among these are the Engineering Ambassadors peer advising and mentoring program, the Engineering Fellows Program, and advising and tutoring offered by the Broadening Opportunity through Leadership and Diversity (BOLD) Center Student Success Center. For more information on these programs, see http://www.colorado.edu/engineering-advising/resources-support/academic-support-tutoring.

Career Advising
In addition to the career advising provided by CEAE faculty advisors, Career Services, within the Division of Student Affairs, provides career counseling, internship coordination, career fairs, on-campus interviewing, and job postings for students in the College of Engineering and Applied Science. In addition to the generalists in the central Career Services office, two professional staff members are housed in the College, dedicated to providing more specialized assistance in career and professional development, identifying internships, advocating co-op programs, designing engineering-specific career development programs, liaising with employers, and answering questions. Students within the College are encouraged to participate in all career development and on-campus recruiting programs across campus. For more information, see http://www.colorado.edu/career/.

Other Advising
The CEAE Department has a faculty Enrichment Program Coordinator who is available to meet with students about enrichment activities—study abroad, internships, undergraduate research, and service.

In Fall 2016, the CEAE Department piloted a peer mentoring program, through which new AREN students can sign up to be assigned a junior or senior peer mentor. Peer mentors are not intended to provide academic advising or tutoring, but can provide advice based on their own experiences in the program. In addition, peer mentors help students navigate campus life and the transition from high school to college.

E. Work in Lieu of Courses

University and College policy on awarding college credit for work in lieu of courses is summarized here:

Advanced Placement (AP) Examinations
College credit may be granted on the basis of the College Board's Advanced Placement tests, for students who have taken an advanced placement course in high school and who make the required score in the College Board's Advanced Placement examination. See the Advanced Placement Chart at http://www.colorado.edu/admissions/undergraduate/apply/freshman/credit to determine what examination score is required to earn CU-Boulder Course Equivalent college credit.

International Baccalaureate (IB) Examinations
College credit may be granted for approved IB examinations with minimum scores. See the International Baccalaureate Chart at http://www.colorado.edu/admissions/undergraduate/apply/freshman/credit to determine what examination score is required to earn CU-Boulder Course Equivalent college credit.

College-Level Examination Program (CLEP)
Credit for College Board subject examinations of the College-Level Examination Program (CLEP) in general biology, general chemistry, general psychology, introductory macroeconomics, introductory microeconomics, introductory sociology, and calculus may be granted for a score at or above the 67th percentile. CLEP general examinations are not accepted for credit at CU-Boulder.

Military Credit
Credit for military schooling is evaluated upon receipt of Form DD 214, Service Separation Certificate, or the Joint Services Transcript (JST). Only work that has received an upper-division baccalaureate recommendation by the American Council on Education (ACE) can be awarded credit. This work, however, is transferred and recorded at the lower-division level. Foreign language credit taken through the State Department, Department of Defense, or Defense Language Institute is assigned the recommended ACE credit.

Work Experience

It is the academic policy of the College of Engineering and Applied Science that credits accrued in the official records of a student that were awarded for work or co-op experience do not apply toward degree requirements.

F. Graduation Requirements

To be eligible for a Bachelor of Science degree in Architectural Engineering from the University of Colorado Boulder, a student must meet the following minimum requirements:

1. The satisfactory completion of the prescribed and elective work in the AREN BS curriculum. A student must complete a minimum number of 128 semester hours, of which the last 45 shall be earned after admission to the College of Engineering and Applied Science as a degree student.
2. A minimum cumulative grade point average of 2.250 for all courses attempted and for all courses that count toward graduation requirements, excluding P grades for courses taken Pass/Fail. (Pass/Fail courses do not count for graduation credit.)
3. A minimum cumulative grade point average of 2.250 for all CEAE course work. This “Major GPA” is computed separately from the student’s cumulative grade point average and includes only AREN and CVEN courses.
4. Successful completion of all Minimum Academic Preparation Standards (MAPS) requirements of the College.
5. Successful completion of WRTG 3030, *Writing on Science and Society* or an approved alternate writing course (HUEN 1010, HUEN 3100, WRTG 3035, or PHYS 3050). Any other exceptions to the WRTG 3030 requirement must be approved via petition by the Assistant Dean for Students.
6. Completion of the Fundamentals of Engineering (FE) Examination during the student’s senior year. Graduation is not contingent upon passing.
7. Submission of a completed graduation application, online via MyCUInfo.

To be eligible for a Baccalaureate Degree from the College of Engineering and Applied Science on the Boulder Campus, a student must meet the following minimum requirements:

1. The satisfactory completion of the prescribed and elective work in any curriculum as determined by the college and the appropriate academic department/program. A student must complete a minimum number of semester hours, not less than 128, of which the last 45 must be Boulder coursework earned after admission to the University and the College.
2. A University of Colorado cumulative grade point average of 2.250 for all courses attempted.
3. A separately computed grade point average, Major GPA, of at least 2.250. The way the Major GPA is computed is to take the most recently earned grade in all courses designated by the major department/program.
4. The satisfactory completion of all Minimum Academic Preparation Standards (MAPS) deficiencies.

Students should meet with their academic advisor to discuss progress towards degree requirements, and then if appropriate, apply for graduation via the online Student Center according to the timelines posted on the Registrar's website http://www.colorado.edu/registrar/students/graduation/apply).

The CEAE department reviews individual student records and utilizes degree audits to confirm baccalaureate degree requirements have been met. Confirmation of Graduates meetings are convened by the Assistant Dean for Students of the College with to approve a certified list of graduates by representatives of degree-granting departments and programs following the close of the fall and spring semesters and the final summer term.

The process for ensuring and documenting that each graduate completes all graduation requirements largely rests in the Department and is managed by both faculty and staff. The process includes the following elements:

1. Each student is required to receive academic advising every semester of their academic career.
2. Students can perform an online degree audit to check their progress toward graduation at any time.
3. Students request a graduation check in the semester before they intend to graduate. The AREN undergraduate academic advisor then completes the graduation check form, and indicates incomplete requirements.
4. At the student's final academic advising appointment (prior to registration for their final semester of classes), the student and faculty advisor review the graduation check and complete a CEAE Graduation Certification Form listing all remaining coursework needed for graduation. Both student and faculty member sign the certification form. The AREN undergraduate academic advisor reviews the certification form and ensures that the requirements listed are correct.
5. Prior to the student's final semester, the AREN undergraduate academic advisor reviews the student's course schedule and ensures that they are enrolled in all required courses. The academic advisor notifies the student of any barriers to expected graduation.
6. A member of the Operations Committee, a standing CEAE Department faculty committee responsible for review of student records for graduation, performs an independent preliminary audit of the student's record.
7. At the beginning of the student's final semester, the AREN undergraduate academic advisor sends out a graduation checklist to all graduating seniors, and asks each student to come in for a final graduation appointment to review any incomplete graduation requirements, processes, and deadlines for completion.
8. After completion of the final semester, the AREN undergraduate academic advisor updates the graduation check form with final grades and GPAs. The academic advisor confirms that all graduation requirements have been met, including successful completion of all required courses, MAPS requirements, the FE Exam, and minimum GPA requirements. The academic advisor also reviews the online degree audit and confirms that it shows all requirements met. The academic advisor updates the student's file with a printout of the online degree audit and an updated transcript showing all coursework.
9. The Operations Committee Chair performs a final review of the student's file and officially signs off on the graduation check form.

G. Transcripts of Recent Graduates

The program will provide transcripts under separate cover as supplemental materials. The transcript specifies Bachelor of Science in Architectural Engineering. For each student transcript, we will provide a degree audit for the option each student chose to pursue (e.g. Construction Engineering and Management, Mechanical Systems, Lighting and Electrical Systems, Structural Systems), as well as a curricula guide for the Architectural Engineering degree, which shows each of these options.

CRITERION 2. PROGRAM EDUCATIONAL OBJECTIVES

A. Mission Statement

CU-Boulder's vision is grounded in its statutory mission as a national public research university. In Colorado statute, the university is defined as the "comprehensive graduate research university with selective admissions standards . . . offer(ing) a comprehensive array of undergraduate, master and doctoral degree programs" of what is now designated the University of Colorado System.

CU-Boulder recognizes the exceptional opportunities associated with its role as a research university, and values the unique strength and character research achievements bring to undergraduate education. It is keenly aware of its responsibility for educating the next generation of citizens and leaders, and for fostering the spirit of discovery through research. Indeed, CU-Boulder believes that its students, both graduate and undergraduate, benefit from the comprehensive mix of programs and research excellence that characterize a flagship university. Thus, CU-Boulder's statutory mission is relevant today and will remain relevant tomorrow. (http://www.colorado.edu/about/mission)

The mission of the College of Engineering & Applied Science is:

> The college's mission is to generate new knowledge in engineering and related fields, and to equip students from diverse backgrounds to become leaders and citizens responsible for the betterment of individuals and society. Our vision is to be a recognized world leader for excellence and innovation in engineering research and education, with an emphasis on inclusive excellence, active learning and global society. (http://www.colorado.edu/engineering/about/mission-vision)

"The Civil, Environmental and Architectural Engineering Department's mission is the education of undergraduate and graduate students to become leaders in the professional practice of engineering, contributing to technological advances that benefit humankind while enhancing the earth's physical and biological resources." (http://www.colorado.edu/ceae/welcome)

B. Program Educational Objectives

The educational objective of the architectural engineering program is for graduates to:

- Attain a broad knowledge and skills necessary to successfully begin and sustain a career
- Become leaders who advance the state-of-the art, in one of four core disciplines of the building industry: electrical and lighting systems; heating, ventilating, and air conditioning (HVAC) systems; structural systems; construction engineering and management.

These objectives are published on the departmental website: http://www.colorado.edu/ceae/current-students/undergraduate-studies/educational-objectives-outcomes

The objectives are also published in the University of Colorado catalog: https://catalog.colorado.edu/undergraduate/colleges-schools/engineering-applied-science/programs-study/civil-environmental-architectural-engineering/architectural-engineering-bachelor-science-bs/

C. Consistency of the Program Educational Objectives with the Mission of the Institution

The overall themes in these mission statements include the education of professionals who exhibit technological knowledge, leadership, and responsible citizenship; these are reflected strongly in the educational objectives of the Architectural Engineering program.

D. Program Constituencies

The primary constituents of the AREN program are the students and alumni of the program, and the employers of our graduates. The departmental faculty members are also a constituency.

The AREN students and alumni are served through the program objectives by having employable skills that will help them find and advance in rewarding careers, building from their foundational skills in architectural engineering. The alumni are invited to provide feedback to the program objectives formally via the online alumni survey distributed each summer. Alumni about five and/or eight years after earning their Bachelor's degree are invited to participate in the alumni survey.

Employers of our graduates are served through the program objectives by having employees with competence and commitment to keeping their technical skills up-to-date.

Alumni and employers of our graduate are invited to serve on advisory boards (i.e. the Joint Evaluation Committees, JECs) through which they can review and provide additional input to the educational objectives.

The departmental faculty members can use the program objectives to guide their teaching and mentoring activities of architectural engineering students moving through the program. The faculty can revise these objectives if they believe that they are no longer serving our students, alumni, and the engineering profession.

E. Process for Review of the Program Educational Objectives

There are two primary mechanisms that review the program educational objectives, and provide input into revisions. First, the Joint Evaluation Committee (JEC) process reviews the educational objectives and the associated feedback from alumni. Each JEC is comprised of the program constituencies: practicing, professional engineers who are employers of our graduates and/or program alumni; one or more current students; and departmental faculty representatives. Each JEC focuses on a sub-discipline of the CEAE department. Typically, one or two JECs meet each academic year. There are three JECs that review elements related to AREN: building systems, construction engineering and management, and structural engineering & mechanics. Each JEC reviews the program educational objectives. JECs for each sub-discipline reconvene every 3 years. The JECs that have met since the last ABET review are summarized below. The JECs are required to review the educational objectives and recommend changes.

Focus	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
Building Systems	X			X		
Construction Engineering and Management			X			X
Structural Engineering & Mechanics		X			X	

Second, alumni have formal input into the program objectives through an alumni survey instrument. Each summer, alumni five years (and recently also eight years) after graduation are asked to evaluate the appropriateness and their accomplishment of the program objectives. The feedback from the alumni is provided to the JECs for their consideration.

All constituents also have informal but important input through ongoing contacts with the program faculty. Potential changes to the program objectives arising from input from program constituents or assessment information are discussed and approved by the CEAE faculty. The discussion process is often facilitated via the departmental curriculum committee, which has representatives from the major faculty groups in the department. The potential changes are also discussed by the faculty at large and must be approved by a majority vote.

The 2015 AREN JEC report expressed concern with the low response-rate by CEAE alumni to the survey. As such, it has recommended that AREN initiates a "specific 'guerilla' survey utilizing the existing professional networks of the faculty." AREN faculty agreed to develop a short 5-minute survey to be sent to alumni and to personally invite individual alumni to take the survey to yield a higher response rate. Although a specific AREN questionnaire was not used in 2016, one of the AREN faculty sent personal e-mails to all AREN students to solicit response to the survey sent by the college.

CRITERION 3. STUDENT OUTCOMES

A. Student Outcomes

The outcomes that students are expected to have attained upon graduation with a bachelor of science degree in architectural engineering are listed below; a mapping to the ABET (a) to (k) Student Outcomes is shown in brackets:

1. [a] the ability to apply knowledge of mathematics, science and engineering
2. [b] the ability to design and conduct experiments
3. [b] the ability to analyze and interpret data
4. [c] the ability to design a system or component to meet desired needs
5. [d] the ability to function on multidisciplinary teams
6. [e] the ability to identify, formulate and solve engineering problems
7. [f] an understanding of professional and ethical responsibilities
8. [g] the ability to communicate effectively through writing and/or drawing
9. [g] the ability to communicate effectively through oral presentations
10. [h] an understanding of the impact of engineering on society
11. [i] an understanding of the necessity to engage in lifelong learning
12. [j] a knowledge of contemporary issues in civil, environmental and architectural engineering
13. [k] the ability to use modern engineering techniques, skills and tools

These outcomes have remained consistent since the previous ABET review.

These outcomes are published on the departmental website: http://www.colorado.edu/ceae/current-students/undergraduate-studies/educational-objectives-outcomes

The outcomes are also published in the University of Colorado catalog: https://catalog.colorado.edu/undergraduate/colleges-schools/engineering-applied-science/programs-study/civil-environmental-architectural-engineering/architectural-engineering-bachelor-science-bs/

B. Relationship of Student Outcomes to Program Educational Objectives

The architectural engineering program objectives map to the 13 student outcomes of our program, as shown below where an "x" indicates that the accomplishment of the related outcome is an important ingredient for accomplishing the objective. Table 3.1 below illustrates that the two program educational objectives are linked to two or more outcomes, so that processes that are used to assess the outcomes indirectly help to ensure that the overall objectives are being accomplished. Philosophically, consistency between the architectural engineering program objectives and the general educational outcomes for engineering students is desirable for ensuring the professional success of our graduates.

Table 3.1: Mapping of Student Outcomes to the Program Objectives

	Student Outcomes												
Program Objectives	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Successfully begin and sustain a career	x	x	x	x	x	x	x	x	x	x	x	x	x
2. Become leaders who advance the state-of-the art in 1 of 4 core disciplines of building industry				x									x

CRITERION 4. CONTINUOUS IMPROVEMENT

A. Student Outcomes

Outcomes Assessment Methods Summary

The table below provides a summary of the multiple direct and indirect methods that are used to assess achievement of each of the student outcomes. Not all methods are used for all outcomes. The highlighting in green indicates that the outcomes have been consistently met at a sufficient level. Yellow indicates variable fulfillment and/or marginal fulfillment of the outcome based on the metric in question. Red indicates that we failed to meet our goal for that indicator of the outcome. Each of the assessment methods is described in more detail in the paragraphs below.

The FE exam is the national NCEES Fundamentals of Engineering exam. It is a direct evaluation method that is used to assess 7 of the 13 student outcomes. All CU AREN students are required to take the exam before they graduate; they typically take the exam during one of their last two semesters. There is no exam specific to architectural engineering, so most of the AREN students take the "Other Disciplines" exam; a few students also take the Civil Engineering exam. Data are provided from the NCEES summarizing the performance of our students twice per year (returned to the university about three months after the students take the exam). The FE exam topics have been mapped to our student outcomes. Outcomes are flagged as a concern if CU AREN students have a ratio score relative to national AREN students at 0.92 or lower (with the old exam format, the threshold for concern was performing 5% or more below the national average for AREN students). Data highlights including the overall pass rate and any weaknesses identified are presented to the CEAE faculty at an at-large meeting once per semester. Any problems are also discussed by the CEAE curriculum committee.

The capstone course offers an opportunity to evaluate the cumulative knowledge of students on many of the outcomes. Five faculty and/or PhD students representing each AREN discipline (CEM, lighting/electrical, mechanical, structures) grade their respective project deliverables. Up until 2016, each instructor has used their own rubric to directly assess student performance on the outcomes based on required deliverables specified at each design phase (conceptual, schematic, design development). All faculty graded on a 100-point scale, where superior = 90% or more, adequate = 80%-90%, needs improvement = 70-80%, and poor = below 70%. In 2017 all senior capstone faculty have adopted a similar rubric that clearly describes on a scale from 5 to 1 what constitutes professional (5), adequate (4), needs improvement (3), poor (2), and unacceptable (1) work. The content of the rubric is tailored to the assignment within a discipline. This rubric yields grades based on a 100-point system. In addition, faculty along with industry mentors grade two oral presentations (conceptual and schematic). Each team also receives specific feedback with suggestions for improvement. The 5-point rubric described above has been consistently employed to assess the quality of reports (written and drawing communication). Individual assignments related to professional issues are used as evidence of achievement of some student outcomes. A graduate student serving as teaching assistant (TA) grades the individual homework assignments. Examples of rubrics mentioned here will be presented below with the evidence of student outcomes.

Within specific courses, various assignments (or questions on assignments), projects, lab write-ups, or exams are used as embedded indicators to directly measure student learning of some outcomes. Frequently, the normal grades on a particular assignment or question on an assignment are converted to a four-point scale, where: superior = 90% or more, adequate = 80%-90%, needs improvement = 70-80%, and poor = below 70%. The target is for 80% or more of our students to be rated adequate or above on each embedded indicator. These data are presented to the JEC for evaluation, and the JECs often directly examine student work during their assessments. Thus, the JEC feedback can also be considered a direct assessment.

Two indirect assessment methods are also used to evaluate each of the 13 student outcomes. First, at the end of each semester, CU students are asked to evaluate the extent to which each of the AREN and CVEN undergraduate courses contribute to their achievement of the 13 student learning outcomes. These are questions that have been added to the university-wide Faculty Course Questionnaires (FCQs) that are administered by the campus. We expect that student ratings (on a scale of *not applicable = 0* to 6) should be 4 or higher for a minimum of three or more required courses. The data for relevant courses are presented to the JECs. Data from selected courses targeted for each outcome are presented for each outcome in the following sections. Each academic year, the data from required courses are compiled in a spreadsheet to ensure that our targets are being met. In addition, the student evaluation data are compared to faculty ratings of how their courses contribute to the learning outcomes.

The second indirect assessment method used to evaluate each of the 13 student outcomes is the senior survey. The senior survey is administered by the College of Engineering & Applied Science; students graduating in May, August and December are emailed invitations to participate in the survey, which is administered via Qualtrics. Response rates are typically very high (over 90%) for AREN students. In one section of the survey, students rate their achievement of the 13 student outcomes, using a scale of 1 to 5. Achievement should be rated at 3.5 or higher to be satisfactory. The college previously returned data twice per year; it now combines the data for an academic year into a single report. The 2016/2017 graduates data is not included, since due to quality checks it is not expected to be distributed to departments until September/October (following the historical schedule). The senior survey data are presented to the JECs for evaluation. They are also examined and summarized in an annual report written by the Assessment Coordinator and reviewed by the Department Chair, and then posted on the College assessment website.

Student Outcomes Assessment Methods Summary

[N/A = not applicable; green = outcomes consistently met at a sufficient level; yellow = variable fulfillment and/or marginal fulfillment of the outcome]

Direct Assessment				Indirect Assessment	
CU AREN Student Outcomes [ABET a-k]	NCEES FE exam	AREN 4317 Design course	Other course direct assessment || JEC review	Student FCQ ratings, avg top 3	Senior survey avg. rating
1. apply knowledge of math, science, & engineering [a]	4 topics	N/A	College-wide service level courses	5.2	4.2
2. design & conduct experiments [b]	N/A	N/A	AR2120, 3540 CV3161	4.4	3.7
3. analyze and interpret data [b]	statistics	N/A	AR3010, 3540 CV 3161	5.0	4.2
4. design a system or component to meet desired needs [c]	N/A	Final report	Proficiency Courses	5.2	4.1
5. function on multi-disciplinary teams [d]	N/A	Peer evaluations	AR1316 CV3246	5.0	4.4
6. identify, formulate, and solve engineering problems [e]	4 topics	Final Report	Most courses	5.1	4.3
7. professional and ethical responsibilities [f]	ethics	Reflection Essay	AR1316 CV3246	5.0	4.0
8. communicate by writing and/or drawing [g]	N/A	Final report	*WRTG3030;* AREN 1027, 3540	4.5/5.0	4.0
9. oral communication [g]	N/A	Presentatio ns	AR1316	4.7	4.0
10. impact of engineering on society [h]	N/A	Programmi ng Final report	AR1316 CV3246	4.9	3.8
11. necessity to engage in life-long learning [i]	Overall FE pass rate	Reflection Essay	AR1316 CV3246	4.8	4.2
12. knowledge of contemporary issues [j]	Eng. economics	Final Report	AR1316, CV3246	4.7	3.8
13. modern engrg techniques, skills, tools [k]	Computers/ data & instrument	Final report	AR1027, 3540 CV2012, 3161	4.9	4.1

The data for each outcome will be presented in detail in the following sections.

Outcome 1 (a). Apply knowledge of math, science, and engineering fundamentals

Outcome 1 (a): FE exam

Direct assessment of this outcome is largely conducted by student performance on the NCEES Fundamentals of Engineering (FE) exam. Since the revision of the exam in January 2014 from an 8-hour format to a ~5-hour online format, we have decided to rely on 4 topics from the Other Disciplines exam to evaluate this outcome: math, chemistry, statics, and dynamics. Data across an academic year have been combined, due to very low student numbers in some semesters (example: fall 2014 and fall 2015, only 3 students each term). Ratio scores are reported, representing the ratio of the average percentage of questions on a topic that CU AREN students answer correctly divided by the average percentage of questions on a topic that AREN students nationally answer correctly. Academic year weighted averages are reported, since some semesters have a low number of test takers. The goal is to equal or exceed a ratio score of 0.92. We successfully met this goal for all topics individually except in fall 2016 for two of the topics. Most AREN students take the FE exam in the spring. Because data from spring 2017 will not be available in time to include it in this report, it is not possible to combine data across the academic year as done for the two previous years. It is conceivable that the overall averages would be higher once the data from spring 2017 is included. Green highlights indicate where on average CU students performed better than their peers nationally. Averaged across the four topics, CU AREN students performed above national AREN peers in two evaluation cycles. Thus, no deficiency is evident.

Academic Year/Term:	Sp 14	F2014-S15	F2015-S16	F2016
n	*18*	*28*	*21*	*7*
FE Exam Topic	**Ratio Scores of CU performance vs. National**			
Math	0.97	0.98	1.07	0.96
Chemistry	0.98	0.95	1.02	0.93
Statics	1.06	0.92	1.01	0.91
Dynamics	1.03	0.97	1.07	0.89
Average Outcome 1	**1.01**	**0.95**	**1.04**	**0.92**

Previously, with the old format of the FE exam we used student performance on 7 topics to assess students' ability to apply knowledge of math, science, and engineering fundamentals. These were topics on the morning part of the exam that did not map to another outcome and for which CU AREN students take at least 1 required course. The average percentage of questions on each topic that CU AREN students answered correctly was compared to the average for AREN students nationwide; the difference is shown. If the CU students were not more than 5% below their national peers, the performance was considered acceptable. In one academic year performance in strength of materials failed to meet this goal; in one semester with a low number of examinees (fall 2013) both statics and strength of materials failed to meet our minimum standard. Averaged across the 7 FE topics of interest, in all evaluation cycles we met our minimum goal. The results show that CU AREN students are adequately able to apply knowledge of math, science, and engineering fundamentals.

Academic Year/Term:	F2011-S12	F2012-S13	Fall 2013
n	*44*	*34*	*9*
Topic on the FE exam	**CU % correct – Natl % correct**		
Math	+1	0	+8
Chemistry	-2	-2	+2
Statics	-5	-2	-18
Strength Materials	-5	-7	-13
Electricity & Magnetism	+3	-1	+5
Fluid mechanics	+5	+1	-4
Thermodynamics	+3	-1	+5
Average Outcome 1	**0**	**-2**	**-2**

Outcome 1 (a): Courses

Many of the service level courses taken by AREN majors along with most other engineering majors build the foundation for this outcome: Calculus 1, 2, 3; Linear Algebra and Differential Equations; Chemistry for Engineers; General Physics 1; General Physics 2; Experimental Physics I. These courses are required for many different engineering majors and are therefore reviewed by specially convened "Task Forces" of the CEAS Undergraduate Education Council.

A review of the calculus courses through Applied Math (APPM) was conducted in 2014-2016, with several math surveys conducted. The students who pass through the calculus sequence have strong knowledge and competency. The concern is the high percentage of students who are not passing these courses on the first try. No deficiency related to calculus knowledge is evident.

In 2014, a response was submitted to the chemistry review committee's 2010 report. Prof. Joe Ryan from CEAE served on the chemistry review committee. The review concerns did not relate to a lack of student knowledge upon passing the course, but rather the generally poor student experience in the course. Course changes included smaller lectures, a recitation, incorporation of active learning, and on-line homework. No deficiency related to basic chemistry knowledge was evident.

In addition, almost all AREN and CVEN courses also include this outcome to some extent, since math and science fundamentals are being applied. Given the strength of direct assessment via the FE exam, additional direct assessment evidence is not gathered to assess this outcome.

Outcome 1 (a): JEC Review

The JECs have not noted any weaknesses in the areas of math, science, and engineering knowledge.

Outcome 1 (a): Student Ratings on Course FCQs (0-6)

This outcome had the second highest overall average rating by students across all required courses in the architectural engineering curriculum, averaging 4.5-4.7 across all courses and all semesters of data. In all, 9 required courses were at or above 4.0 for an average student rating. Therefore, the student FCQ ratings indicate no weaknesses in this outcome. The table below presents average student ratings for three representative courses; these courses were offered both fall and spring semester, so two sets of FCQ values per year are shown. This outcome is one of the strengths of CU AREN students.

Math, Science, Engineering Outcome: Average Student Ratings on Course FCQs (0-6 scale)

Academic Year	CVEN 2121 Analytical Mechanics 1	CVEN 3161 Mechanics of Materials 1	CVEN 3525 Structural Analysis
2012-13	N/A, 4.7	N/A, 5.1	N/A, 4.7
2013-14	5.2, 4.8	5.1, 5.6	5.1, 5.0
2014-15	4.6, 5.3	4.4, 5.5	5.1, 5.1
2015-16	5.3, 5.6	5.3, 5.6	5.5, 3.5
2016-17	5.0, 4.6	4.9, 4.0	4.4, 5.6

N/A = the university left the question off the FCQ form that term

Outcome 1 (a): Senior Survey

On the survey distributed to all graduating senior students, students are asked to rate their personal achievement and the importance of the outcome “ability to apply knowledge of math, science, and engineering” using a Likert-scale from 1 to 5. These achievement ratings all exceeded 3.5 by a safe margin and indicate no weaknesses for this outcome.

Senior Survey Avg rating 1-5 scale	Year	2011 -12	2012 -13	2013 -14	2014 -15	2015 -16
# responses		*43*	*39*	*34*	*38*	*31*
Math, Science, and Engineering		4.1	4.2	4.4	4.4	4.1

<u>Summary</u>: Even though FE performance is uneven between academic years, the average for this outcome is never lower than the set goal of 0.92. All other direct and indirect assessment measures met our targets in each academic year. Therefore, this outcome has been sufficiently achieved.

Outcome 2 (b). Design and Conduct Experiments

Outcome 2 (b) Course Direct Assessments

The primary required AREN courses with laboratory experiments are: CVEN 3161 Mechanics of Materials 1, AREN 2120 Fluid Mechanics and Heat Transfer, and AREN 3540 Illumination I. Example data are shown below. Each professor determines the rubric and criteria for scoring the lab reports. Rubric samples are provided Appendix E. In general, 90% and above is considered superior, 80-90% adequate, and less than 80% below adequate. The goal is to have these lab grades serve as embedded indicators of students' abilities to design and conduct experiments.

CVEN 3161 Mechanics of Materials 1

Student grades on the final lab report of the semester were used to indicate adequate ability to design and conduct experiments (and analyze and interpret the data). The performance of AREN students was tracked separately from Civil Engineering (CVEN) students enrolled in the course from 2014 through 2016. Data from previous years indicate performance for both AREN and CVEN students combined.

The final laboratory of CVEN 3161 is titled 'Background and Theory for the Concrete Flexure Test'. In this lab, students mix concrete following a specific proportion of cement and aggregates, place the concrete mix in molds and let it cure. Students write a formal report that includes among other things the experimental procedure and results. As part of their analysis, students plot the load vs. displacement curves for five specimens, calculate the flexural modulus of elasticity and maximum tensile stress, plot the actual w/c ratio vs. both the 28-day flexural strengths and average modulus of elasticity, and calculate the upper and lower bound of compressive strengths. Students also need to consider similarities and differences between samples, explain deviation from anticipated results, identify any large errors and attempt to explain the possible causes, and discuss their own visual observations.

Design and Conduct Experiments: Student Performance on Laboratory Portion of Course

Term	*# students*	Percentage of Students at Each Level		
		% below adequate	% adequate	% superior
S2017	*20*	5	20	75
S2016	*16*	0	0	100
S2015	*11*	0	0	100
S2014	*24*	5	26	68
F2014	*35*	6	6	89
F2013	*34*	0	11	89
F2012	*52*	2	17	81
S2012	*90*	3	24	72
F2011	*40*	33	37	30

* spring used for evaluation due to larger enrollment

For this course with a lab component, the data (up to this point) indicate sufficient fulfillment of this outcome, since >80% of the students possessed an adequate ability to conduct the experiments in 7 out of the 8 semesters.

AREN 2120 Fluid Mechanics and Heat Transfer

In this class, students design and build a model house with comfortable indoor air temperature for both day and night. Specific physical and performance constraints are given. After groups of three design and build their house, they measure, analyze, interpret and document its thermal performance.

Design and Conduct Experiments: Student Performance on Laboratory Portion of Course

Term	*# students*	Percentage of Students at Each Level		
		% below adequate	% adequate	% superior
S2017	36	17	44	39
S2016	37	0	5	95
S2015	30	7	53	40
S2014	35	6	37	57
S2013	45	13	42	44
S2012	41	0	0	100

For this course, the data indicate sufficient fulfillment of this outcome, since >80% of the students possessed an adequate ability to conduct the experiments.

AREN 3540 Illumination I

Students conduct an illuminance survey where students determine horizontal illuminances of at least 40 positions at work plane height. Students then produce an iso-illuminance plot using Excel. The deliverable is a report that shows among other things the data summary (average illuminance in the space along with the mean deviation), contour plot and an AutoCAD drawing (to scale) of the room showing where the measurements were taken.

Design and Conduct Experiments: Student Performance on Laboratory Portion of Course

Term *	*# students*	Percentage of Students at Each Level		
		% below adequate	% adequate	% superior
F2013	38	8	18	74
F2014	34	0	26	74
F2015	38	24	18	58
F2016	39	0	38	62

* Only 4 semesters are available as the instructor of record began teaching this particular lab in 2013.

For this class, the data indicate sufficient fulfillment of this outcome for all years except in 2015 where 76% of the students possessed an adequate ability to conduct the experiments.

Outcome 2 (b) JEC

The JEC process often focuses significant attention on laboratory-based courses, including review of student work. Indeed, the 2015 AREN JEC report indicates that "in general the curriculum seems light on laboratory classes" and refers to GEEN 1400 First-Year Engineering Projects as a course to emulate (interdisciplinary hands-on design/build/test course.) The faculty response corroborated the information shown above for Mechanics of Materials I, Fluid Mechanics and Heat Transfer, and Illumination I, and affirmed that sufficient and relevant laboratory work is embedded in AREN courses.

Outcome 2 (b) Student Course FCQs

At the end of the semester, students rate the extent to which a course improved their ability to design and conduct experiments; data for the six required courses in the curriculum with the highest ratings are summarized below. Some large variation in the responses between semesters is evident, which appears primarily driven by the course instructor and changes in course content over time. In 2013-14 the goal of having three or more courses rated at 4.0 or higher for this outcome was just achieved since some of the courses in this academic years met the minimum standard. In general, though, we met this requirement.

Design and Conduct Experiments Outcome: Student Ratings on Course FCQs (0-6 scale)

Academic Year	AREN 1027 Eng Drawing	AREN 2120 Fluids Heat Xfer	AREN 3540 Illum I	CVEN 3161 Mech of Materials 1	CVEN 3246 Intro Const	CVEN 2012 Geomatics
2012-13	4.0	4.7	3.9	4.0, 4.3	3.1, 3.6	4.4
2013-14	2.3	4.0	NO	3.8, 4.3	3.6, 4.0	3.2
2014-15	4.4	4.5	3.4	3.7, 4.4	3.2, 4.0	3.5
2015-16	4.4	4.8	4.4	5.0, 4.5	3.9, 4.4	3.9
2016-17	3.3	5.3	4.5	4.6, 3.6	4.0, 4.6	3.6

NO = course not offered in fall 2013 or spring 2014; taught spring 2013 and fall 2014

Outcome 2 (b) Senior Survey

The seniors rated their personal achievement of the ability to design and conduct experiments at an adequate level, as shown in the table below. However, as achievement was marginal in three assessment cycles, we will explore ways to infuse more experiments into the curriculum.

Senior survey Avg ratings 1-5 scale	Year	2011 -12	2012 -13	2013 -14	2014 -15	2015 -16
# responses		*43*	*39*	*34*	*38*	*31*
Design and conduct experiments		3.6	3.6	3.9	4.1	3.5

Summary: The indirect assessment methods are the weakest data in terms of meeting our goal. While courses taught back to back in an academic year show uneven results, overall, our minimum criteria is met. Given the totality of the direct and indirect assessment data, the students are sufficiently meeting the outcome to design and conduct experiments.

Outcome 3 (b). Analyze and Interpret Data

Outcome 3 (b) FE Exam

Student performance on the NCEES Fundamentals of Engineering exam on the topic of probability and statistics is an indicator of our students' abilities to analyze and interpret data. In three academic years, CU AREN students performed better than national peers; one academic year was below peers but within acceptable levels (above ratio scores of 0.92, less than 5% below peers); one academic year performance did not meet our minimum criteria. The unstable performance results in flagging this as an area of concern.

FE topics	Year	11-12	12-13	F13	Sp14	14-15	15-16	Fall 16
	n CU students	*44*	*35*	*9*	*18*	*28*	*21*	*7*
Probability & statistics	Ratio score				0.98	0.89	1.01	1.16
	% Difference	*6*	*8*	*-3*				

Outcome 3 (b) JEC

The JEC reviews have not noted any weaknesses of the students in the ability to analyze and interpret data. However, the 2016 Structures JEC committee provided "general observations on the curriculum." Specifically, they note that a probability and statistics course is not required for AREN students. They recommended that "AREN students should be exposed to some probability and statistics elsewhere in the coursework. For example, basic concepts should be introduced in LRFD topics of steel and reinforced concrete design courses". The faculty indicates that CVEN 3256 Construction Equipment and Methods is a prerequisite for some areas of concentration and covers some basics of probability and statistics. However, not all AREN students take this course. The structures faculty "will wait and see how the AREN faculty handle this, and then reassess whether we need to provide some material in the concrete and steel design courses, but this would take valuable time, and be merely a review for civil engineering students."

Outcome 3 (b) Student Ratings on Course FCQs

Students are expected to analyze and interpret data in several required AREN courses. The students' ratings for the five courses with the most content related to this outcome are summarized below. Students consistently gave strong ratings to four courses. This is indirect evidence of fulfillment of this outcome.

Analyze and Interpret Data Outcome: Student Ratings on Required Course FCQs (0-6 scale)

Academic Year	AREN 2120 Fluids Heat Xfer	AREN 3540 Illum 1	AREN 3010 Mech Sys	CVEN 2012 Geomatics	CVEN 3161Mech Matls
2012-13	4.7	4.8	5.3	4.9	4.6, 4.9
2013-14	3.7	NO	4.7	4.3	4.8, 5.3
2014-15	4.3	5.3	4.4	4.3	4.2, 5.1
2015-16	4.9	5.1	4.1	4.8	5.3, 5.1
2016-17	5.4	5.2	3.8	4.7	4.8, 4.2

NO = course not offered in fall 2013 or spring 2014; taught spring 2013 and fall 2014

Outcome 3 (b) Senior Survey

The ability to analyze and interpret data was rated at an adequate level by seniors in all assessment cycles. No weakness is evident from these data.

Senior survey	Year	2011	2012	2013	2014	2015
Avg ratings 1-5 scale		-12	-13	-14	-15	-16
# responses		*43*	*39*	*34*	*38*	*31*
Analyze & interpret data		4.1	4.2	4.4	4.4	3.8

Summary: In total, the direct evidence from the FE exam and indirect data from students' self-assessments indicates that architectural engineering students graduate with sufficient ability to analyze and interpret data.

Outcome 4 (c). Design a System or Component

Outcome 4 (c) Senior Design Rubric

Direct evidence of students' ability to design a system to comply with a variety of constraints and criteria is documented in the capstone senior design course. Students design the structural, HVAC, and lighting and electrical systems along with construction management processes for a small to medium-size commercial building. Students are organized in teams; each team contains one or two representatives of each discipline. Students submit project reports at the conceptual, schematic, and design development phases of design. At each phase, students of each discipline are graded on a 100-point scale where 90% and above is considered superior, 80-90% adequate, less than 80% below adequate. The table below presents a compilation of grades organized by discipline and then by design phase. The intent is to show formative improvement from one phase to the next (conceptual and schematic phases) and summative progress evidenced in the final report (design development phase).

In 2017, all senior capstone faculty used a similar rubric that clearly describes on a scale from 5 to 1 what constitutes professional (5), adequate (4), needs improvement (3), poor (2), and unacceptable (1) work. The content of the rubric is tailored to the assignment within a discipline. Because the rubric yields grades based on a 100-point system, 2017 percentages below are congruent with percentages from all previous years. An example of 2017 rubric is shown in Table 4-1 (below).

Design Outcome by Discipline

Discipline	Design Phase	Year	# Students	Percentage of Students at Each Level		
				% below adequate	% adequate	% superior
CEM	Conceptual Phase	S2012	49	10	61	29
		S2013	37	0	62	38
		S2014	36	28	44	28
		S2015	40	13	63	25
		S2016	32	0	88	13
		S2017	32	0	38	62
	Schematic Phase	S2012	49	10	43	47
		S2013	37	14	51	35
		S2014	36	0	14	86
		S2015	40	0	0	100
		S2016	32	0	0	100
		S2017	32	0	0	100
	Design Development Phase	S2012	49	0	0	100
		S2013	37	0	0	100
		S2014	36	0	14	86
		S2015	40	0	0	100
		S2016	32	0	0	100
		S2017	32	0	0	100
HVAC	Conceptual Phase	S2012	49	10	51	39
		S2013	37	0	38	62
		S2014	36	0	28	72
		S2015	40	0	0	100

Discipline	Design Phase	Year	# Students	Percentage of Students at Each Level		
				% below adequate	% adequate	% superior
		S2016	32	13	38	50
		S2017	0	0	50	50
	Schematic Phase	S2012	49	0	41	59
		S2013	37	0	0	100
		S2014	36	0	28	72
		S2015	40	0	13	88
		S2016	32	0	50	50
		S2017	32	0	38	62
	Design Development Phase	S2012	49	10	20	69
		S2013	37	11	14	76
		S2014	36	0	14	86
		S2015	40	0	0	100
		S2016	32	13	38	50
		S2017	32	0	13	87
Lighting and Electrical *	Conceptual Phase	S2012	49	10	31	59
		S2013	37	0	38	62
		S2014	36	0	42	58
		S2015	40	0	25	75
		S2016	32	0	50	50
		S2017	32	0	38	62
	Schematic Phase	S2012	49	0	51	49
		S2013	37	0	22	78
		S2014	36	0	72	28
		S2015	40	0	20	80
		S2016	32	0	50	50
		S2017	32	0	25	75
	Design Development Phase	S2012	49	0	10	80
		S2013	37	0	8	92
		S2014	36	8	28	64
		S2015	40	0	0	100
		S2016	32	0	13	88
		S2017	32	0	25	75
Structures	Conceptual Phase	S2012	49	10	10	80
		S2013	37	0	46	54
		S2014	36	0	14	86
		S2015	40	13	25	63
		S2016	32	0	38	63
		S2017	32	0	88	12
	Schematic Phase	S2012	49	0	31	69
		S2013	37	0	59	41
		S2014	36	0	14	86
		S2015	40	0	25	75
		S2016	32	0	13	88
		S2017	32	0	0	100

	Design Development Phase	S2012	49	10	31	49
		S2013	37	0	46	54
		S2014	36	0	42	58
		S2015	40	0	13	88
		S2016	32	0	0	100
		S2017	32	0	13	87

* Lighting and Electrical grades have been averaged.

The design data indicate sufficient fulfillment of this outcome, since >80% of the students (except for in 2014 CEM conceptual phase) possessed an adequate ability to design a system or component.

Outcome 4 (c) JEC

The recommendation from the 2015 JEC AREN report to "strongly consider an integrated course with a CU Denver architecture course where architectural students play the role of the architect and generate the building design" could be argued relates to the students' ability to design a system or component. In 2016, an experimental course between AREN students and the environmental design (architecture) students at CU Boulder took place. The faculty is assessing the success of such experiment and "consider a more permanent solution in collaboration with the ENVD [Environmental Design] students in the future."

Outcome 4 (c) Student Ratings on Course FCQs

Students were asked to rate this statement "The course improved my ability to design a system or process to meet desired needs." Design was highly rated by the students as an outcome in four required architectural engineering courses. The results indicate strong design content, and no weakness in this area.

Design Outcome: Student Ratings on Required Course FCQs (0-6 scale)

Academic Year	AREN 2120 Fluids Heat Xfer	AREN 3010 Mech Systems	AREN 3540 Illum 1	AREN 4317 Capstone Dsn
2012-13	4.7	5.2	5.2	5.5
2013-14	4.6	4.9	NO	5.3
2014-15	5.0	4.7	5.5	5.1
2015-16	5.0	4.1	5.5	5.0
2016-17	5.4	4.5	5.5	5.7

NO = course not offered in fall 2013 or spring 2014; taught spring 2013 and fall 2014

Outcome 4 (c) Senior Survey

The senior survey included three questions related to design ability; results are summarized below. First the students rated their "ability to design a system, component or process to meet desired needs within realistic constraints", based on how well they individually achieved this outcome. The ratings are 4.0 and higher which indicate adequate fulfillment of this outcome.

The students also indicated their level of agreement (1-Strongly Disagree, 2-Disagree, 3-Neither Agree Nor Disagree, 4-Agree, 5-Strongly Agree) to two statements:

My (major) capstone/senior design project reinforced the concepts I learned in my College of Engineering education

My (major) capstone/senior design project prepared me for an engineering career The senior responses to both questions show that students generally agree with these statements. No deficiency in this outcome was identified based on these data.

Senior Survey Avg ratings 1-5 scale	Year	2011 -12	2012 -13	2013 -14	2014 -15	2015 -16
# responses		*42-43*	*37-39*	*33-34*	*37-38*	*30-31*
Ability to design a system to meet desired needs		4.0	4.3	4.3	4.4	4.0
Senior design project reinforced the concepts I learned in engrg		4.3	4.3	4.1	4.0	4.1
Senior design project prepared me for an engineering career		4.0	4.0	4.0	3.8	4.1

<u>Summary:</u> The direct assessment data from capstone design is supported by the indirect assessment data, and demonstrates that the students have adequate abilities to design when they graduate.

Table 4.1 – Rubric for conceptual design submittal for lighting discipline

	Levels of Achievement				
	Professional	**Adequate**	**Needs Improvement**	**Poor**	**Unacceptable**
Item	**5**	**4**	**3**	**2**	**1**
Space-by-space programming	The report provides a complete and thorough program for the public interior spaces and exterior main features. This means that the report addresses all of the architectural, psychological, and task and physiological factors; all factors are explained or justified.	The program analysis is complete but brief and may lack some detail.	The program is complete but is not well developed or is hard to follow; some factors are not explained or justified.	Factors are presented as a list without any explanation or justification; factors may be missing.	The overall programming is inadequate or missing entirely.
Light concept and visual support	The concept statement is clear, concise, and reasonable; the concept is congruent with the type and style of building and supports the purpose and activities set by the library; the images provided show the desired lighting effects; therefore they fully support the concept.	The concept statement is somewhat vague but the images provided help clarify it; the lighting concept is congruent with the style of the building and supports the activities.	The concept statement is vague and the images provided may not help clarify the concept statement; the reader may question the adequacy of the concept with respect to the style of the building or its support to the library's activities.	The concept statement is vague and the images provided do not clarify the concept statement; the concept is not congruent with the style of the building nor supports the library's activities.	The concept is unintelligible, unreasonable, farfetched, or missing entirely. The images provided do not relate at all to the concept statement or are entirely missing.
Light Maps	The light maps/plans clearly reflect the proposed lighting concept and lighting effects. This means that they communicate visually and through text if necessary the location and distribution of the proposed light.	The maps/plans reflect the proposed lighting concept and lighting effects, but the graphic representation of such effects may be lacking.	The maps/plans may not fully reflect the proposed lighting concept or desired lighting effects; the maps/plans do not communicate the desired lighting effects clearly.	The light map/plans are incomplete; the lighting effects presented do not relate to the lighting concept; the visual representation of the lighting effects is confusing.	The light maps/plans are unprofessional, incomprehensive, do not communicate the concept at all, or are missing entirely.

Lighting design criteria	The lighting design criteria is thorough and complete: the text includes horizontal/vertical Illuminances for all spaces. The student understands the need for multiple illuminance values based on use of the space, occupancy needs, and/or layers of light; the text provides accent illuminance ratios and luminance ratios where appropriate as well as building and space-by-space lighting power allowances for ASHRAE 2010, ASHRAE mandatory controls, and CU Boulder outdoor lighting standards.	The lighting design criteria includes horizontal/vertical Illuminances for all spaces. The student may not provide illuminance values based on use of the space, occupancy needs, and/or layers of light; the text may not provide all accent illuminance ratios or luminance ratios it provides building and space-by-space lighting power allowances for ASHRAE 2010. Mandatory ASHRAE controls are included and CU Boulder outdoor lighting standards, but details are missing.	The lighting design criteria includes horizontal/vertical Illuminances for all spaces. The student does not provide multiple illuminance values; the text does not provide all accent illuminance ratios or luminance ratios; building and space-by-space lighting power allowances for ASHRAE 2010, mandatory ASHRAE controls and/or CU Boulder outdoor lighting standards are incomplete.	The text lists recommended Illuminances for some required spaces; it is apparent that the student has chosen illuminances without discernment for why those values are necessary or appropriate; building and space-by-space lighting power allowances may not be complete. Mandatory controls and outdoor lighting compliance are missing.	The overall lighting design criteria is inadequate or missing entirely.

Outcome 5 (d). Multidisciplinary Teamwork

Outcome 5 (d) Senior Design Rubric

Students often work in teams in courses throughout the AREN program, beginning in their first year with courses such as GEEN 1400 Engineering Projects. In addition to the required courses, many of the upper-level elective courses also have teamwork as an integral part of the course project work. While the teamwork experience in the first three years of the curriculum provides continuous opportunity for students to collaborate on complex projects, most of these efforts are not multidisciplinary. By comparison, AREN 4317 Architectural Engineering Design provides a true multidisciplinary experience in which teams of up to five students, each working in a different discipline of the AREN program, work together to develop a building design. Students in this course are fully exposed to the collaborative and integrated design environment in which they work to a common goal, but with discipline-specific and often competing objectives, requirements, and schedules. In addition, they must interact with a team of faculty and professionals throughout the project. To understand how well students work in their teams, they all must participate in a confidential assessment developed by CATME[1]. They rate themselves and their peers after the completion of each design phase. The sub-categories for teamwork varied somewhat each year. In general, these include: contribution to work, interaction with teammates, keeping team on track, and expecting quality.

CATME results are used in three ways:

1. The instructor of record provides guidance and mentoring to the student teams, and intervene as needed with teams that are dysfunctional.

2. CATME generates an adjustment factor which "attempts to show the contribution of a given student relative to the other members of their team" (CATME.org). This factor is applied to students' final grades to better reflect the individual contribution of a given student within the team and throughout the semester. CATME caps the factor at 1.05 and values above 0.95 are rounded up to 1.00 as values in this range are considered noise. Adjustment factors used in this class include the students' self-ratings. The data shown below are averages of adjustment factors from the three design phases, where above 1.02 = superior, between 0.95 and 1.02 = adequate, and below 0.95 = below adequate.

CATME Results – Peer evaluation including self-ratings

		Percentage of Students at Each Level		
Year	# Students	% below adequate <0.95	% Adequate >1.02-<0.95	% superior >1.02
2012	49	18	37	45
2013	37	14	41	46
2014	36	19	44	36

[1] CATME is a web-based tool developed by Purdue University designed to, among other things, enhance "team learning by teaching students how to contribute effectively to teamwork and creating accountability for team-member contributions." More information can be found at https://info.catme.org/.

2015	40	8	48	45
2016	32	22	38	41
2017	32	3	66	31

The minimum level for sufficient achievement of this outcome is that 80% or more of the students are adequate or higher on each aspect of teamwork. This goal was achieved in all years except in 2016 where 78% of the students achieved the minimum level of adequate or above.

3. CATME results are shared with all students and they are asked to reflect on their experience as part of the team and provide specific steps for improvement. Reflection essays are required for the conceptual and schematic phases. Students are graded on a 10-point scale where 9 and above = superior, 8-9 = adequate, and less than 8 = below adequate.

CATME Reflection Essays

			Percentage of Students at Each Level			
Phase	Year	# Students	Non-compliance	% below adequate	% Adequate	% superior
Conceptual	S2012	49	12	0	4	84
	S2013	37	0	5	0	95
	S2014	36	6	0	0	94
	S2015	40	13	0	3	85
	S2016	32	9	6	13	72
	S2017	32	3	0	0	97
Schematic	S2012	49	12	4	0	84
	S2013	37	16	0	0	84
	S2014	36	19	8	17	56
	S2015	40	5	3	8	85
	S2016	32	9	6	9	75
	S2017	32	9	0	6	84

The minimum level for sufficient achievement of this outcome was achieved in all years except in the schematic phase in 2014 where 73% of the students achieved the minimum level.

In addition to CATME peer reviews and self-analysis, the course also requires teams to produce meeting minutes to foster team communication. Team members are asked to record meeting minutes every time they meet. Prior to 2016, students were instructed to take turns recording minutes to ensure that everybody in the team contributed. Because some students took this assignment more seriously than others, the level of effort was uneven. Starting in 2016 every student in the team is required to file a minimum of three minutes (one per design phase) for a total of 12 to 15 minutes per team to ensure team interaction. The data below shows the number of meeting minutes generated by students each semester.

Meeting Minutes

Year	# Students	Non-compliance	Number of Meeting Minutes			
			1	2	3	>3
2012	49	2	21	13	10	3
2013	37	3	25	7	2	0
2014	36	1	10	18	5	2
2015	40	5	8	12	10	5
2016	32	0	0	2	18	12
2017	32	0	0	4	13	15

Outcome 5 (d) Student Ratings on Course FCQs

The ability to function on multidisciplinary teams was rated at 4 or higher in ~6 courses, although only intermittently in some of the courses; examples of the FCQ ratings from four routinely strong courses are shown below. The most truly "multidisciplinary" experience occurs in the GEEN 1400 First Year Engineering Projects course, where each section includes students from all engineering majors. Civil and architectural engineering students work together on teams in AREN 1316 (from 2012-2016), CVEN 2012 Geomatics, and CVEN 3246 Introduction to Construction. In the senior capstone design course, architectural engineering students take on different roles in the project (building systems, structural, and construction).

Each year, a minimum of three courses were rated at 4 or higher, so no weakness in this outcome was found based on this indirect evidence of course ratings by students.

Multidisciplinary Teamwork: Student Ratings on Required Course FCQs

Academic Year	AREN 1316 Intro AREN	CVEN 2012 Geomatics	CVEN3246 Intro Constr	AREN 4317 Senior Design
2011-12	3.2	4.4	4.8, 5.3	5.4
2012-13	3.9	4.3	5.0, 4.9	5.7
2013-14	4.2	4.3	4.9, 5.0	5.3
2014-15	4.6	3.9	4.8, 4.9	5.1
2015-16	5.0	4.6	5.3, 5.1	5.5
2016-17	4.1	4.4	5.1, 5.3	5.8

Outcome 5 (d) Senior Survey

The ability to function on a multidisciplinary team was the highest-rated outcome by AREN students, with ratings at and above 4.3. No weakness is evident from these data.

Senior Survey (avg ratings 1-5 scale)	Year	2011 -12	2012 -13	2013 -14	2014 -15	2015 -16
# responses		*42*	*39*	*34*	*36*	*31*
Function on multidisciplinary team		4.3	4.5	4.3	4.5	4.7

Summary: The direct and indirect assessments provide sufficient evidence that our students reliability graduate with the ability to function on multidisciplinary teams.

Outcome 6 (e). Identify, formulate, and solve engineering problems

Outcome 6 (e) FE Exam

Student performance on the FE exam on four topic areas that are taught within the CU AREN curriculum were selected to represent students' ability to solve engineering problems. Our goal is to be not more than 5% below the performance of national AREN peers (when percentage correct was reported on the old exam format for the *other disciplines* exam administered in the afternoon) or a ratio score not lower than 0.92 (given that previously ~60% of the questions were answered correctly, thus CU 0.55 / natl 0.60 =0.92). Except for fall 2016, we met our goal in all topics, and in four academic years CU AREN students performed above their national AREN peers. Overall, no weakness in this outcome is evident.

FE Topic	YEAR	11-12	12-13	F13	Sp14	14-15	15-16	F16
	# CU students	*44*	*35*	*9*	*18*	*28*	*21*	*7*
Strength Matls	Ratio				.95	.95	.99	.94
Engrg Matls	*% vs. Natl*	*-3*	*-1*	*-4*				
Fluids - Gases	Ratio				1.01	.95	1.04	.91
Fluids	*% vs. Natl*	*+0.5*	*+2*	*+2*				
Elect power magn	Ratio				1.02	.96	1.03	1.05
Electricity & mag	*% vs. Natl*	*+10*	*+2*	*+2*				
Heat mass e xfer	Ratio				1.06	.99	1.03	.94
Thermo / heat	*% vs. Natl*	*+3*	*+1*	*-2*				
4-topic avg	Ratio				*1.01*	*.96*	*1.02*	*.96*
	% vs. Natl	*+3*	*+1*	*-0.5*				

Outcome 6 (e) Student Ratings on Course FCQs

The ability to solve engineering problems was the highest rated outcome by the students of the required courses in the curriculum overall, with an average rating of 4.6-4.7 across all courses in the curriculum. Thus, practically any course could be used to assess this outcome. Data from two engineering science courses (statics and fluids/heat transfer) and two fundamental building systems courses were selected for illustrative purposes, shown below. The data show that our goal of three or more courses rated at 4 or higher was met each year. Therefore, this provides indirect evidence that student knowledge for this outcome is sufficient.

Problem Solving Outcome: Student Ratings on Required Course FCQs (0-6 scale)

Academic Year	AREN 2120 Fluids Heat Xfer	CVEN 2121 Analytical Mech1	AREN 3010 Mech Systems	AREN 3540 Illumination 1
2011-12	5.0	5.4, 3.8	5.0	4.7
2012-13	5.0	4.9, 4.2	4.8	4.7
2013-14	4.6	5.3, 4.9	4.7	NO
2014-15	5.0	4.5, 5.5	4.0	5.3
2015-16	5.1	5.5, 5.7	3.4	5.4
2016-17	5.3	5.2, 4.4	4.4	5.5

NO = course not offered in fall 2013 or spring 2014; taught spring 2013 and fall 2014

Outcome 6 (e) Senior Survey

The ability to identify, formulate, and solve engineering problems was rated at a sufficient level of average achievement by AREN students, with ratings at or above 4.2. No weakness is evident from this data.

Senior Survey (avg ratings 1-5 scale)	Year	2011 -12	2012 -13	2013 -14	2014 -15	2015 -16
# responses		*43*	*38*	*34*	*36*	*31*
ID, formulate, solve eng problems		4.2	4.3	4.2	4.4	4.3

Summary: The direct assessment data from the FE exam, strong student ratings in several required undergraduate architectural engineering courses, and self-ratings by students on the senior survey all support that CU AREN students have adequate ability to identify, formulate, and solve engineering problems when they graduate.

Outcome 7 (f). Professional and Ethical Responsibility

Outcome 7(f) FE Exam

There are questions on the FE exam that relate to professional and ethical responsibility. In all evaluation cycles, except in fall 2016, we met or exceeded our minimum goal. In three academic years, CU AREN students performed better than their national peers. Thus, no weakness in students' knowledge of professional and ethical issues was found.

FE Topic	Year	11-12	12-13	F13	Sp14	14-15	15-16	F16
	n CU students	*44*	*35*	*9*	*18*	*28*	*21*	*7*
Profession & ethics	Ratio score				.96	.94	1.05	.87
	% Difference	*+1*	*+0.5*	*-2*				

Outcome 7 (f) Direct Assessment: Student Performance on Homework

In the Introduction to Architectural Engineering course, one assignment related specifically to ethics and professional licensure. Students' knowledge of ethics evidenced on the homework assignment is summarized below, where a score of >90% was rated superior, 80-80% adequate, 70-80% needs improvement, and <70% poor. Each year, expect in fall 2016, over 80% of the students demonstrated adequate knowledge of ethics, meeting our goal for this outcome.

AREN1316 Intro to AREN Course			Percentage of Students at Each Performance Level			
Homework Topic	Year	n	Poor	Needs Improvement	Adequate	Superior
Ethics	F2012	35	3	0	9	88
	F2013	33	12	3	6	79
	F2014	36	14	3	8	75
	F2015	26	8	0	0	92
	F2016	33	24	0	9	67

Outcome 7 (f) Student Ratings on Course FCQs

The understanding of ethics and professional responsibility is a focus in a small number of courses. The emphasis on ethics is focused in three locations in the curriculum: beginning in the first semester with the Introduction to Architectural Engineering course (starting in fall 2012), in the middle with the Introduction to Construction course (for most students, spring of sophomore year), and in the end with Senior Design. As these three courses were reliably rated by students at over 4 on the FCQs, adequate fulfillment of this outcome based on indirect evidence was found.

Professional and Ethical Responsibility: Student Ratings on Required Course FCQs

Academic Year	AREN 1316 Intro AREN	CVEN 3246 Intro Construction	AREN 3540 Illumination 1	AREN 4317 Design
2011-12	3.9	4.9, 5.3	3.3	4.7
2012-13	4.7	5.0, 4.6	3.3	5.4
2013-14	5.1	5.1, 4.6	NO	4.7
2014-15	5.2	5.4, 4.6	4.3	4.2
2015-16	5.4	5.3, 5.2	4.4	4.6
2016-17	4.9	5.3, 4.9	4.4	5.5

NO = course not offered in fall 2013 or spring 2014; taught spring 2013 and fall 2014

Outcome 7 (f) Senior Survey

Two survey items were used to evaluate this outcome: an understanding of professional responsibilities of an engineer and understanding of the ethical issues confronting an engineer. Both were rated at a sufficient level of average achievement by AREN students, although ethical issues were rated at the lowest acceptable level in one assessment cycle and both items were marginally rated most recently. These data indicate that we met our minimum goal for this outcome; however, we will strive to increase attention given to these outcomes in our curriculum.

Senior Survey (avg ratings 1-5 scale)	Year:	2011 -12	2012 -13	2013 -14	2014 -15	2015 -16
# responses		*42*	*39*	*34*	*38*	*31*
Professional responsibilities		3.9	4.2	4.2	4.2	3.7
Ethical issues		3.5	4.0	4.1	4.1	3.6

<u>Summary:</u> Both the direct and indirect data are supportive that architectural engineering students at CU have sufficient knowledge of ethical and professional issues.

Outcome 8 (g). Effective Communication through Writing and/or Drawings

Outcome 8 (g) Senior Design Rubric

Communication through drawing is a key outcome for our program. This outcome is emphasized from the very beginning when students take an engineering drawing class their first year. Subsequent courses expect students to be able to interpret and produce simple Revit documents (e.g. AREN 3010 Mechanical Systems for Building, AREN 3540 Illumination I). The upper-level discipline-specific design electives further develop our students' drawing and graphical communication skills, and the senior design course (AREN 4317) provides the final proof of achievement of this outcome as the students in that course must produce complete sets of design development drawing documents.

Communication through writing is similarly emphasized throughout the AREN curriculum. In the first-year introductory course (AREN 1316), students write a series of reflective essays. Similarly, in GEEN 1400 Engineering Projects students write a technical report related to their semester-long project. Assignments in courses such as AREN 3010, AREN 3540 and CVEN 3161 Mechanical of Materials I require students to prepare formal technical reports. The students also take a technical writing course required of all Engineering students. It is common for project reports to be submitted online as single PDF files, requiring students to develop skills in electronic document assembly and organization.

In the senior capstone class, teams produce formal technical reports along with architectural and engineering related drawings at each phase of the design process. Students are given feedback and graded on report formatting, style, organization, syntax and grammar as well as drawing quality and style compliance. An example of a rubric is shown on Table 8.1. Students are graded on a 100-point scale where 90 and above = superior, 80-90 = adequate, and less than 80 = below adequate.

Quality of Report and Drawings

			Percentage of Students at Each Level		
Phase	Year	# Students	% below adequate	% adequate	% superior
Conceptual	S2012	49	0	20	80
	S2013	37	0	0	100
	S2014	36	0	44	56
	S2015	40	0	63	38
	S2016	32	0	13	88
	S2017	32	0	0	100
Schematic	S2012	49	0	20	80
	S2013	37	0	24	76
	S2014	36	0	14	86
	S2015	40	0	38	63
	S2016	32	0	38	63
	S2017	32	0	38	63

			Percentage of Students at Each Level		
Phase	Year	# Students	% below adequate	% adequate	% superior
Design Development	S2012	49		31	69
	S2013	37	0	0	100
	S2014	36	0	0	100
	S2015	40	0	0	100
	S2016	32	0	0	100
	S2017	32	0	0	100

The minimum level for sufficient achievement of this outcome (80%) was achieved in all years. In the Design Development phase, it is not unusual for students to receive the maximum grade for their reports as feedback from the previous phases is taken seriously and students understand what is required of a professional report.

Outcome 8 (g) JEC Review

Some of the JECs have commented on written communication abilities. The 2014 Construction Engineering & Management (CEM) JEC recommended placing a greater emphasis on technical writing; faculty noted that "CVEN 3246 involves a project where 30% of the score is writing, and the students also receive direct one-on-one feedback from the instructor on their draft reports."

The 2015 AREN JEC provided several recommendations specific to communication through writing and/or drawings:

1. Use REVIT in a project class; faculty noted that REVIT is taught in AREN 1027 and that all senior design projects are in REVIT.
2. Provide a "general understanding of architectural graphic standards including symbols and line weights; and how to use a drawing and illustration to convey a design concept". The faculty indicated that "this could be achieved with an AREN 1316 refocus." A potential option, which will be revisited in the design of a new curriculum, is to replace architectural history with a junior design studio.
3. Obtaining "a full REVIT model of a small stand-along building" for student review in senior capstone so that students can use it as a reference. This practice was implemented in the senior capstone class in 2016.
4. "Introduce Construction Specifications Institute (CSI) specifications and CSI writing standards and format in the WRTG 3030 (Writing on Sci/Soc.) technical writing class." The faculty replied that in addition to having the REVIT model as a reference, the drawings and specifications are analyzed by the project teams. Furthermore, a full class period on writing specifications led by industry professionals occurs in senior design.

Outcome 8 (g) Student Ratings on Course FCQs

The ability to communicate effectively via writing and drawing were separately rated items by the students, and different courses emphasize these outcomes. Written communication is the focus of an entire required junior-level writing course; but it is offered outside the department and AREN students are spread across numerous sections. Written communication is a strong focus in the senior capstone design course (as described above), somewhat of a focus in Introduction to Architectural Engineering and Introduction to Construction (less so recently), and also a focus in courses that require laboratory write-ups, such as CVEN 3161. However, the extent to which instructors focus on quality writing as part of the labs varies, as shown below for CVEN 3161. In 2011-12 and 2016-17, we just met our goal of three or more required courses with average ratings by students of 4 or higher, since some of the courses in these academic years met the minimum standard.

Communicate in writing: Student Ratings on Required Course FCQs (0-6 scale)

Academic Year	AREN 1316 Intro AREN	AREN 3540 Illum I	CVEN 3246 Intro Constr	CVEN 3161 Mech Matls	AREN 4317 Design
2011-12	2.9	3.9	4.1, 4.1	2.8, 3.5	5.2
2012-13	4.2	3.5	4.1, 4.2	2.8, 4.2	5.3
2013-14	3.9	NO	3.8, 4.2	3.4, 4.7	4.8
2014-15	4.4	4.2	3.4, 3.8	2.6, 4.1	4.6
2015-16	4.6	4.2	4.2, 4.4	4.3, 4.4	4.7
2016-17	4.0	4.1	3.8, 4.4	3.5, 3.0	5.5

NO = course not offered in fall 2013 or spring 2014; taught spring 2013 and fall 2014

Students take a full 3-credit course on engineering drawing. Drawing is also a focus in Geomatics, Introduction to Construction, and senior design. Each year, at least three courses had a rating of 4 or higher, indicating satisfactory fulfillment of this outcome based on indirect evidence.

Communicate via drawings outcome: Student Ratings on Required Course FCQs (0-6 scale)

Academic Year	AREN 1027 Drawing	CVEN 2012 Geomatics	CVEN 3246 Intro Construction	AREN 4317 Senior Design
2011-12	5.3	4.2	4.2, 4.1	5.3
2012-13	4.7	4.2	4.4, 4.4	5.6
2013-14	4.6	2.8	4.6, 4.0	5.2
2014-15	5.0	3.3	4.6, 4.1	4.9
2015-16	5.0	4.4	4.9, 5.1	4.7
2016-17	5.2. 4.5	2.9	5.0, 4.7	5.3

Outcome 8 (g) Senior Survey

The ability to communicate effectively in writing (reports, etc.) and using drawings were rated at a sufficient level of average achievement by AREN students, with marginal performance for written communication in one evaluation cycles. No weakness is evident from this data.

Senior Survey (avg ratings, 1-5 scale)	Year:	2011 -12	2012 -13	2013 -14	2014 -15	2015 -16
# responses		*43*	*39*	*34*	*38*	*31*
Communicate in writing		3.7	3.9	4.1	3.9	3.8
Communicate using drawings		4.2	4.3	4.0	4.3	4.0

Summary: While the focus on communication through writing varies from course to course, it is clear that once senior design is completed, students have the ability to communicate in writing, which is confirmed by the senior survey data. Based on this, this outcome is being met.

Table 8.1 – Rubric for report and drawing set

	Levels of Achievement				
	Professional	**Adequate**	**Needs Improvement**	**Poor**	**Unacceptable**
Item	**5**	**4**	**3**	**2**	**1**
Site & floor plans, elevations	A complete set of drawings is provided (site plans, floor plans, and elevations). The drawings contain all the required architectural formatting elements, which are consistent throughout: title block revised to include the information relevant to this project; standard architectural sheet numbering; scale; north arrow; drawing titles, drawing legends.	A complete set of drawings is provided; the drawings contain most of the required architectural formatting elements; there are slight inconsistencies from sheet to sheet.	A complete set of drawings is provided but some of the required architectural formatting elements are poorly executed or missing; there are inconsistencies from sheet to sheet.	Some drawings are missing; many of the required architectural formatting elements are poorly executed or missing; there are obvious inconsistencies from sheet to sheet.	Most or all drawings are missing; the required architectural formatting elements have been ignored; there is no coordination between drawings.
Report Quality: formatting and overall quality	The report looks like a professional document in that it contains all the elements of a professional document (cover page, executive summary, table of contents, introduction, section titles, appendix titles, formatting elements such as page numbers, titles on charts and table, captions on illustrations and images, cross-reference between text and images where appropriate), it is well organized and easy to navigate. In addition, the report is well written, easy to understand, grammatically correct, and free of spelling errors.	The report looks like a professional document but is missing a few formatting elements; it is well organized and easy to navigate; the text can be followed without much difficulty; it contains a few grammar and/or spelling errors.	The report fails to include important formatting elements; the organization is lacking and therefore it is not easy to navigate; some effort is required to understand the text; there are grammar and/or spelling errors.	The report looks like a school report in that it contains only the basic elements of a professional document; the text is difficult to follow and there are obvious grammar and/or spelling errors.	There is not attempt to follow any of the formatting guidelines. The report is poorly organized and poorly written.

Outcome 9 (g). Effective Communication through Oral Presentations

Outcome 9 (g) Senior Design Rubric

For architectural engineers, oral presentations do not only occur in a formal, large-group setting, but also in less formal settings such as design team meetings and client presentations. This diversity of settings for oral communication is reflected in the AREN program. Practice at this outcome begins in the first semester, as students in both AREN 1316 Intro to Architectural Engineering and GEEN 1400 Engineering Projects courses must present their projects to the class. Although there is little coaching and feedback at this level, it is still an important exercise for our students. Student presentations in the main engineering science courses are infrequent, though presentations are much more common in the sixth through eighth semesters as students take design courses with more project deliverables.

Architectural Design (ARCH 4010), which is a required class for all AREN students, places a large emphasis on oral communication, including the less formal communication that is very common during the design process. Students meet regularly in small groups with faculty and external reviewers, and must present their design ideas in this smaller group context. Often, students are required to compose presentation “boards” for these sessions, and they receive feedback on the design content and the effectiveness of the presentation.

Other upper-level design courses also place an emphasis on oral communication practice. AREN 4317 Architectural Engineering Design is the main assessment opportunity for oral communication. In addition to regular design review meetings with faculty members and professional mentors, the conceptual, schematic design phases involve a formal presentation. Each team delivers a 15-20-minute presentation with an additional 5-10 minutes for questions and feedback. At the end of the presentation, the faculty and industry mentors evaluate the presentations using a rubric. Students are graded on a 100-point scale where 90 and above = superior, 80-90 = adequate, and less than 80 = below adequate. The rubric (see Figure 9.1) may somewhat change in the level of detail depending on the design phase being evaluated.

Communication through Oral Presentations

			Percentage of Students at Each Level		
Phase	Year	# Students	% below adequate	% adequate	% superior
Conceptual	S2012	49	0	31	69
	S2013	37	0	11	89
	S2014	36	0	14	86
	S2015	40	0	63	38
	S2016	32	0	13	88
	S2017	32	0	19	81
Schematic	S2012	49	0	20	80
	S2013	37	0	51	49
	S2014	36	0	44	56
	S2015	40	0	38	63
	S2016	32	0	0	100
	S2017	32	0	0	100

The minimum level for sufficient achievement of this outcome (80%) was achieved in all years.

Outcome 9 (g) JEC Review

Some of the JECs have commented on oral communication abilities. The 2014 Construction Engineering & Management (CEM) JEC recommended improving the oral and presentation skills of the students. The CEM faculty responded: "greater emphasis on oral presentation has recently been introduced throughout the CEM curriculum. …students do give presentations on their bridge projects in CVEN 3246."

Outcome 9 (g) Student Ratings on Course FCQs

The ability to communicate effectively via oral presentations is only included within a few courses in the curriculum, based on student evaluation data. The largest emphasis is in the senior design course. Oral presentation has had a variable focus in other courses, such as historically higher in Introduction to Construction. In two years, we missed our goal in not having at least three courses rated as 4.0 or higher by the students for oral presentations. Thus, the oral presentations outcome did not reliably meet our indirect criteria for student FCQs

Communicate via oral presentations: Student Ratings on Required Course FCQs

Academic Year	AREN 1316 Intro AREN	AREN 1027 Eng Drawing	AREN 2406/2050 Bldg Matls*	CVEN 3246 Intro Constr	AREN 4317 Design
2011-12	1.4	1.6	5.0, --	3.0, 4.0	5.0
2012-13	3.4	3.7	4.9, --	3.7, 4.2	5.7
2013-14	3.9	3.7	--, 5.1	3.0, 3.5	5.2
2014-15	4.1	4.7	--, 2.3	2.7, 2.5	4.8
2015-16	3.9	4.5	--, 2.3	3.2, 2.8	5.2
2016-17	2.6	5.0, 3.8	--, 4.5	2.8, 2.9	5.6

* old curriculum required course; new curriculum required course

Outcome 9 (g) Senior Survey

The ability to communicate effectively via oral presentations showed improvement over time, increasing from a marginal level of achievement rating of 3.7 in 2011-12 to 4.2 in 2014-15. These data indicate a sufficient level of average achievement by AREN seniors.

Senior Survey Avg rating 1-5 scale	Year:	2011 -12	2012 -13	2013 -14	2014 -15	2015 -16
# responses		*43*	*39*	*34*	*38*	*31*
Oral communication		3.7	4.0	4.2	4.2	4.2

Summary: The strongest measure that students have sufficient ability to make oral presentations is based on direct evaluation via the co-instructors and industry mentors of the senior design course. The students make two formal oral presentations in the course and the data shows strong evidence of good oral presentation abilities by most students. Thus, strong focus in that single course outweighs the fact that many courses do not emphasize oral communication. The direct assessment measurement supports sufficient attainment of this outcome.

Figure 9.1 – Rubric for oral presentation

AREN 4317 – Architectural Engineering Design
Schematic Design Presentations
Friday March 24, 2017

Faculty / Mentor: ___________________________________

Team: ________________________________ **Discipline: __________________**

Overall Group Presentation	*** Letter Grade: A, A-, B+…** See grade equivalents on separate handout	
General Comments:		

Student Presentation (40%)	**Possible Points**	**Points Earned**	**TOTAL**
• Content is clearly organized and supports purpose	15		
• Presenters are professional in dress, language, and style. Presenters speak with appropriate pace and volume	15		
• Visuals are clear, consistent, readable, and understandable	10		
General Comments:			

Technical Content (60%) – Discipline Mentors & Faculty	**Possible Points**	**Points Earned**	**TOTAL**
• Topic mastery, including technical correctness	20		
• Appropriate level of detail	20		
• Completeness of analysis and interpretation of data	20		
General Comments (use back if additional space is needed):			

Adapted from Rubric by Dr. Lisa Bullard, Dept. of Chemical & Biomolecular Engineering, N.C. State University.
Adapted from Rubric by Dr. Lisa Bullard, Dept. of Chemical & Biomolecular Engineering, N.C. State University.

Outcome 10 (h). Understand the impact of engineering on society

Outcome 10 (h) Direct Assessment: Course Assignments

In the Introduction to Architectural Engineering course, much of the content is focused on the impact of engineering in a global, economic, environmental, and societal context. For example, the second homework encompassed sustainability, including the three pillars of sustainability (social, environmental, and economic). Using student performance on this assignment as an embedded indicator, students routinely demonstrated adequate knowledge of this outcome, with over 80% at the adequate or higher level.

Intro AREN Course Homework	Year	n	Percentage of Students at Each Performance Level: Poor	Needs Improvement	Adequate	Superior
Environmental, economic, social impacts	F2012	35	9	6	14	71
	F2013	33	12	0	18	70
	F2014	36	3	6	14	78
	F2015	26	4	4	23	69
	F2016	33	9	3	45	42

In addition, courses that cover building energy systems (mechanical and electrical/lighting) include discussions related to energy use, environmental effect in building design and the impact of those systems on the use of energy resources. The senior capstone class requires students to demonstrate code and standard compliance for all four disciplines. Teams are also encouraged to pursue LEED points for their designs and demonstrate compliance. Elective courses in the humanities and social sciences are intended to broaden our students' understanding of the broader social context of engineering practice. The large number of elective classes available makes formal assessment of this outcome for those courses difficult. However, the required History and Theories of Architecture courses (ENVD 3114 and 3134), which partially fulfill our students' humanities requirements, provide a broader perspective on the role of building design and construction in society.

Outcome 10 (h) Student Ratings on Course FCQs

The impact of engineering on society was routinely rated by AREN students as a strong outcome for three required courses, at the beginning, middle, and end of the curriculum.

Impacts on Society: Student Ratings on Required Course FCQs (0-6)

Academic Year	AREN 1316 Introduction AREN	CVEN 3246 Intro Construction	AREN 4317 Design
2011-12	4.6	4.7, 5.0	4.7
2012-13	4.7	4.8, 5.0	4.8
2013-14	5.2	4.9, 5.0	4.3
2014-15	5.2	4.9, 4.9	4.4
2015-16	5.4	4.9, 5.5	4.0
2016-17	4.8	5.6, 5.2	5.1

Outcome 10 (h) Senior Survey

The impacts of engineering solutions in a global, economic, environmental, and social context was rated at a sufficient level of average achievement by AREN students, with ratings at or above 3.6 (on a 1-5 scale, with target over 3.5). Although this is one of the lower-rated outcomes by AREN seniors, adequate achievement was found.

Senior Survey Avg rating 1-5 scale	Year	2011 -12	2012 -13	2013 -14	2014 -15	2015 -16
# responses		*43*	*39*	*34*	*38*	*31*
Societal context		3.6	3.9	3.8	4.2	3.7

Summary: Both indirect measures were consistently strong in students' self-reported understanding of the impact of engineering in a global, economic, environmental, and social context. The direct measure in the first-year introductory course was also consistently strong.

Outcome 11 (i). Necessity to Engage in Life-Long Learning (LLL)

Outcome 11 (i) FE Exam

We believe that students' overall performance on the FE exam is indicative of their motivation, ability, and willingness to engage in lifelong learning, given that this is a first step on the path to become a licensed PE, and PE licensure requires additional learning. CU AREN student performance has been highly variable, perhaps because there is no disciplinary exam for these students—AREN students primarily take the "other disciplines" exam, which is not a good fit to the topics in our curriculum. A few students take the civil engineering exam, but generally do poorly. In one academic year, we failed to meet our goal with only 63% of CU AREN students passing the exam, 11% fewer than national peers. In fall 2016, only 43% of CU AREN students passed the exam, 31 % fewer than national peers. It is important to note, that only 7 students took the exam, which appears worse than it is. In fact, while spring 2017 official results will not be available in time for this report, we know from student records that out of 24 students who have taken the FE exam as of May 31, 2017, 22 passed. Therefore, we anticipate that the results for 2106-17 academic year will be positive. Overall, CU AREN students performed above national peers in three academic years, with 87% of the 2015-16 CU AREN students passing the FE exam, 16% more than national peers. Thus, we continue to monitor this outcome due to failure to reliably meet our goal.

Year	11-12	12-13	F13	Sp14	14-15	15-16	F16
n CU students	*53*	*40*	*11*				*7*
New exam % difference				+2	-11	+16	-31
Old exam % Difference	*+4*	*+3*	*-5*				

Outcome 11 (i) Direct Assessment: Course Assignments

Life-long learning for architectural engineers takes several forms. To achieve this outcome, AREN students should be aware of the various professional societies related to AREN practice, since much of the learning that occurs after graduation takes place through those organizations. This awareness includes a familiarity with some of the publications offered by the professional and trade organizations. As students size and select equipment for their designs, they need to know the primary manufacturers of the products used in buildings, and must understand how to access information from those manufacturers, because much of the advancement in knowledge that is needed relates to the technologies used in these building products. Students also must understand that the codes, standards, and rating systems that guide building design evolve over time, and that continuing education is required to stay abreast of the latest requirements.

Achievement of this objective begins in our first-year Introduction to Architectural Engineering course, AREN 1316. The professional societies are introduced and their primary publications shown; students are strongly encouraged to become involved in one of the student chapters of these societies. Guest speakers from the profession in this class often discuss their personal methods for staying up-to-date on building practices and technologies, reinforcing for the students the necessity of life-long learning. In the second and third years, courses across the AREN curriculum require students to access information from manufacturers' websites as part of their regular assignments. Use of the internet for obtaining product information is reinforced through many of the upper-level discipline specific courses, including AREN 3540 Illumination I and 3010 Mechanical Systems for Buildings. The role of life-long learning is further reinforced in the AREN 4317 capstone design class through a lecture specific to the importance of life-long learning. Students are assigned a short essay to describe their understanding of the importance of life-long learning on their careers. Students are graded on a scale of 10 points, where above 9 = superior, 8-9 = adequate, below 8 = below adequate.

Life-Long Learning Reflection Essay

		Percentage of Students at Each Performance Level			
Year	# Students	Non-compliance	% below adequate	% adequate	% superior
S2012	49	16	0	0	84
S2013	37	8	0	0	92
S2014	36	6	0	0	94
S2015	40	20	0	15	65
S2016	32	47	3	22	28
S2017	32	3	0	3	94

The minimum level for sufficient achievement of this outcome is that 80% or more of the students are adequate or higher. This goal was achieved in all years except in 2016 where, for this year alone, the assignment was offered as extra credit. The instructor determined that many students were not going to comply with the assignment due to back-to-back deliverables; however, some would if an incentive was provided. As such, 53% of the students achieved the minimum level; 47% of the students did not take advantage of it.

Outcome 11 (i) Student Ratings on Course FCQs

The *need for* and *ability to* engage in lifelong learning were both rated as potential course outcomes. These two outcomes are shown below. Three required courses in the AREN curriculum routinely had average ratings for both aspects above 4.0: Introduction to AREN, Introduction to Construction, and capstone design. Thus, we met our target for student ratings of this outcome.

Need for/ability to engage in lifelong learning: Student Ratings on Required Courses (0-6)

Year	AREN 1316 Intro AREN	CVEN 3246 Intro Constr	AREN 4317 Design
2011-12	4.6 / 4.5	4.4 / 4.3, 5.1 / 5.0	5.1 / 4.8
2012-13	4.4 / 4.1	4.3 / 4.3, 4.7 / 5.1	5.4 / 5.4
2013-14	4.5 / 4.3	4.4 / 4.4, 4.8 / 4.7	4.7 / 4.6
2014-15	4.6 / 4.3	4.2 / 4.2, 4.3 / 4.1	4.5 / 4.4
2015-16	5.0 / 4.7	4.7, 5.0 / 4.7, 4.7	4.6 / 4.7
2016-17	4.6 / 4.4	5.2, 5.0 / 5.0, 4.9	5.3 / 5.3

Outcome 11 Senior Survey

Two survey items were used to evaluate this outcome: motivation, ability, and willingness to engage in lifelong learning, and ability to use the Internet, library, or other sources to research an issue. The second item relates to the ability to engage in lifelong learning on one's own. Both were rated at a sufficient level of average achievement by AREN students. No weakness is evident from these data.

Senior Survey Avg rating 1-5 scale	Year	2011 -12	2012 -13	2013 -14	2014 -15	2015 -16
# responses		*43*	*39*	*34*	*38*	*30-31*
Lifelong learning		3.8	4.2	4.0	4.2	4.1
Research an issue		4.1	4.5	4.3	4.3	4.3

Summary: We believe that students have an awareness of the importance of LLL and an ability to engage in LLL. The indirect assessment data is consistently strong while the multiple direct measures is variable. At present, efforts are underway to explore ways to bolster the commitment of the students to lifelong learning as evidenced by commitment to pursue professional licensure, though many AREN students simply do not have professional licensure in their future plans.

Outcome 12 (j). Contemporary Issues

Outcome 12 (j) FE Exam

There are questions on the FE exam that measure students' knowledge of engineering economics topics. We believe that economic issues are contemporary issues relevant to architectural engineering, and thus consider this a direct assessment related to this outcome. In no assessment cycle did CU AREN students fail to meet our minimum standard (-5% or 0.92 ratio score). In two academic years, CU AREN students performed better than national AREN peers. Thus, the FE data show that we are meeting this outcome.

FE Topic	Year	11-12	12-13	F13	Sp14	14-15	15-16	F17
	n CU students	*44*	*35*	*9*	*18*	*28*	*21*	
Engineering Economics	Ratio score				.93	.93	1.15	1.03
	% Difference	*+7*	*-2*	*+3*				

Outcome 12 (j) Direct Assessment: Course Assignments

The Introduction to Architectural Engineering course focuses on contemporary issues, including needs for infrastructure. In 2014-2016, the first question on the first assignment asked students to describe a contemporary challenge in architectural engineering that inspired their career goals; the problem was worth 15 points. Similarly, in 2012 and 2013, question 3c on the first assignment had students describe a current project that they found in the news that would involve an architectural engineer. If students received >90% of the points their performance was deemed superior, 80-90% adequate, 70-80% needs improvement, and <70% poor. Student performance demonstrated an acceptable level of knowledge of contemporary issues, with consistently over 80% of the students rated as adequate or higher.

Intro AREN Course Homework 1	Year	n	Percentage of Students at Each Performance Level: Poor	Needs Improvement	Adequate	Superior
Q1/3c. Contemporary issue	F2012	35	6	9	23	63
	F2013+	34	3	3	0	94
	F2014	36	6	3	25	67
	F2015	26	8	0	23	69
	F2016	38	0	5	26	68

+ In 2013, the normal professor was on sabbatical; the instructor that year did not log student performance on question 3c distinct from the rest of homework 1.

Within the AREN professional community, sustainability and building information modeling (BIM) have been the dominant contemporary issues over the past decade. Students begin their exposure to these topics in their first year in AREN 1027 Engineering Drawing, where they begin using the Autodesk Revit building information modeling tool. Sustainability concepts are also introduced in AREN 1316 Intro to Architectural Engineering and are reinforced throughout the curriculum in the building systems and construction courses. In senior design, students develop their integrated designs in the context of the LEED rating system and real-world budget constraints, with guidance from professional mentors, using modern tools such as AGI32, EQuest and Navisworks. In addition, the use, implementation, and compliance documentation of ASCE 7-10, ANSI/ASHRAE; IBC, IES, NEC codes and standards are paramount in this class. These are used as minimum standards for building design and are also used in AREN 3010 Mechanical Systems, AREN 4110 HVAC Design and AREN 4550 Illumination II accordingly.

Outcome 12 (j) Student Ratings on Course FCQs

An understanding of current events and contemporary issues was achieved in a few required courses as the student ratings show below. The minimum criterion was met in all years except 2011-2012 (prior to the new format of AREN 1316).

Current Events and Contemporary Issues: Student Ratings on Required Course FCQs (0-6)

Academic Year	AREN 1316 Intro AREN	AREN 2406/2050 Bldg Matls	CVEN 3246 Intro Constr
2011-12	3.4	4.1, --	4.4, 4.8
2012-13	4.4	4.9, --	4.9, 4.6
2013-14	4.2	--, 5.1	5.0, 4.6
2014-15	4.7	--, 4.4	4.9, 3.9
2015-16	4.8	--, 4.5	5.2, 5.4
2016-17	4.2	--, 5.3	5.6, 4.1

Outcome 12 (j) Senior Survey

Two questions relate to outcome 12: "an understanding of current events and contemporary issues" and "apply the principles of sustainability to design." The average student rating for understanding current events failed to meet our minimum goal among the 2011-12 seniors, and remained marginal in the other assessment cycles. However, the students were much more positive in rating the specific example of sustainability as a contemporary issue. The data indicate that this outcome is of concern, but has met a minimum acceptable level of fulfillment in recent years.

Senior Survey Avg rating 1-5 scale	Year	2011 -12	2012 -13	2013 -14	2014 -15	2015 -16
# responses		*43*	*39*	*34*	*38*	*31*
Current events		2.9	3.6	3.6	3.6	3.3
Sustainability		4.0	4.5	4.1	4.2	4.0

<u>Summary:</u> Direct assessment data from the FE exam showed that CU students have adequate knowledge of engineering economics. Direct assessment data from the first-year introduction to architectural engineering course found that students have adequate knowledge of contemporary issues in 2012-2016, based on performance on a related homework assignment. Among the indirect assessment data, most courses met our target of being assessed by students at 4.0 or higher, while the graduating senior survey data shows borderline success on the area of current events, but strong results on the area of sustainability. Overall, we feel that this objective is met.

Outcome 13 (k). Modern engineering techniques, skills, and tools

Outcome 13 (k) FE Exam

CU AREN student performance on the instrument and data acquisition section of the current FE Other Disciplines exam and previously the computers questions are believed to be a direct assessment method for the modern techniques outcome. CU AREN performance has been consistently very strong, exceeding national peers in all assessment cycles. This is strong direct evidence of achievement of this outcome.

FE Data	Year	11-12	12-13	F13	Sp14	14-15	15-16	F16
	n CU students				*18*	*28*	*21*	*7*
Instr & Data	Ratio score				1.11	1.08	1.10	0.92
Computers	*% Difference*	*+5*	*+6*	*+4*				

Outcome 13 (k) Senior Design Rubric

For AREN students, “modern engineering techniques, skills and tools” must begin with drawing and the use of building information modeling (Revit)—the fundamental beginning point for today’s practitioner. AREN students complete the required three-credit AREN 1027 Engineering Drawing in the first year to develop their skills in this area. CVEN 2012 Geomatics offers another opportunity to use state-of-the-art tools such as GPS and GIS technology.

Beyond drawing and surveying, professionals in AREN practice also rely on skills with computer analysis of engineering systems. While almost all students entering the AREN program are proficient in spreadsheet analysis tools, their abilities are expanded in CHEN 1310 with additional computer programming skills. In addition, several discipline-specific engineering software tools are used in AREN practice and are included in the coursework in the third and fourth years. For example, students are introduced to the eQUEST building energy modeling software in AREN 3010 and use the Trane TRACE700 software for HVAC system design in AREN 4110 HVAC Design. AREN 4550 Illumination II requires that students learn and use the AGI32 and Visual lighting related-programs. The Department has arrangements in place with vendors of many of these programs that allow for student licenses and for site licensing in our Bechtel Computing Lab, described in Criterion 7 Facilities.

In the AREN 4317 design class students use many of the tools and programs described above and starting in 2017 students will perform drawing coordination and clash detection using REVIT Architecture. Before 2017, students performed clash detection manually. Nevertheless, the result is the same in that students use this technique to ensure that building systems are designed and placed appropriately. The data shown below relates to clash detection mini-reports produced by representatives of the teams (all team members have specific duties in addition to their discipline submittals. Depending on the year allocated responsibilities are mini-reports on clash detection, LEED, report quality assurance, BUG rating compliance for outdoor lighting, and so forth). If students received >90% of the points their performance was deemed superior, 80-90% adequate, 70-80% needs improvement, and <70% poor.

		Percentage of Students at Each Performance Level			
Year	# Students	Non-compliance	% below adequate	% adequate	% superior
S2012	10	10	0	20	70
S2013	9	0	11	11	78
S2014	7	0	0	57	43
S2015	10	0	10	10	80
S2016	8	0	0	13	88
S2017	8	0	13	13	75

Students have achieved the minimum level for sufficient achievement as 80% or more of the students rated adequate or higher.

Outcome 13 (j) JEC Review

The 2014 Construction Engineering & Management (CEM) JEC was concerned about diminished CAD/Drawing content in the curriculum and stated that "CEM students need to be comfortable using modern CAD modeling programs." The faculty indicated that an assignment requiring the use of CAD would be introduced into CVEN 3256 Construction Equipment and Methods. That course is the proficiency course for CEM; therefore, not all CVEN students take the course, but those interested in CEM certainly enroll.

The 2015 AREN JEC report indicates that since BIM is becoming a significant tool for facility design and construction and is used for facility maintenance by tracking material, age of components, energy performance and preventative maintenance, a course on BIM should be provided in lieu of geomatics. The AREN faculty agreed and will be coordinating with other faculty in the department to consider alternatives to the Geomatics course to be implemented when a revised AREN curriculum comes into effect (see pages 68-9).

In addition, the report advises to "ensure students are comfortable with concept and graphic presentation, including program (Photoshop, InDesign/Illustrator, SketchUp, etc.)" The faculty asserts that these are taught in the environmental design studio classes that all AREN students must take in their senior year.

Outcome 13 (k) Student Ratings on Course FCQs

An ability to use modern tools necessary for engineering practice routinely receives high ratings from students in four required courses. Thus, we have met our target and have indirect evidence that AREN students have met this outcome.

Modern engineering tools: Student Ratings on Required Course FCQs (0-6)

Academic Year	CVEN 2012 Geomatics	AREN 1027 Eng Drawing	AREN 3540 Illumination 1	AREN 4317 Design
2011-12	5.2	5.4	4.8	5.1
2012-13	5.0	5.0	4.8	5.3
2013-14	4.6	4.7	NO	4.7
2014-15	4.4	4.7	5.2	4.4
2015-16	4.8	4.4	4.9	4.9
2016-17	4.9	4.3	5.3	5.3

NO = course not offered in fall 2013 or spring 2014; taught spring 2013 and fall 2014

Outcome 13 (k) Senior Survey

Students rated their achievement of the outcome 'ability to use the techniques, skills, and modern engineering tools such as common software programs necessary for engineering practice'. AREN seniors rated this outcome at an adequate level of achievement in all assessment cycles; thus, we met our goal for this outcome.

Senior Survey Avg rating 1-5 scale	Year	2011 -12	2012 -13	2013 -14	2014 -15	2015 -16
# responses		*43*	*39*	*34*	*38*	*31*
Modern tools		4.0	4.2	4.1	4.4	3.9

Summary: Both direct and indirect assessment data show good knowledge of CU student of modern engineering techniques and tools. CU architectural engineering students have satisfied this outcome.

C. Continuous Improvement

Major Curriculum Revisions

After the previous ABET review, the curriculum changed to its current format. The majority of these changes were motivated by feedback from the JEC process and student surveys, as well as recent changes to the ABET EAC architectural engineering program criteria. Another important motivator was aligning the AREN curriculum with similar programs around the country where more freedom was afforded to students when it came to choosing upper level courses. The changes were explored for nearly a year by the curriculum committee and approved by a vote of the faculty at a special retreat that was held in May 2012. The changes increased the Introduction to Architectural Engineering course to two-credits, allowing us to bolster students' knowledge around outcomes 7f ethics and professional responsibility, 10h societal context, 11i lifelong learning, and 12j contemporary issues. Further, the curriculum added GEEN 1400 First Year Engineering Projects. This gave students a design experience in a multidisciplinary teamwork setting in their first year (5d), as well as practice with written reports and oral presentations (8g, 9g). Historical data from the Engineering College have shown that students who take GEEN 1400 are more likely to persist in engineering. Including this course in the AREN curriculum seemed important given the declining enrollment in AREN after the recession. The revisions made to the curriculum also added flexibility as it eased the number of required proficiency level courses to two sub-discipline areas of AREN (rather than requiring students to take proficiency courses in all four sub-disciplines.) It also added one 3-credit free elective. This gave students the freedom to choose courses of interest, in alignment with educational motivation literature on self-determination theory.

AREN faculty have regularly shared with each other observations related to how students have responded to the 2012 revised curriculum. For example, senior capstone faculty have noted that students are able to perform well in their own tracks but they are lacking the overarching familiarity of building systems interaction (the senior capstone class fills this gap, but in the past students came to the class with that understanding). The faculty have also noted through student advising that many third-year students are anxious about choosing their proficiencies as they feel they do not have a strong enough basis for choosing one over the other. Through 2015, the AREN faculty discussed measures to address these concerns. The 2015 AREN JEC report concurred with the need to study curriculum options as follows:

1. Knowledge on how to design AREN systems does not come until the fundamental courses during semester 5. Choosing two proficiency classes in semester 6 does not leave a complete impression on the student of how a building is designed (i.e. statics, dynamics and mechanics of materials alone do not prepare the student to understand basic structural design in a building. That understanding comes from steel/concrete design.)

2. The faculty mentioned that the two-track proficiency system gives students more choice. Is it more choice, or is it the illusion of choice? A negative aspect is that the two-track system creates student apprehension in choosing a path.

3. By choosing two proficiency classes in semester 6, there is not enough semester time to recover from a bad "choice." How do students shore up the knowledge missed in the other two tracks?

4. Realign the concept of the two-track proficiency choice to align with the objectives stated in the Areas of Knowledge section of the Architectural Engineering Educational Objectives & Outcomes.

5. How does the two-track proficiency system during semester 6 impact the Capstone course in asymmetric student interest regarding discipline distribution? Curriculum will need a solution for how to approach senior design without pushing students to do a discipline that is not their emphasis.

In spring 2016, the AREN faculty began the process of revising the curriculum. A preliminary draft of the revised curriculum has been sent to the CEAE Curriculum Committee for initial comments. If approved, implementation may occur during the 2018 academic year.

Major Changes Proposed

1. Require basic design courses for all AREN students (AREN4110, AREN4570, CVEN4545 orCVEN4555, and AREN 4550)
2. Require two concentration courses for each track
3. Develop a new junior level Studio course to replace ENVD 3134, which would be pre-requisite for ARCH 4010, which in turn remains a pre-requisite for AREN Senior Design (AREN 4317).
4. Remove CVEN 2012 Introduction to Geomatics from the AREN curriculum.

The 2015 AREN JEC report also recommended an overhaul of AREN 1316 Introduction to Architectural and AREN 2050 Engineering Systems for Buildings to a) ensure that students are equally acquainted with all AREN disciplines and professors, b) reinforce the student's choices as architectural engineers in coming semesters, and c) expose students to more industry professionals representing all AREN areas of practice. This recommendation led the AREN faculty to propose the separation the separation of AREN 1316 Intro to Architectural Engineering from CVEN 1317 Intro to Civil & Environmental Engineering so that content is dedicated and specific to either Architectural or Civil engineering (1 credit each). The intent is to provide more exposure to the various concentrations within architectural engineering. Such exposure kicks off the AREN educational objective of producing leaders in one of the four core AREN disciplines. The proposal was approved and voted by the CEAE Faculty in spring 2016. Implementation begins in fall 2017.

Specific Student Outcome Improvements

8[g] Written Communication

The 2014 Construction Engineering and Management JEC mentioned that they believe that the communication skills of the students are weak and the curriculum should do more to encourage improved writing skills. This topic has been discussed in CEAE faculty meetings, and upon a proposal from CEAE is now being reviewed College-wide by the Undergraduate Engineering Council (UEC). In the meantime, individual CEAE faculty are trying to increase their emphasis on written communication within their CEAE courses. Introduction to Construction includes a project with 30% of the grade based on writing (and includes instructor feedback on a draft of the report), and Prof. Lupita Montoya includes a small writing assignment within the required Thermodynamics course. It is hoped that this infusion approach to writing-in-context may yield gains as students move through the curriculum.

11[i] Lifelong Learning
The pass rates of architectural engineering students on the FE exam have intermittently failed to meet our goal to be within 5% of the pass rates for AREN students nationally. This has been a concern among the AREN and CEAE faculty, with discussion in numerous faculty meetings, and our Joint Evaluation Committees. Therefore, practice FE exams were added as a required element in the AREN capstone design course. Interestingly, the 2015 AREN JEC report takes exception to this practice by saying that "the committee all agree that there is an importance in emphasizing taking the FE exam but feel that preparation for the exam should not take the place of critical class time in the AREN 4317 Capstone course. Exam preparation can be short night courses, or student organized study sessions outside the AREN curriculum." This comment refers in part to the fact that prior to 2015, several lecture periods in senior design were dedicated to the review of FE topics. However, in 2015 the department began offering online review modules, which has reduced the amount of class time spent on FE exam preparation. Having students go through mock practice exams in senior capstone has proven to yield positive results because students collectively feel the need to do well.

In addition, there is a lecture and a homework assignment that emphasize the importance of professional licensure, which reinforces the content in the first-year Introduction to Architectural Engineering course. In AREN 2120 Fluid Mechanics and Heat Transfer, an FE-style review session has been added to get the student exposure to the types of questions they would encounter in the FE exam and to review the material.

D. Additional Information

The FE exam serves as a direct assessment method for 7 of our 13 student outcomes. The 'other disciplines' engineering exam requirements from the NCEES, performance reports from the NCEES on the performance of CU architectural engineering students and the full FE summary spreadsheet will be available for examination at the time of the visit.

Student reports and presentations in the senior capstone design course are used as direct assessments for four student outcomes. The course dossier will include current and historical data from the course rubric.

Assignments in other courses that are used to assess student outcomes, including laboratory reports and homework assignments from the Introduction to Architectural Engineering course will be available for examination in files compiled for each relevant outcome, as well as the course dossiers.

CRITERION 5. CURRICULUM

A. Program Curriculum

The Architectural Engineering curriculum is commonly presented to students, faculty, and other constituents via a so-called “Block Diagram”. The block diagram lays out the expected and recommended order of courses to complete the requirements for the program in eight semesters (four academic years). The first semester is shown in the bottom row of the diagram, and subsequent semesters build to the final semester at the top. The block diagram indicates courses that are part of pre-requisite and co-requisite sequences in their proper order. Some courses are also offered only fall or spring semester, and those courses are shown in an appropriate location (and also denoted with a #). Students have opportunities to select courses, including two Architectural Engineering proficiency courses, three humanities/social science courses (H&SS elective), four CEAE technical electives, and one free elective. There are lists of acceptable courses for each of these choices. The AREN proficiency courses come from a list of four options. The technical elective list is quite extensive; it is periodically reviewed by the curriculum committee and published online for students (http://www.colorado.edu/ceae/sites/default/files/attached-files/ceae_tech_elective_list_-_march_2015.pdf). HH&SS electives are vetted by the H&SS subcommittee of the CEAS and approved by the Undergraduate Education Council of the College. It, which can then vote to approve them. These H&SS electives include courses offered by the Herbst Program of Humanities. It also includes courses approved as part of the core curriculum of the College of Arts & Sciences in the topic areas of contemporary societies, human diversity, foreign language, historical context, ideals & values, literature & the arts, and United States context. Additional courses have been approved (http://www.colorado.edu/engineering-advising/get-your-degree/degree-requirements/humanities-social-sciences-and-writing-requirements). Finally, the curriculum also includes one free minimally elective.

We have included below the 2016-17 Block Diagram, which illustrates the curriculum completed by the majority of 2016 AREN graduates and the 2017-18 Block Diagram which contains revisions that will take effect in fall 2017.

After the Block Diagram, the curriculum has also been shown in Table 5-1. Courses have been listed from first to eighth semester, in the same recommended order shown in the Block Diagram. The maximum section enrollments for all courses in the program for the last two terms the course was taught have been included. Many courses only have a lecture. Other courses also include recitations or laboratories, so the enrollment for those types of scheduled meetings is also shown.

ARCHITECTURAL ENGINEERING BLOCK DIAGRAM

Sem	CR						
8 SPR	17	**Tech Elective-3**	**Tech Elective-3**		**AREN 4317-5 #** AREN Design (ARCH 4010*)	**ENVD 3134-3 #** History and Theory of ENVD: Precincts	**HSS Elective-3**
7 FALL	17	**Concentration II** AREN/CVEN XXXX-3***	**AREN/CVEN Tech Elective-3**		**ARCH 4010-5 #** Arch. Design (Senior standing)	**ENVD 3114-3 #** History and Theory of ENVD: Buildings	**HSS Elective-3**
6 SPR	15	**Concentration I** AREN/CVEN XXXX-3***	**AREN/CVEN Tech Elective-3**	**Proficiency I***** **CVEN 4545/4555-3** Structural Design **AREN 4110-3** HVAC Design **AREN 4550/4560/4570-3** Light./Elec. **CVEN 3256-3** Const. Equip./Methods		**Proficiency II*****	**College-Appr. Writing Course-3****
5 FALL	15		**AREN 3540-3 #** Illumination 1 (CHEN 1310, APPM 2350)	**AREN 3010-3 #** Mech. Systems (AREN 2050, 2110, 2120)	**ECEN 3030-3 #** Electrical Circuits (APPM 2360)	**CVEN 3525-3** Structural Analysis (CVEN 3161)	**Free Elective-3**
4 SPR	16	**APPM 2360-4** Introduction to Linear Algebra & Differential Equations (APPM 1360)	**CHEN 1310-3** Engrg. Computing (co-req. APPM 1350)	**AREN 2120-3 #** Fluid Mech. & Heat Transfer (APPM 2350, AREN 2110, co-req. APPM 2360)	**CVEN 3246-3** Introduction to Construction (4th-semester standing)	**CVEN 3161-3** Mechanics of Materials I (CVEN 2121, co-req. APPM 2360)	
3 FALL	17	**APPM 2350-4** Calculus III for Engineers (APPM 1360)	**PHYS 1120-4** Gen. Physics II (PHYS 1110, co-req. APPM 1360)	**AREN 2110-3** Thermodynamics (PHYS 1110, co-req. APPM 1360)	**AREN 2050-3 #** Building Materials and Systems (Soph. standing)	**CVEN 2121-3** Analytical Mechanics I (PHYS 1110, co-req. APPM 2350)	
2 SPR	17	**APPM 1360-4** Calculus II for Engineers (APPM 1350)	**PHYS 1110-4** Gen. Physics I (co-req. APPM 1350)		**CVEN 2012-3 #** Introduction to Geomatics	**GEEN 1400-3** Engrg. Projects OR **Basic Engineering Elective**	**HSS Elective-3****
1 FALL	14	**APPM 1350-4** Calculus I for Engineers (APPM 1235 or ALEKS score 76+)	**CHEN 1211-4** Gen. Chem. for Engineers (1 yr. HS chem. or CHEM 1021)	**CHEM 1221-1** General Chemistry Lab for Engineers (co-req. CHEN 1211)	**AREN 1316-2 #** Introduction to Architectural Engineering	**AREN 1027-3** Engineering Drawing OR **AREN 1037-3**	

\# Course is offered only once per year (FALL or SPRING as shown).
( ) Prerequisite and co-requisite requirements for course listed.
* Other prerequisites: AREN 3010, AREN 3540, CVEN 3246, CVEN 3525, ECEN 3030.

** College-approved writing courses: HUEN 1010 (taken in first two semesters of college only); or HUEN 3100, WRTG 3030, WRTG 3035, or PHYS 3050 (junior standing).
*** Some Proficiency and Concentration courses are offered in different semesters (fall and/or spring) than shown on the block diagram.

ARCHITECTURAL ENGINEERING BLOCK DIAGRAM – Effective Fall 2017

Sem	CR						
8 SPR	17	**Tech Elective-3**	**Tech Elective-3**		**AREN 4317-5 #** AREN Design (ARCH 4010*)	**ENVD 3134-3 #** History and Theory of ENVD: Precincts	**HSS Elective-3**
7 FALL	17	**Concentration II** AREN/CVEN XXXX-3***	**AREN/CVEN Tech Elective-3**		**ARCH 4010-5 #** Arch. Design (Senior standing)	**ENVD 3114-3 #** History and Theory of ENVD: Buildings	**HSS Elective-3**
6 SPR	15	**Concentration I** AREN/CVEN XXXX-3***	**AREN/CVEN Tech Elective-3**	**Proficiency I***** **CVEN 4545/4555-3** Structural Design **AREN 4110-3** HVAC Design **AREN 4550/4560/4570-3** Light./Elec. **CVEN 3256-3** Const. Equip./Methods		**Proficiency II*** **	**College-Appr. Writing Course-3****
5 FALL	15		**AREN 3540-3 #** Illumination 1 (CSCI 1320, APPM 2350)	**AREN 3010-3 #** Mech. Systems (AREN 2050, 2110, 2120)	**ECEN 3030-3 #** Electrical Circuits (APPM 2360)	**CVEN 3525-3** Structural Analysis (CVEN 3161)	**Free Elective-3**
4 SPR	17	**APPM 2360-4** Introduction to Linear Algebra & Differential Equations (APPM 1360)	**CSCI 1320-4** Computer Sci. 1: Engineering Applications (APPM 1350)	**AREN 2120-3 #** Fluid Mech. & Heat Transfer (APPM 2350, AREN 2110, co-req. APPM 2360)	**CVEN 3246-3** Introduction to Construction (4th-semester standing)	**CVEN 3161-3** Mechanics of Materials I (CVEN 2121, co-req. APPM 2360)	
3 FALL	17	**APPM 2350-4** Calculus III for Engineers (APPM 1360)	**PHYS 1120-4** Gen. Physics II (PHYS 1110, co-req. APPM 1360)	**AREN 2110-3** Thermodynamics (PHYS 1110, co-req. APPM 1360)	**AREN 2050-3 #** Building Materials and Systems (Soph. standing)	**CVEN 2121-3** Analytical Mechanics I (PHYS 1110, co-req. APPM 2350)	
2 SPR	14	**APPM 1360-4** Calculus II for Engineers (APPM 1350)	**PHYS 1110-4** Gen. Physics I (co-req. APPM 1350)		**AREN 1027-3** Engineering Drawing	**GEEN 1400-3** Engrg. Projects OR **Basic Engineering Elective**	
1 FALL	16	**APPM 1350-4** Calculus I for Engineers (APPM 1235 or placement)	**CHEN 1211-4** Gen. Chem. for Engineers (1 yr. HS chem. or CHEM 1021)	**CHEM 1221-1** General Chemistry Lab for Engineers (co-req. CHEN 1211)	**AREN 1316-1 #** Introduction to Architectural Engineering	**CVEN 2012-3 #** Introduction to Geomatics	**HSS Elective-3****

#	Course is offered only once per year (FALL or SPRING as shown).
( )	Prerequisite and co-requisite requirements for course listed.
*	Other prerequisites: AREN 3010, AREN 3540, CVEN 3246, CVEN 3525, ECEN 3030.
**	College-approved writing courses: HUEN 1010 (taken in first two semesters of college only); or HUEN 3100, WRTG 3030, WRTG 3035, or PHYS 3050 (junior standing).
***	Some Proficiency and Concentration courses are offered in different semesters (fall and/or spring) than shown on the block diagram.

Table 5-1 Curriculum: Architectural Engineering – All Students

Course (Department, Number, Title) List all courses in the program by term starting with the first term of the first year and ending with the last term of the final year. [1 = first semester; 8 = final semester]	Indicate Whether Course is Required, Elective or a Selected Elective by an R, an E or an SE.[1]	*Subject Area (Credit Hours)* Math & Basic Sciences	Engineering Topics Check if Contains Significant Design (√)	General Education	Other	Last Two Terms the Course was Offered: Year and, Semester, or Quarter	Maximum Section Enrollment for the Last Two Terms the Course was Offered[2]
[1] AREN 1316 Introduction to Architectural Engineering	R		*2*			*2016F, 2015F*	*74, 81*
[1] APPM 1350 Calculus 1 for Engineers	R	4				*2017S, 2016F*	*L 104, 123 R 26, 26*
[1] CHEN 1211 General Chemistry for Engineers	R	4				*2017S, 2016F*	*L 100, 384 R 35, 35*
[1] CHEM 1221 Engineering General Chemistry Lab	R	1				*2017S, 2016F*	*Lb 20, 21*
[1] AREN 1027 Engineering Drawing	R		*1*			*2017S, 2016F*	*L 66, 72 Lb 44, 46*
[2] APPM 1360 Calculus 2 for Engineers	R	4				*2017S, 2016F*	*L 133, 118 R 26, 26*
[2] PHYS 1110 General Physics 1	R	4				*2017S, 2016F*	*L 316, 339 R 28, 29*
[2] GEEN 1400 Engineering Projects or Basic Engineering Elective	R		*3√*			*2017S, 2016F*	*32, 33*
[2] CVEN 2012 Introduction to Geomatics	R		*3*			*2017S, 2016S*	*L 97, 105 Lb 20, 20*
[2] Humanities or social science elective	SE			*3*			*~200*
[3] APPM 2350 Calculus 3 for Engineers	R	4				*2017S, 2016F*	*L 115, 133 R 26, 26*
[3] PHYS 1120 General Physics 2	R	4				*2017S, 2016F*	*L 331, 272 R 29, 29*
[3] AREN 2050 Building Materials and Systems	R	1	*2*			*2017S, 2016F*	*44, 7(summer)*

Course (Department, Number, Title) List all courses in the program by term starting with the first term of the first year and ending with the last term of the final year. [1 = first semester; 8 = final semester]	Indicate Whether Course is Required, Elective or a Selected Elective by an R, an E or an SE.[1]	*Subject Area (Credit Hours)* Math & Basic Sciences	Engineering Topics Check if Contains Significant Design (√)	General Education	Other	Last Two Terms the Course was Offered: Year and, Semester, or Quarter	Maximum Section Enrollment for the Last Two Terms the Course was Offered[2]
[3] CVEN 2121 Analytical Mechanics 1	R		*3*			*2017S, 2016F*	*62, 106*
[3] AREN 2110 Thermodynamics	R		*3*			*2017S, 2016F*	*56, 72*
[4] APPM 2360 Intro. to Differential Equations with Linear Algebra	R	4				*2017S, 2016F*	*L 145, 148 R 26, 27*
[4] AREN 2120 Fluid Mechanics & Heat Transfer	R	1	*3*			*S2017, S2016*	*37, 30*
[4] CVEN 3161 Mechanics of Materials 1	R		*3*			*2017S, 2016F*	*L 79, 38 Lb 53, 38*
[4] CHEN 1310 Engineering Computing	R		*3*			*S2017, F2016*	*L 178, 231 R 25, 25*
[4] CVEN 3246 Introduction to Construction	R		*3√*			*S2017, F2016*	*49, 62*
[5] AREN 3540 Illumination 1	R	2	*1*			*2016F, 2015F*	*39, 36*
[5] AREN 3010 Mechanical Systems	R		*3√*			*2016F, 2015F*	*30, 24*
[5] CVEN 3525 Structural Analysis	R		*3*			*2017S, 2016F*	*30, 83*
[5] ECEN 3030 Electrical Circuits	R	1	*2*			*2016F, 2015F*	*30, 33*
[5] Free Elective	E				*3*		
[6] Architectural Engineering Proficiency Course 1*	SE		*3√*				
[6] Architectural Engineering Proficiency Course 2 *	SE		*3√*				
[6] WRTG 3030 Writing on Science & Society	SE			*3*		*2017S, 2016F*	*19, 19*
[6] AREN/CVEN concentration course 1 *	SE		*3*				
[6] AREN/CVEN xxxx technical elective	SE		*3*				*~70, 80*
[7] AREN/CVEN concentration course 2 *	SE		*3*				
[7] AREN/CVEN xxxx technical elective	SE		*3*				*~70, 80*
[7] ARCH 4010 Architectural Design	R		*5*			*2016F, 2015F*	*31, 35*
[7] ENVD 3114 History and Theory of ENVD: Buildings	R			*3*		*2017S, 2006F*	*240*
[7] Humanities or social science elective	SE			*3*			*~200*

Course (Department, Number, Title) List all courses in the program by term starting with the first term of the first year and ending with the last term of the final year. [1 = first semester; 8 = final semester]	Indicate Whether Course is Required, Elective or a Selected Elective by an R, an E or an SE.[1]	*Subject Area (Credit Hours)*				Last Two Terms the Course was Offered: Year and, Semester, or Quarter	Maximum Section Enrollment for the Last Two Terms the Course was Offered[2]
		Math & Basic Sciences	Engineering Topics Check if Contains Significant Design (√)	General Education	Other		
[8] AREN 4317 Architectural Engineering Design	R		*5√*			*2017S, 2016S*	*32, 32*
[8] Technical elective	SE		*3*				*~100, 100*
[8] Technical elective	SE		*3*				*~100, 100*
[8] ENVD 3134 History and Theory of ENVD: Precincts	R			*3*		*2017S*	*219, 134*
[8] Humanities or social science elective	SE			*3*			*~200*
TOTALS-ABET BASIC-LEVEL REQUIREMENTS		34	*73*	*18*	*3*		
OVERALL TOTAL CREDIT HOURS FOR COMPLETION OF THE PROGRAM							
PERCENT OF TOTAL		27%	*57%*	*14%*	*2%*		
Total must satisfy either credit hours or percentage	Minimum Semester Credit Hours	32 Hours	48 Hours				
	Minimum Percentage	25%	37.5 %				

1. **Required** courses are required of all students in the program, **elective** courses (often referred to as open or free electives) are optional for students, and **selected elective** courses are those for which students must take one or more courses from a specified group.
2. For courses that include multiple elements (lecture, laboratory, recitation, etc.), indicate the maximum enrollment in each element. For selected elective courses, indicate the maximum enrollment for each option.

* The four AREN specializations require different courses (proficiency, concentration) depending on specialization. **See Tables 5-1b, c, d, e.**

AREN Proficiency, select two of the following 4 options:

- AREN 4110-3 HVAC Design
- CVEN 3256 Construction Equipment and Methods
- CVEN 4545 or CVEN 4555 Structural Design – Steel Design or Reinforced Concrete Design
- AREN 4550, AREN 4560, or AREN 4570 – Illumination 2 or Luminous Radiative Transfer or Building Electrical Systems Design

AREN Concentration required courses:

- CEM: AREN 4506 Project Management I, AREN 4606 Project Management II
- Lighting & Electrical: AREN 4560 Luminous Radiative Transfer, AREN 4570 Building Electrical Systems (whichever not used to fulfill proficiency requirement)
- Mechanical: AREN 4010 HVAC System Modeling and Control, AREN 4890 Sustainable Building Design
- Structures: CVEN 4161 Mechanics of Materials I, CVEN 4545 Steel Design or CVEN 4555 – Reinforced Concrete (whichever not used to fulfill proficiency requirement)

Instructional materials and student work verifying compliance with ABET criteria for the categories indicated above will be required during the campus visit.

Table 5-1b Curriculum: *Architectural Engineering – Construction Engineering Management Option **

Course (Department, Number, Title) List all courses in the program by term starting with the first term of the first year and ending with the last term of the final year. [1 = first semester; 8 = final semester]	Indicate Whether Course is Required, Elective or a Selected Elective by an R, an E or an SE.[1]	*Subject Area (Credit Hours)*				Last Two Terms the Course was Offered: Year and, Semester, or Quarter	Maximum Section Enrollment for the Last Two Terms the Course was Offered[2]
		Math & Basic Sciences	Engineering Topics Check if Contains Significant Design (√)	General Education	Other		
Semester 6							
[6] CVEN 3256 Construction Equipment & Methods (Proficiency 1)	SE		*3√*			*2016F, 2015F*	*55, 54*
[6] Proficiency 2 (Choose 1)	SE		*3√*				
AREN 4110 HVAC Design						*2017S, 2016S*	*16, 8*
AREN 4550 Illumination II OR						*2017S, 2016S*	*25, 22*
AREN 4560 Luminous Radiative Transfer OR						*2016S, 2015S,*	*16, 9*
AREN 4570 Electrical Systems						*2016F, 2015F*	*15, 10*
CVEN 4545 Steel Design OR						*2017S, 2016S*	*45, 39*
CVEN 4555 Reinforced Concrete Design						*2016F, 2015F*	*44, 54*
[6] WRTG 3030 Writing on Science & Society	*SE*			*3*		*2017S, 2016F*	*19, 19*
[6] AREN 4506 Project Management I (Concentration 1)	SE		*3*			*2016F, 2016S*	*30, 27*
[6] AREN/CVEN xxxx technical elective	SE		*3*			*2017S, 2016F*	*~70, 80*
Semester 7							
[7] AREN/CVEN xxxx technical elective	SE		*3*			*2017S, 2016F*	*~70, 80*
[7] Technical elective	SE		*3*				*~100, 100*
[7] ARCH 4010 Architectural Design	*R*		*5*			*2016F, 2015F*	*31, 35*
[7] ENVD 3114 History and Theory of ENVD: Buildings	*R*			*3*		*2016F*	*240*
[7] Humanities or social science elective	*SE*			*3*			*~200*
Semester 8							
[8] AREN 4317 Architectural Engineering Design	*R*		*5√*			*2017S, 2016S*	*32, 40*
[8] AREN 4606 Project Management II (Concentration 2)	SE		*3*			*2017S, 2016S*	*43, 45*
[8] Technical elective	SE		3				*~100, 100*

Course (Department, Number, Title) List all courses in the program by term starting with the first term of the first year and ending with the last term of the final year. [1 = first semester; 8 = final semester]	Indicate Whether Course is Required, Elective or a Selected Elective by an R, an E or an SE.[1]	*Subject Area (Credit Hours)*				Last Two Terms the Course was Offered: Year and, Semester, or Quarter	Maximum Section Enrollment for the Last Two Terms the Course was Offered[2]
		Math & Basic Sciences	Engineering Topics Check if Contains Significant Design (√)	General Education	Other		
[8] ENVD 3134 History and Theory of ENVD: Precincts	*R*			*3*		*2017S, 2016S*	*219, 134*
[8] Humanities or social science elective	*SE*			*3*			*~200*

* The required curriculum for all students during their first five semesters is given in Table 5-1a. Courses in grey italics are required of all students.

*Table 5-1c Curriculum: Architectural Engineering – Lighting & Electrical Systems Option **

Course (Department, Number, Title) List all courses in the program by term starting with the first term of the first year and ending with the last term of the final year. [1 = first semester; 8 = final semester]	Indicate Whether Course is Required, Elective or a Selected Elective by an R, an E or an SE.[1]	*Subject Area (Credit Hours)* Math & Basic Sciences	Engineering Topics Check if Contains Significant Design (√)	General Education	Other	Last Two Terms the Course was Offered: Year and, Semester, or Quarter	Maximum Section Enrollment for the Last Two Terms the Course was Offered[2]
Semester 6							
[6] Proficiency 1 (Choose 1)	SE		*3√*				
AREN 4550 Illumination II OR						*2017S, 2016S*	*25, 22*
AREN 4560 Luminous Radiative Transfer OR						*2016S, 2015S,*	*16, 9*
AREN 4570 Electrical Systems						*2016F, 2015F*	*15, 10*
[6] Proficiency Course 2 (Choose 1)	SE		*3√*				
CVEN 3256 Construction Equipment & Methods						*2016F, 2015F*	*55, 54*
AREN 4110 HVAC Design						*2017S, 2016S*	*16, 8*
CVEN 4545 Steel Design OR						*2017S, 2016S*	*45, 39*
CVEN 4555 Reinforced Concrete Design						*2016F, 2015F*	*44, 54*
[6] WRTG 3030 Writing on Science & Society	*SE*			*3*		*2017S, 2016F*	*19, 19*
[6] Concentration 1	SE		*3*				
AREN 4550 Illumination II OR AREN 4560 Luminous Radiative Transfer OR AREN 4570 Electrical Systems (whichever two not selected as proficiency)						*See above*	*See above*
[6] AREN/CVEN xxxx technical elective	SE		*3*			*2017S, 2016F*	*~70, 80*
Semester 7							
[7] Concentration 2	SE		*3*				
AREN 4550 Illumination II OR AREN 4560 Luminous Radiative Transfer OR AREN 4570 Electrical Systems (whichever two not selected as proficiency)						*See above*	*See above*
[7] AREN/CVEN xxxx technical elective	SE		*3*			*2017S, 2016F*	*~70, 80*
[7] ARCH 4010 Architectural Design	*R*		*5*			*2016F, 2015F*	*31, 35*

Course (Department, Number, Title) List all courses in the program by term starting with the first term of the first year and ending with the last term of the final year. [1 = first semester; 8 = final semester]	Indicate Whether Course is Required, Elective or a Selected Elective by an R, an E or an SE.[1]	*Subject Area (Credit Hours)*				Last Two Terms the Course was Offered: Year and, Semester, or Quarter	Maximum Section Enrollment for the Last Two Terms the Course was Offered[2]
		Math & Basic Sciences	Engineering Topics Check if Contains Significant Design (√)	General Education	Other		
[7] ENVD 3114 History and Theory of ENVD: Buildings	*R*			*3*		*2016F*	*240*
[7] Humanities or social science elective	*SE*			*3*			*~200*
Semester 8							
[8] AREN 4317 Architectural Engineering Design	*R*		*5√*			*2017S, 2016S*	*32, 40*
[8] Technical elective	SE		*3*			*2017S, 2016F*	*~100,100*
[8] Technical elective	SE		*3*			*2017S, 2016F*	*~100,100*
[8] ENVD 3134 History and Theory of ENVD: Precincts	*R*			*3*		*2017S, 2016S*	*219, 134*
[8] Humanities or social science elective	*SE*			*3*			*~200*

* The required curriculum for all students during their first five semesters is given in Table 5-1a. Courses in grey italics are required of all students.

***Table 5-1d Curriculum:** Architectural Engineering – Mechanical Systems Option **

Course (Department, Number, Title) List all courses in the program by term starting with the first term of the first year and ending with the last term of the final year. [1 = first semester; 8 = final semester]	Indicate Whether Course is Required, Elective or a Selected Elective by an R, an E or an SE.[1]	*Subject Area (Credit Hours)* Math & Basic Sciences	Engineering Topics Check if Contains Significant Design (√)	General Education	Other	Last Two Terms the Course was Offered: Year and, Semester, or Quarter	Maximum Section Enrollment for the Last Two Terms the Course was Offered[2]
Semester 6							
[6] AREN 4110 HVAC Design (Proficiency 1)	SE		*3√*			*2017S, 2016S*	*16, 8*
[6] Proficiency Course 2 (Choose 1)	SE		*3√*				
CVEN 3256 Construction Equipment & Methods						*2016F, 2015F*	*55, 54*
AREN 4550 Illumination II OR						*2017S, 2016S*	*25, 22*
AREN 4560 Luminous Radiative Transfer OR						*2016S, 2015S,*	*16, 9*
AREN 4570 Electrical Systems						*2016F, 2015F*	*15, 10*
CVEN 4545 Steel Design OR						*2017S, 2016S*	*45, 39*
CVEN 4555 Reinforced Concrete Design						*2016F, 2015F*	*44, 54*
[6] WRTG 3030 Writing on Science & Society	*SE*			*3*		*2017S, 2016F*	*19, 19*
[6] AREN 4830 Computer Simulation of Building Systems (Concentration 1)	SE		*3*			*2017S, 2016S*	0^+*, 2*
[6] AREN/CVEN xxxx technical elective	SE		*3*			*2017S, 2016F*	*~70, 80*
Semester 7							
[7] AREN 4890 Sustainable Building Design (Concentration 2)	SE		*3*			*2016S*	*16*
[7] AREN/CVEN xxxx technical elective	SE		*3*			*2017S, 2016F*	*~70, 80*
[7] ARCH 4010 Architectural Design	*R*		*5*			*2016F, 2015F*	*31, 35*
[7] ENVD 3114 History and Theory of ENVD: Buildings	*R*			*3*		*2016F*	*240*
[7] Humanities or social science elective	*SE*			*3*			*~200*
Semester 8							
[8] AREN 4317 Architectural Engineering Design	*R*		*5√*			*2017S, 2016S*	*32, 40*
[8] Technical elective	SE		*3*			*2017S, 2016F*	*~100, 100*
[8] Technical elective	SE		*3*			*2017S, 2016F*	*~100, 100*

Course (Department, Number, Title) List all courses in the program by term starting with the first term of the first year and ending with the last term of the final year. [1 = first semester; 8 = final semester]	Indicate Whether Course is Required, Elective or a Selected Elective by an R, an E or an SE.[1]	*Subject Area (Credit Hours)*				Last Two Terms the Course was Offered: Year and, Semester, or Quarter	Maximum Section Enrollment for the Last Two Terms the Course was Offered[2]
		Math & Basic Sciences	Engineering Topics Check if Contains Significant Design (√)	General Education	Other		
[8] ENVD 3134 History and Theory of ENVD: Precincts	*R*			*3*		*2017S, 2016S*	*219, 134*
[8] Humanities or social science elective	*SE*			*3*			*~200*

* The required curriculum for all students during their first five semesters is given in Table 5-1a. Courses in grey italics are required of all students.

[+] No undergraduates took this course

*Table 5-1e Curriculum: Architectural Engineering – Structural Systems Option **

Course (Department, Number, Title) List all courses in the program by term starting with the first term of the first year and ending with the last term of the final year. [1 = first semester; 8 = final semester]	Indicate Whether Course is Required, Elective or a Selected Elective by an R, an E or an SE.[1]	*Subject Area (Credit Hours)*				Last Two Terms the Course was Offered: Year and, Semester, or Quarter	Maximum Section Enrollment for the Last Two Terms the Course was Offered[2]
		Math & Basic Sciences	Engineering Topics Check if Contains Significant Design (√)	General Education	Other		
Semester 6							
[6] Proficiency 1	SE		3√				
CVEN 4545 Steel Design OR						*2017S, 2016S*	*45, 39*
CVEN 4555 Reinforced Concrete Design						*2016F, 2015F*	*44, 54*
[6] Proficiency 2 (Choose 1)	SE		3√				
CVEN 3256 Construction Equipment & Methods						*2016F, 2015F*	*55, 54*
AREN 4110 HVAC Design						*2017S, 2016S*	*16, 8*
AREN 4550 Illumination II OR						*2017S, 2016S*	*25, 22*
AREN 4560 Luminous Radiative Transfer OR						*2016S, 2015S,*	*16, 9*
AREN 4570 Electrical Systems						*2016F, 2015F*	*15, 10*
[6] WRTG 3030 Writing on Science & Society	*SE*			*3*		*2017S, 2016F*	*19, 19*
[6] Concentration 1	SE		*3*			*2016F, 2015F*	*34, 38*
[6] AREN/CVEN xxxx technical elective	SE		*3*			*2017S, 2016F*	*~70, 80*
Semester 7							
[7] CVEN 4161 Mechanics of Materials II (Concentration 2)	SE		*3*				
CVEN 4545 or 4555 (whichever not selected as proficiency – see above)						*See above*	*See above*
[7] AREN/CVEN xxxx technical elective	SE		*3*			*2017S, 2016F*	*~70, 80*
[7] ARCH 4010 Architectural Design	*R*		*5*			*2016F, 2015F*	*31, 35*
[7] ENVD 3114 History and Theory of ENVD: Buildings	*R*			*3*		*2016F*	*240*
[7] Humanities or social science elective	*SE*			*3*			*~200*
Semester 8							
[8] AREN 4317 Architectural Engineering Design	R		*5√*			*2017S, 2016S*	*32, 40*

Course (Department, Number, Title) List all courses in the program by term starting with the first term of the first year and ending with the last term of the final year. [1 = first semester; 8 = final semester]	Indicate Whether Course is Required, Elective or a Selected Elective by an R, an E or an SE.[1]	*Subject Area (Credit Hours)* Math & Basic Sciences	Engineering Topics Check if Contains Significant Design (√)	General Education	Other	Last Two Terms the Course was Offered: Year and, Semester, or Quarter	Maximum Section Enrollment for the Last Two Terms the Course was Offered[2]
[8] Technical elective	SE		*3*			*2017S, 2016F*	*~100, 100*
[8] Technical elective	SE		*3*			*2017S, 2016F*	*~100, 100*
[8] ENVD 3134 History and Theory of ENVD: Precincts	*R*			*3*		*2017S, 2016S*	*219, 134*
[8] Humanities or social science elective	*SE*			*3*			*~200*

* The required curriculum for all students during their first five semesters is given in Table 5-1a. Courses in grey italics are required of all students.

Curriculum Alignment with Program Educational Objectives

The overall philosophy of the architectural engineering curriculum is to provide all students with a broad foundation in engineering, architecture, and architectural engineering, then to provide each student with the opportunity for in-depth study in a specific discipline within architectural engineering. As such, the program provides both breadth and depth; breadth in that each AREN student must take courses in two specialty areas as well as general architecture, fundamental engineering and architectural engineering courses; depth in that each student must select an area for specialization and complete a core curriculum of courses for that area. The four areas from which students select one "track" are mapped to the four core disciplines—Construction Engineering & Management, Mechanical Systems, Lighting & Electrical Systems, and Structural Systems. Each track is defined by two concentration courses and four technical electives. Students may take up to 6 credits of technical electives outside of the department in consultation with their faculty advisor. All students pursuing the architectural engineering degree must take a common, 5-credit senior capstone design course that provides a culminating design experience.

The program objectives are linked to the desired outcomes, as shown previously in section 3B. The outcomes are fulfilled by various required courses in the curriculum, as described more fully below. For example, all courses contribute to successfully begin and sustain a career (objective 1). The alignment of the curriculum with the program educational objectives is summarized in the table below.

Objective	1st yr courses	2nd yr courses	3rd year courses	4th year courses	Notes
1. Successfully begin and sustain a career	All provide foundation	All provide foundation	All provide foundation	All provide foundation	Proficiency structure
2. Become leaders who advance the state-of-the arte in 1 of 4 core disciplines of building industry	Intro to AREN	Building Materials and Systems	AREN fundamental, proficiency, and concentration courses	AREN concentration courses Senior design	

Throughout the program, a series of required "overview" style courses serve to provide the foundation for either of the four core disciplines of the building industry (objective 2). In the very first semester the AREN 1316: Introduction to Architectural Engineering introduces students to the nature of professional practice in the building industry. The presentations in this class enable students to better understand the ultimate "end-point" and objective of the AREN program. The first year of the program also includes a course in engineering drawing, with introductions to Revit and building information modeling, to begin building some of the professional communication skills required for achieving the program objectives.

In the second year, students begin their exposure to the core four disciplines with AREN 2050 Building Materials and Systems which investigates the broad subject of building materials, sustainability, building assembly details, and systems and methods of building construction. Students explore codes and classifications, construction contract types, foundations, wood, steel, concrete, masonry, cladding, doors and windows, interiors, finishes, mechanical, electrical, plumbing, life safety and conveyance systems. Upon completion of the course, students have a foundational understanding of building systems and the process required to construct a building. Other courses in the second year provide the required fundamentals for later study of building structural, mechanical, and lighting systems, and provide the skills in computing needed for upper-level coursework and for professional practice.

During the second semester of the second year and the first semester of the third year, students take five required engineering courses that span the four sub-disciplines of architectural engineering: AREN 3010 Mechanical Systems, AREN 3246 Introduction to Construction, AREN 3540 Illumination I, ECEN 3030 Electrical Circuits, and CVEN 3525 Structural Analysis. During this time, students must give serious thought to their area of specialty within the program, as students choose their area of concentration by the spring semester of the third year and must be ready to take both the proficiency course and the first concentration course within their area.

Upon completion of the third year, students have had a design courses in two of the AREN disciplines (one as part of their concentration and the second of their choosing), which provide both a breadth and depth that prepares students for meaningful summer internships during the summer after their third year. The second AREN educational program objective is fully accomplished through both the concentration courses and the block of technical electives that students take in the last three semesters. These courses enable students to develop sufficient depth in an area of interest to complete their preparation for career in the building engineering fields.

In the design-oriented electives, students gain experience with the techniques and software tools used in professional practice, and usually gain further experience in presenting design ideas in a professional setting. The fourth year also sees our students continuing to develop their professional communication skills, through oral presentations in many of the smaller technical elective classes and through the required technical writing course. While working on their specialty areas in the fourth year, students also gain greater breadth in their professional preparation through 11 credits of study in Architecture. During the final semester, students take a required course that represents the final steps in their preparation for professional practice: AREN 4317 Architectural Engineering Design. The AREN Design course serves as the culminating integrative experience for AREN students, in which they work in teams to complete the design of all the engineering systems for a small commercial building. The architectural design for the building is completed by the students during the ARCH 4010 course in the penultimate semester, so that by the completion of this 10-credit, yearlong sequence, the students have experienced the building design process from initial concept to final engineering of systems. The AREN 4317 course emphasizes the documentation and presentation of design that is expected of practicing professionals, and involves design professionals in the mentoring, evaluation, and assessment for the project. The AREN Design course also covers a series of topics related to professional practice and serves as a final review for the Fundamentals of Engineering (FE) examination. As emphasized above, the AREN curriculum is designed to enable students to achieve the overall program objective that students “attain a broad knowledge and skills necessary to successfully begin and sustain a career, and to become leaders who advance the state-of-the art, in one of four core disciplines of the building industry.”

Mapping Curriculum to Student Educational Outcomes

All engineering courses in the AREN curriculum have been mapped to the extent to which they contribute to each of the 13 student outcomes, based on faculty ratings: large contribution (red), medium (orange), small (yellow), none.

Missing from the table are required courses in the curriculum outside of engineering. They primarily contribute to outcome 1 [4 semesters of calculus and math; 2 semesters of physics, 1 semester of chemistry], outcome 13 [Engineering Computing], and outcome 8 [writing course]. The humanities and social science electives [15 credits] contribute to outcome 10.

The two proficiency courses, two concentration courses, and four technical electives taken by the students also contribute significantly to the achievement of the outcomes. But these will vary based on the specific courses selected by the students. The mapping of the proficiency courses and common AREN/CVEN electives to the 13 outcomes is shown in an additional table below.

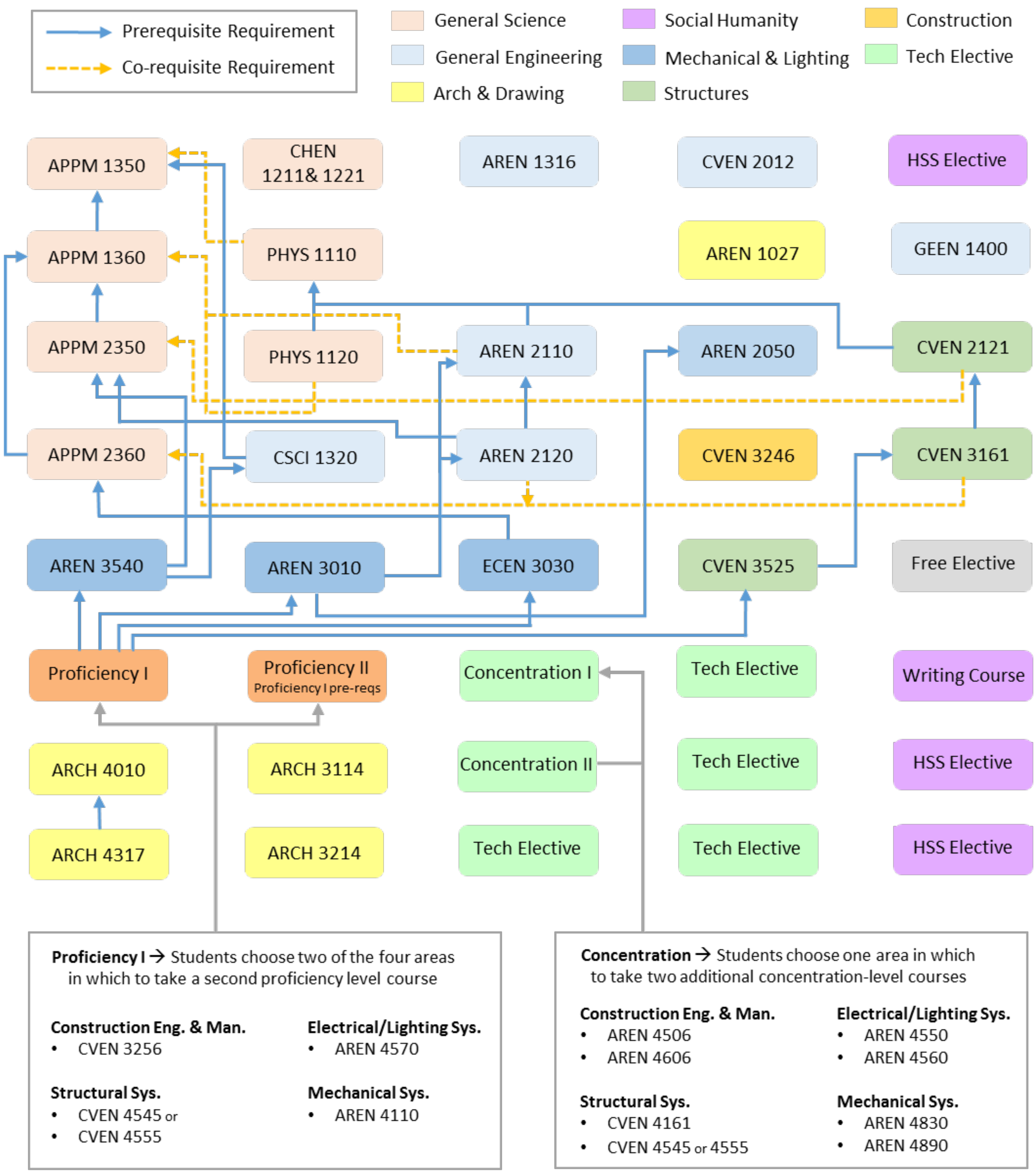
Alignment of Required engineering courses in the AREN degree with Outcomes [faculty ratings: red = large, orange = medium, yellow = small; average student ratings on a scale from 0 to 6 shown as the numbers in each cell]. N/A = data not available.

	Student Outcomes												
Courses [semester]	**1a**	**2b**	**3b**	**4c**	**5d**	**6e**	**7f**	**8g**	**9g**	**10h**	**11i**	**12j**	**13k**
AREN 1027-3 [1]													
AREN 1316-2 [1]													
CVEN 2012-3 [2]													
AREN 2050-3 [3]													
AREN 2110-3 [3]													
CVEN 2121-3 [3]													
AREN 2120-3 [4]													
CVEN 3161-3 [4]													
CVEN 3246-3 [4]													
AREN 3010-3 [5]													
AREN 3540-3 [5]													
CVEN 3525-3 [5]													
AREN 4317-5 [8]													
Total # L courses	9L	0L	3L	3L	3L	5L	1L	4L	0L	1L	1L	1L	6L
Total # M courses	1M	3M	1M	3M	0M	3M	3M	5M	3M	4M	6M	4M	4M

Alignment of selective elective engineering courses in the AREN degree with Outcomes [faculty ratings: red = large, orange = medium, yellow = small; average student ratings on a scale from 0 to 6 shown as the numbers in each cell] N/A = data not available

		Student Outcomes												
Discipline	**Courses**	**1a**	**2b**	**3b**	**4c**	**5d**	**6e**	**7f**	**8g**	**9g**	**10h**	**11i**	**12j**	**13k**
	Proficiencies (select 2)													
CEM	CVEN 3256-3													
Light & Electrical	AREN 4550-3 OR													
	AREN 4560-3 OR													
	AREN 4570-3													
Mechanical	AREN 4110-3													
CEM	CVEN 4545-3 OR													
	CVEN 4555-3													
	Concentrations:													
CEM	AREN 4506-3													
	AREN 4606-3													
Light & Electrical	AREN 4550/60/70-3	Same as in Proficiencies												
Mechanical	AREN 4830-3													
	AREN 4890-3													
Structures	CVEN 4161-3													
	CVEN 4545/55-3	Same as in Proficiencies												
Total # L courses		3L	0L	L	7L	2L	2L	1L	3L	3L	0L	1L	1L	5L
Total # M courses		5M	1M	2M	2M	1M	4M	2M	3M	1M	5M	4M	1M	4M

Flowchart illustrating prerequisite structure of AREN required courses (based on 2017-18 Block Diagram)



Curricular Areas and General and Program Criteria

The ABET basic-level general criteria require that a minimum of 32 credit hours or 25% of the total credit hours must be in the curricular area of math and basic sciences and that a minimum of 48 credit hours or 37.5% of the total credit hours must be in the curricular area of engineering topics. Table 5-1 shows that the AREN curriculum meets these requirements.

Math and basic sciences: Table 5-1 shows that the program contains sufficient coverage of the math and basic science requirements, with 34 credits or 25% of the curriculum. These are courses from applied math (APPM), chemistry, physics, and basic science courses such as Building Materials and Systems, Fluid Mechanics, and Electrical Systems.

Engineering topics and design: Table 5-1 also shows that the program contains sufficient coverage to meet the engineering topics requirement, with 73 credit hours or 57% of the curriculum devoted to these topics. The table also shows which of these courses contain a large amount of design. See evidence in the colored mapping tables.

General education: The curriculum provides 18 credits of humanities and social sciences coursework (H&SS), including 6 credits that are upper-division and an upper-division writing course. The College provides a listing of approved courses for these electives (see http://www.colorado.edu/engineering-advising/get-your-degree/degree-requirements/humanities-social-sciences-and-writing-requirements) to ensure that the courses have sufficient quality and complement the technical portions of the curriculum; in general, courses that are "skills" oriented are not approved for these electives. Instead, the College's list focuses on courses with a broad view of history, literature and the humanities. The majority of these courses are approved as College of Arts & Sciences (A&S) core courses, and as such undergo scrutiny from A&S to ensure quality. Courses beyond this A&S core that are approved for engineering students are reviewed by the H&SS subcommittee of the CEAS and then approved by the Undergraduate Education Council. Students are encouraged to pick a particular area of humanities or social science and devote their humanities electives to courses in that single area. Many also choose to take advantage of the College's Herbst Program of Humanities for Engineers, described in Appendix D.

Other: The curriculum revisions that were voted in by the CEAE faculty in 2012 included three credits of free electives. These credits were classified as "other". They may be technical or non-technical courses. They provide students with a small amount of autonomy to customize their college experience. They may include study abroad courses, courses that contribute to a minor or certificate, etc.

Major Design Experience

The AREN curriculum has elements throughout the four years that are focused on preparing students for engineering practice. The program culminates in a major design experience in the required AREN 4317Architectural Engineering Design course. The course builds directly on previous courses with architectural and engineering design content. Before taking AREN 4317, students take ARCH 4010 Architectural Design, four fundamental engineering analysis courses and at least two proficiency courses (design) all related to the four building disciplines.

Fundamental engineering analysis courses:
- CVEN 3525 Structural Analysis
- AREN 3010 Mechanical Systems for Buildings
- ECEN 3030 Electrical Circuits
- AREN 3540 Illumination 1
- AREN 3246 Intro to Building Construction

Proficiency courses:
- CVEN 4545 Steel Design or CVEN 4555 Reinforced Concrete Design
- AREN 4110 HVAC Design
- AREN 4570 Building Electrical System Design or Illumination 2 or Luminous Radiative Transfer
- CVEN 3246 Construction Equipment & Methods

In addition, students are required to take two concentration courses within each discipline:
- Structural Systems:
    - CVEN 4161 Mechanics of Materials II
    - CVEN 4545 Steel Design or CVEN 4555 Reinforced Concrete Design (whichever two are not selected as proficiency)
- Mechanical Systems:
    - AREN 4830 Computer Simulation of Building Systems
    - AREN 4890 Sustainable Building Design
- Lighting and Electrical Systems:
    - AREN 4570 Building Electrical System Design or Illumination 2 or Luminous Radiative Transfer (whichever two are not selected as proficiency)
- Construction Engineering Management:
    - AREN 4506 Project Management I
    - AREN 4606 Project Management II

In these discipline-specific design courses, students are introduced to methods of analysis and software tools widely used in the industry. They are also exposed to codes and standards that guide and constrain designs, including the International Building Code (IBC), the National Electric Code (NEC), ASCE/SEI 7 Minimum Design Loads for Buildings and Other Structures, ANSI/ASHRAE/IESNA Standard 90.1 Energy Efficiency for Buildings Except Low-Rise Residential Buildings, ANSI/ASHRAE Standard 62.1 Ventilation for Acceptable Indoor Air Quality, and the USGBC LEED Rating System.

The final-year design experience begins with ARCH 4010 Architectural Design, offered in the fall semester. This course is taught by faculty from the College of Architecture and Planning, and is a 5-credit studio-based course. Students gain an overview of the architectural design process, and apply this process to a series of design projects. The final project in that course entails the architectural design for a small to medium two-story building such as a museum, library, or research and design collaborative building, with a floor area of approximately 15,000 ft^2 to 30,000 ft^2. Realistic constraints are placed on this project, as the building is developed for a specific site with relevant life safety and local codes considered. The result of the project is a comprehensive program and a set of architectural plans for the building.

Students bring the architectural design for their building in ARCH 4010 into AREN 4317 Architectural Engineering Design in their final spring semester. In this course, students work in small teams (4-5 people) to refine the architectural design and to design all the engineering systems for the building: structural, mechanical, lighting and electrical, as well as develop construction costs and a schedule for project delivery. The student teams are formed based on specialty areas and are multi-disciplinary in nature, with at least one team member focusing on structural, mechanical, electrical/lighting, and construction engineering deliverables. While the course is organized and managed by the faculty member in charge, it is not uncommon for over a dozen professionals to be involved in the course. Other program faculty in the four disciplines serve as the discipline-specific experts who provide review lectures, meet regularly with the individual student teams, and evaluate the work in their particular disciplines. Partnered with each faculty member are at least three industry mentors from the local engineering community, who present case studies of their work, meet with students to help guide the integrated design process, and participate in evaluating and providing feedback on project deliverables. There are also lectures by building professionals throughout the semester on topics such as sustainable design, professional ethics, teamwork, and building information modeling. Students must again face realistic constraints on their design ideas, as they seek to integrate the various systems in the project and address code-related issues.

Throughout the course, students demonstrate their progress through a series of interim submittals and presentations, following the typical professional progression of programming, conceptual design, schematic design, and design development. The final deliverables for the course are complete sets of documents and drawings for the various engineering systems of the building. Successful completion of the AREN 4317 course represents the achievement of many of the program's outcomes.

The following represents a typical deliverable package (final report) required from each group:

a. Project abstract and introduction
b. Program (project parameters)
    i. Site
    ii. Building
    iii. Story
    iv. Architectural drawings
c. Written narratives describing process and design calculations per discipline:
    i. Construction
        1. Base cost estimate
        2. Risk and contingency analysis
        3. Schedule
        4. Cost monitoring and reporting
        5. Value engineering
        6. Codes

    ii. Structures
        1. Codes
        2. Applicable loads

        3. Structural system and material selection
        4. Framing and LLRS narrative
        5. Moment frame design
        6. Moment frame connection
    iii. Mechanical
        1. Benchmark and EUI targets
        2. Ventilation and thermal comfort requirements
        3. Zoning plan
        4. HVAC system research and selection
        5. Load calculations
        6. Equipment sizing
        7. Design methodology
    iv. Electrical
        1. Electrical load calculations
        2. Emergency systems
        3. Codes
    v. Lighting
        1. Design concept
        2. Lighting design criteria
        3. Luminaire selection
        4. Daylighting study
        5. Electric lighting compliance
        6. Code discussion and compliance
        7. Renderings
d. Drawings, calculations, and specifications set presented in appendix form
    i. Architecture
        1. Site plan
        2. Floor plans
        3. Sections
        4. Elevations
        5. 3D models
    ii. Construction
        1. Site plan
        2. Estimate table
        3. Schedule
        4. Risk analysis table
        5. Industry quote table
    iii. Structural
        1. Calculations:
            a. Joist and deck
            b. Beams
            c. Columns
            d. Lateral loads
            e. Overturning moment
            f. Moment frame
            g. Moment frame connections (shear / flange)

                h. Shear wall
            2. Drawings:
                a. Dead and live loads
                b. Snow loads
                c. Wind loads
                d. Floor loads
                e. Column layouts
                f. Governing beams/columns
                g. Lateral load distribution
                h. Stairway design
                i. Moment frame detail
                j. Shear wall detail
        iv. Mechanical
            1. Zoning plans
            2. Duct layout
            3. Single line
            4. Mechanical equipment cut sheets
        v. Electrical
            1. One-line/riser diagram
            2. Site and floor electrical plans
            3. Site and floor lighting circuiting plan
            4. Site and floor electrical HVAC plans
            5. Enlarged electrical rooms
                a. Main service entrance section
                b. Main distribution panel schedule
            6. Power panel schedules
            7. Lighting panel schedules
        vi. Lighting
            1. Lighting concept boards
            2. Site and floor lighting plans
            3. Lighting elevations and sections
            4. Interior and exterior luminaire schedules
            5. Luminaire cut sheets
    e. Various mini reports done by individual team members. Topics change from year to year. Examples of some of the topics are LEED compliance and clash detection.

The deliverables above are consistent with the specific objectives for the course:

1. Integrate the technical sub-disciplines of structural, mechanical, lighting and electrical, and construction engineering management to create a professional-level solution to a 30,000 +/- square-foot building.
2. Gather relevant data; understand "client" needs (as defined by Architectural Engineering faculty and industry mentors); identify budgetary, environmental and ethical constraints; and identify and use applicable regulations, codes and standards.
3. Create feasible alternative designs--where appropriate, and carry out value engineering analysis.

4. Prepare increasingly detailed designs and construction planning that satisfies the project's constraints while also conforming to relevant codes, regulations and established sustainable practices.
5. Prepare design documentation including design rationale and intent, design details and integrated project planning, scheduling and construction cost analysis to support each design stage.
6. Communicate effectively both through oral presentations and written reports/drawings the design intent, proposed solutions, and engineering details.
7. Work in multi-disciplinary teams and in interdisciplinary formats as appropriate during different phases of the project.
8. Realize the importance of obtaining professional credentials and engaging in life-long learning throughout their careers as engineers.
9. Understand the professional and ethical responsibilities they must exercise as students and as future practicing engineers.

Cooperative Education

Cooperative education is not allowed to satisfy curricular requirements addressed by the general or program criteria.

Course Syllabi

In Appendix A, a syllabus is included for each course used to satisfy the mathematics, science, and discipline-specific requirements required by Criterion 5 and applicable program criteria. Further, courses that are commonly taken by architectural engineering students, including all courses that count as proficiency courses and some additional courses are included.

CRITERION 6. FACULTY

A. *Faculty Qualifications*

There are 43 tenured/tenure-track faculty (24 Professors, 8 Associate Professors and 11 Assistant Professors), 5 Senior/Full-time Instructors in the CEAE department. These faculty members are distributed among six specialty "groups" (see table below). See Table 6-1 for the qualifications of these faculty members, presented alphabetically with the exception of the environmental and water resources faculty, who are listed last due to their small contribution to the architectural engineering degree program. (Table 6-2 gives the approximate percentage each individual devotes to architectural engineering, again with the environmental and water resources faculty presented last). The building systems faculty contributes almost solely to Architectural Engineering. The construction and structures faculty contribute about equally to both the Civil and Architectural Engineering programs. A small number of geotechnical and environmental faculty contribute to Architectural Engineering. All CEAE faculty vote on objectives, outcomes, and curriculum matters, and as such have some contribution to the architectural engineering program.

CEAE faculty members are grouped according to their specialization, with groupings shown below.

Specialty	Approx. % to AREN	Full professors	Associate Professors	Assistant Professors	Senior / Full Time Instructors
Building Systems	100	3	0	1	2[+]
Construction	50	3	2	0	1
Geotechnical	10	4	1	3[*]	0
Structures	50	3	2	3	0
Environmental	*20*	*7*	*2*	*2*	*2*
Water Resources	*5*	*4*	*1*	*2*	*0*
Total		24	8	11	5

[+] *Includes Walter Beamer who resigned in Jan. 2017; position filled starting in Aug. 2017*

[*] *One started January 2017*

Four of the tenured/tenure-track faculty have their salaries rostered in the graduate school, and have differential teaching responsibilities as a result (2 Professors, 1 Associate Professor, 1 Assistant Professor). One new faculty member started in January 2017. Six faculty members are affiliated with Research Institutes as Fellows or affiliated faculty (2 CIRES, 3 INSTAAR, RASEI 1 fellow/3 affiliates). The faculty includes high diversity, with 11 women T/TT (26%) and 1 senior instructor (20%) on the faculty, and three faculty from underrepresented minority population (7%). Currently, seven faculty members in CEAE hold endowed chairs (e.g. K. Stanton Lewis Chair of Construction Engineering and Management; Mortenson Chair in Global Engineering) and one professor and one Senior Instructor have professorships (Denver Business Challenge Professorship; Petry Professorship). Five faculty members have received NSF CAREER awards. Three faculty members are in the National Academy of Engineering (NAE). Twenty faculty members are fellows of major professional societies nationally, and three are fellows internationally. (Note: research professors (2) and scholars-in-residence that are associated only with the graduate program (2) are not included.)

Our faculty have been recognized for teaching excellence and educational research. Roseanna Neupauer received the 2006 ExCEED New Faculty Excellence in Teaching Award from the American Society of Civil Engineers (ASCE), the 2008 Charles A. Hutchinson Memorial Teaching Award, the 2010 Peebles Innovation in Teaching Award from CU's College of Engineering and Applied Science (CEAS), and the 2011 Boulder Faculty Assembly Excellence in Teaching Award from the CU-Boulder campus. Prof. Joseph Ryan won the 2010 Outstanding Faculty Advisor Award from the CU CEAS. Professor Bielefeldt won the Best Overall Conference Paper Award from the American Society for Engineering Education (ASEE) twice for her papers presented at the 2009 and 2015 annual conference.

B. Faculty Workload

The normal tenure-track faculty member in the College is evaluated based on an allocation of 40% research, 40% teaching, and 20% service. These weightings can be changed if desired by the faculty member and approved by the Department Chair and Dean. The standard teaching load in CEAE for research-active tenure-track faculty is three courses per year (for typical 3-credit courses). It is expected that these courses include at least one undergraduate course. The faculty members with appointments rostered in the graduate school teach two courses per year (Goosef, Livneh, McKnight, Pfeffer). The full-time senior instructors typically teach five courses per year. CEAE faculty instructional offerings generated 13,726 undergraduate and graduate student credit hours in the 2015-2016 academic year. The courses taught by our faculty comprise the majority of three different undergraduate majors: Civil Engineering, Architectural Engineering, and Environmental Engineering. The faculty workload is summarized in Table 6-2.

The annual research expectations of a tenure-track faculty member in CEAE with a typical research: teaching: service allocation would typically include 4 reviewed journal publications, 3-4 conference or invited presentations, $150,000-$200,000 in research expenditures, and 4-6 supervised graduate students (these are the approximate median values for T/TT faculty in CEAE in the 2016 calendar year). The annual service expectations would typically include contributions to several internal committees within the departmental, college, or campus, participation in national and international professional societies, and editorial review for professional journals.

C. Faculty Size

Faculty Size and Undergraduate Teaching

There is an adequate faculty size to teach and mentor architectural engineering students as shown above. The table below shows the number of Full Time Equivalent (FTE) Faculty, student credit hours (SCH) taught by CEAE faculty, and total number of undergraduate students. CEAE has been below the CU CEAS average for number of student credit hours (SCH) per faculty from 2013 and forward; CEAE is currently at our lowest level in 6 years. SCH are a good metric since our faculty teach courses that serve civil engineering, architectural engineering, and the bulk of the environmental engineering degree.

Fall Semester:	2011	2012	2013	2014	2015	2016
Full Time Equivalent faculty	36.5	39.0	39.5	40.0	40.0	42.0
SCH, all CEAE	17,366	16,394	15,425	13,497	13,666	13,164
CEAE SCH/Faculty	476	420	391	337	342	313
CU CEAS College SCH/Faculty	419	396	410	435	457	474
# architectural engineering undergraduate students	185	149	152	153	143	143

As shown in the table below, the number of FTE faculty in the CEAE department has increased steadily over the past six years. The number of tenure line faculty budgeted elsewhere has remained fairly constant at 3 to 5, while the number of tenure-line faculty (w/o tenure line budgeted elsewhere) has increased from a low of 33 in 2012 to the current high of 38. The number of instructional faculty increased the most, from only 2 in 2011 to 8 currently. This includes instructors to fill vacancies due to sabbatical or in-process hires.

Fall Semester	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
# Faculty FTE Budgeted (Fac)	36.5	39.0	39.5	40.0	40.0	42.0
# Tenure-line Faculty (w/o TBE)	34	33	36	38	37	38
# Tenure-Line Budgeted Elsewhere (TBE)	5	3	3	3	4	4
# Instructional Faculty	2	5	5	7	8	8

In addition to faculty and senor instructors, some individuals are hired to teach specific courses. Occasionally, post-doctoral researchers or Ph.D. students who are building their teaching skills will teach courses under the mentoring supervision of their advisor. More often, highly qualified senior individuals have been hired to teach courses (such as PEs Billington and Keeley). The table below summarizes the individuals who have been hired to teach specific courses in recent years, their qualifications, courses that they have taught, which semester(s), and average student ratings on the FCQs. The FCQ ratings are on a scale of 1-6 [1 = lowest, 6 = highest], and results for two questions are reported below: course overall and instructor overall.

Name	Qualifications	Courses Taught (type), dates [FCQs on scale of 1-6]
Max Billington, PE	- BS Architectural Engineering, University of Colorado Boulder, 1976 - PE in Colorado, California, Nevada, Oklahoma, and Texas - Chief Electrical Engineer, 37 yrs. experience - NCEES certification - LEED AP Building Design + Construction,	**AREN 4570**, Electrical Systems for Buildings, Spring 2014 [Course 2.5, Instructor 2.8]
Lance Cayko	- Master's Architecture 2008 from North Dakota State University - Licensed architect in CO 2015 - Project Manager with Studio H:T (1 yr) - Owner and co-founder of F9 Productions (2009) residential BIM projects	**AREN 1027** Engineering Drawing (required), Fall 2013-Spring 2016 [Course 4.1-5.2, Instructor 4.3-5.2]
Alex Gore	- Masters of Architecture - Masters Degree in Construction Management, North Dakota State University - Founder and co-owner of F9 Productions (2009-present) serving as designer and project manager for multiple residential and commercial BIM projects.	**AREN 1027** Engineering Drawing (required), Fall 2013-Spring 2016 [Course 4.1-5.2, Instructor 4.3-5.2]
Milan Halek	- Senior instructor emeritus - 40 yrs teaching experience at CU - Licensed Land Surveyor in Colorado Returned from retirement to teach.	**CVEN 2012** Intro to Geomatics, Spring 2016 [Course 4.5, Instructor 5.1]
Jeff Keely, PE	- BS and MS Civil Engineering Univ. Washington - Colorado Dept. of Transportation (since 2007) - Design and consulting engineer (12 yrs)	**CVEN 2121** Analytical Mechanics I, Summer 2015,Ssummer 2014 [Course: 4.7-5.0, Instructor: 5.2-5.3]

Name	Qualifications	Courses Taught (type), dates [FCQs on scale of 1-6]
Ryan Novak	- BS Civil Engineering University Wisconsin, MS Civil Engineering CU 2005; - Project manager at UOP (4 yrs) and ERDMAN (3 yrs); - Assistant Professor of Building Construction Management, University of Wisconsin – Platteville (4 yrs)	**CVEN 3246** Intro to Construction, Spring 2015 [Course: 4.3, Instructor: 4.0] **CVEN 3256** Construction Equipment and Methods, Summer 2015 [Course: 4.7, Instructor: 4.9]
Lan Nguyen, PE	- PhD in structural engineering from CU in May 2014. - Structural engineer at Aero Solutions LLC from 2011-2013, including designing tower structural elements such as foundations and upgrades for stability. - Graduate research assistant she design reinforced concrete frames and masonry shear wall panels.	**CVEN 4555** Steel Design, Fall 2014 [Course: 4.9, Instructor: 5.5]
In Ho Cho	- PhD Civil Engineering, California Institute of Technology - BS & MS Civil Engineering, Seoul National University, South Korea - Instructor during Willis Research Fellowship at CU - Expertise in computational science, structural analysis, seismology, and big data approaches to earthquake engineering	**CVEN 2121** Analytical Mechanics, Fall 2013 [Course: 5.0, Instructor 5.4] **CVEN 3161** Mechanics of Materials I, Spring 2013 [Course: 4.9, Instructor: 5.3] **CVEN 3525** Structural Analysis, Spring 2014 [Course: 4.2, Instructor 4.9]

Name	Qualifications	Courses Taught (type), dates [FCQs on scale of 1-6]
Mark Jongewaard	- Master of Science, Civil Engineering, Illumination Emphasis, University of Colorado, May 1991. - President & Principal, LTI Optics, LLC - Adjunct Professor, University of Colorado - Board Member, Rocky Mountain Lighting Academy and Council for Optical Radiation Measurements. - Extensive experience in lighting software development, lighting and optical analysis, illumination optical design and training.	**AREN 4130** Optical Design**,** Fall 2015, Fall 2014, Spring 2013 [Course: 4.7-5.0-5.4, Instructor: 4.9, 5.3-5.6]
Joseph Wujek	- M. A. Industrial Arts (Technology) University of Northern Iowa (UNI), Cedar Falls, IA - CEO/founder of Advanced Building Consultants; Department Chair, FRCC; Advanced Technologies Department. Professor (emeritus) and Program Director, Architectural Engineering Technology and Construction Management, FRCC; - Author of three university-level textbooks in structures, architectural engineering (MEP) systems and sustainability.	**AREN 2050** Building Materials and Systems**,** Spring 2016, Fall 2014, Fall 2013, Spring 2013, Fall 2012, [Course: 5.1-5.1-5.3-4.1-4.2, Instructor: 5.3-5.3-5.7-4.3-4.6] **AREN 4010** HVAC Design, Spring 2015 [Course: 4.4, Instructor: 4.8]

Faculty-Student Interactions

CEAE faculty members are actively involved in advising and mentoring students in the civil, architectural, and environmental engineering programs. Normally each CEAE faculty member advises 6 to 20 undergraduate students, meeting individually with each advisee in each semester of their junior and senior year. Details of the student academic advising have been provided earlier in Section B1. Faculty help students prepare for engineering careers by finding internships, reviewing student's resumes and bringing professional colleagues to meetings of student societies, special seminars and to classes as guest speakers. Through supervision of undergraduate research opportunities and independent study projects, faculty encourage many undergraduate Architectural Engineering students to continue their studies at the Masters level in accordance to the expectations imposed by industry (e.g. the structures field expects students to have earned master's degree upon graduation), either at the University of Colorado or other universities.

Faculty members advise student chapters of professional societies such as Association of General Contractors (AGC), Illuminating Engineering Society of North America (IESNA), Architectural Engineering Institute (AEI), and Society of Women Engineers (SWE). One Civil Engineering faculty member founded Engineers Without Borders (EWB), with the first student chapter at the University of Colorado Boulder. EWB has engaged students to work with practitioners to help communities in developing countries with projects for sustainable infrastructure for water, sanitation, housing, and transportation. This concept of outreach education and service started here at the University of Colorado Boulder has captured the enthusiasm of many engineering students, and there are now EWB student chapters at about half of all engineering programs throughout the US.

University Service Activities
Each faculty member serves on at least one standing Department Committee (Graduate, Curriculum, Operations, Computers, Facilities, Executive). In addition, faculty members serve on dozens of committees at the College and University level for developing curriculum, program evaluation, searches for new faculty and administrators, promotion, awards and fellowships, etc. Of special note, a CEAE faculty member recently served as the Interim Provost and Executive Vice Chancellor for Academic Affairs (Sture) until May 2010 when a permanent Provost was named. The Director of the Campus Diversity Initiative (Hernandez), which includes two NSF-sponsored programs to increase participation of underrepresented minority students in science and engineering research programs, is also a CEAE faculty member. Another CEAE faculty member serves as the Director of the College's interdisciplinary Environmental Engineering BS program (Summers, 2012-present). Faculty resumes in Appendix I-B show the diversity of faculty service to the University community.

Professional Service and Interaction with Practitioners
Most CEAE faculty members are involved in 2 to 10 committees for national professional engineering societies, involving such diverse activities as evaluating revisions in building and material codes, peer review of proposed environmental and health regulations, and development of national research programs. Some examples are: American Society for Testing Materials (ASTM) and American National Standards Institute (ANSI) code-evaluation committees, specialty committees for ASCE, the IESNA, ASHRAE, WEF, and AWWA. Faculty members chair sessions at national and international technical conferences and have themselves been conference directors. Many faculty members volunteer their professional expertise to community boards and public groups such as the Colorado municipalities and state agencies. All these activities regularly bring faculty in contact with their practicing colleagues in Civil and Architectural Engineering. Details of these activities are in the faculty resumes in Appendix B.

D. Professional Development

Support for excellent teaching in Civil and Architectural Engineering is strong. Typically teaching is at least 40% of a professor's activities, and also 40% of annual evaluation of merit assessment used for raises, and is of equal importance as research in promotion and tenure decisions. The nominal teaching load for research-active faculty in Civil and Architectural Engineering is three semester courses per year, including both graduate and undergraduate classes, which is consistent with other departments in the College of Engineering and Applied Science. Faculty members are encouraged to participate in programs to develop their teaching. Many take advantage of support to participate in workshops on engineering curriculum development and teaching methods sponsored by the NSF and professional societies.

The college supports the professional development of faculty through the Faculty Excellence Program (see http://www.colorado.edu/engineering-facultystaff/awards-incentives/college-awards/faculty-excellence-program), which provides a number of financial support opportunities. This program includes:

- **Dean's Faculty Fellowships -** Selected faculty members are given one semester off from teaching a course, to focus on a major initiative in research and scholarly work or development of substantial educational materials or initiatives
- **Dean's Seed Funds for Novel Ideas -** Discretionary funds up to $10,000 provide seed support for new ideas, and are matched 1:1 by the department or program
- **Dean's Performance Awards -** $5,000 awards are given for top performance in categories such as research, teaching, professional progress, and overall performance of junior faculty, based on the annual performance evaluations for the prior calendar year
- **Matching funds** for research grants, laboratory renovation funds, and travel to funding agencies
- **Sabbatical Supplement Program -** This program offers an additional 20% of the academic-year salary to faculty members taking full-year sabbaticals, on top of the normal 50% of the academic-year salary that they receive on sabbatical. The department then retains the remaining 30% of the academic-year salary, and the faculty member is responsible for raising (or forgoing) 30% of her or his salary. In addition, the Dean will provide $4000 in discretionary funds for research, travel, etc. to each faculty member who successfully applies for this program.

The Department encourages professional development through attendance of conferences and workshops. Data are collected on faculty attendance of these events through the annual reporting and evaluation process. If faculty members are not participating in these events, it is noted by the chair. New faculty members have significant start-up packages with moneys designated for travel and professional development. Senior faculty members typically raise their own funds for travel to these events, but they can also make requests for funds from the Department or College.

The College provides overarching guidelines for faculty mentoring. The College holds a new faculty orientation program at the start of the academic year. The Dean delivers a mentoring workshop at orientation and new faculty and their mentors are invited to attend. Assignment of faculty mentors for new faculty is tracked by the Chair and the Dean. In addition, the former Dean has written a document on mentoring for faculty, Tips for Faculty Mentoring (see http://www.colorado.edu/engineering-facultystaff/tips-faculty-mentoring).

The University of Colorado Boulder has a campus-wide Faculty Teaching Excellence Program (FTEP) to help faculty develop new teaching and learning methods. CEAE Engineering faculty have served on FTEP panels to discuss educational innovations and participated in FTEP workshops on special topics such as using the Internet for teaching. FTEP also maintains a classroom visitation program to give teachers feedback and assistance in improving teaching methods for individual courses. Two CEAE faculty have recently participated in the ASCE ExCEEd teaching workshops.

Historically, CEAE faculty have received teaching awards from the College and national awards from ASEE (Young Faculty Award), the Association of Environmental Engineering and Science Professors (Outstanding Teaching), the Illuminating Engineering Society, and the Society of Women Engineers (Distinguished Engineering Educator). Five faculty (Crimaldi, Hernandez, McCartney, Neupauer, Rajaram) have received NSF's prestigious Early Career Development (CAREER) award, which is partially based on the awardee's education plan.

Faculty have developed significant external funding for educational innovations, including NSF education grants to develop a unique teaching flume for fluid mechanics and hydraulics courses, a laboratory geotechnical centrifuge for soil mechanics laboratory projects, and planning for curriculum in service and outreach learning in an initiative called Engineering for Developing Communities. Private industry funding has been obtained to support development of a unique design experience in lighting engineering. In addition to the significant impact of these activities on Civil and Architectural Engineering students' education at the University of Colorado Boulder, publications in journals and presentations at ASEE and other conferences have contributed to new educational efforts at other universities.

For newly hired faculty, the College has a New Faculty Program, which focuses on mentoring and supporting new tenure-track faculty during their first few years.

In addition to teaching-related professional development, most CEAE faculty also routinely attend professional conferences where they present their research findings and learn about the latest developments in their area. Travel to these conferences is most often supported directly from the same grants that fund the research. For example, NSF requires dissemination of research results, and therefore funding to attend a conference to present the results is expected and normal.

E. Authority and Responsibility of Faculty

CEAE Department

The specific CVEN degree requirements are controlled fully by the CEAE faculty and senior instructors, within the constraints of the College of Engineering and Applied Science (CEAS). All changes to required courses in the curriculum must be voted on by the CEAE faculty as a whole. All changes to the program educational objectives and student outcomes are also voted on by the faculty as a whole. Changes are passed if approved by a simple majority of the faculty present at the meeting, if a quorum is present (half plus one of the voting members of the Department). Voting members of the department include those with a full-time University of Colorado appointment in the ranks of Instructor, Senior Instructor, Assistant Professor, Associate Professor, and Professor; Research Assistant Professor, Research Associate Professor and Research Professor. Instructors must have held the position for two years.

The CEAE faculty set up the JEC (Joint Evaluation Committee) process for on-going review of program objectives, student outcomes, and curriculum. Each JEC is aligned with one or two of the six CEAE faculty groups, and at least one JEC meets every year to evaluate the civil and/or architectural engineering programs. One or more faculty serve on each JEC. Two or more faculty are involved in writing the self-study report that is provided to the JEC in advance of its meeting. The departmental Assessment Coordinator provides assessment data for the self-study. After the JEC submits its report of recommendations, the faculty in the reviewed sub-discipline area(s) meet to discuss the recommendations and respond. The responses are then passed to the curriculum committee in the Department, which discusses any recommended changes at the curriculum-level. The curriculum committee is composed of faculty representatives from each of the six groups, and an additional representative from the Engineering for Developing Communities (EDC) program. The curriculum committee reviews assessment data on the program, evaluations by the JEC, and reviews curriculum elements. It can approve content changes within courses, and recommend curriculum changes to the faculty.

Assignments to teach specific courses are generally determined by recommendations to the department chair based on consensus within the appropriate CEAE sub-discipline group. These course assignments take into account instructor interest and expertise, and student FCQs.

A representative from architectural engineering sits on the CEAS Undergraduate Education Council. This individual is appointed by the Chair of CEAE and has been a member of the curriculum committee; for many years, this representative was also the CEAE Assessment Coordinator. The Undergraduate Education Council is chaired by the Associate Dean for Education. Voting members include faculty representatives from each degree program, the Associate Dean for Education, the Assistant Dean for Students, and any other stakeholder granted voting rights by the Associate Dean for Education. Staff representatives from each degree granting program and the directors of the programs and services for student support and learning also participate on the committee. The Undergraduate Education Council is responsible for developing and coordinating undergraduate educational initiatives as described in the College's Strategic Plan and such other activities related to undergraduate education within the College as may be brought before the committee. Additional faculty may also serve on sub-committees that review specific service-level courses as well as other ad hoc task forces.

The CEAE faculty are also represented on the CEAS assessment committee. The purpose of this committee is to consider/develop ongoing assessment measures used at the college and to act in an advisory capacity to the Director of Assessment and Accreditation for surveys that are administered by the Dean's office on behalf of the college's departments and programs. These surveys include the graduating senior survey, first-year student survey, summer internship survey, alumni survey, and employer survey. The CEAE Assessment Coordinator represents CEAE on this committee.

College of Engineering and Applied Science (CEAS)
The following is copied from the College Rules:

Approved: February 8, 2017

The Faculty. The members of the faculty shall consist of all Professors, Associate Professors, Assistant Professors, Teaching Professors, Scholars in Residence, Senior Instructors, Instructors, Research Professors, Research Associate Professors, and Research Assistant Professors in the College of Engineering and Applied Science on the Boulder campus. The Dean may also appoint members to one-year renewable terms from departments outside the College involved in degree granting programs such as Engineering Physics and Applied Mathematics. These additional members may be recommended for membership at the start of each academic year by their respective department chairs. Other additional members from outside the College may be appointed by the Dean for one-year renewable terms.

- **Voting Members.** The voting membership of the faculty shall consist of all Professors, Associate Professors, Assistant Professors, Research Professors, Research Associate Professors, Research Assistant Professors, Teaching Professors, Scholars in Residence, Senior Instructors, and full-time Instructors in the College of Engineering and Applied Science, plus any additional members appointed by the Dean. Faculty with such titles as adjoint, adjunct, visiting, lecturer, research associate, etc., are not voting members of the College but may be voting members of a department (or program) based on the rules of that unit.
- **Powers.** The college faculty shall collaborate with the Dean in the governance of the College of Engineering and Applied Science in all matters that concern only the college (in accordance with the Laws of the Regents, Article 4.A.5). In particular, through shared governance with the administration, the faculty shall have principal responsibility for academic and scholastic policy and ethics, and the faculty shall act jointly with the administration in areas of faculty appointment and review, regulation of student conduct and activities, budgeting review and resource recommendations, selection of academic administrators, determination of candidates for degree, and other policies concerning the general academic welfare of the College (in accordance with the Laws of the Regents, Article 5.E.5).
- **Secretary.** A Secretary shall be appointed by the Dean, to record any decisions and votes.
- **Faculty Meetings.** Faculty meetings shall be held at least once during each of the fall and spring semesters. Special meetings may be called by the dean or shall be called by the dean upon the written request of five members of the faculty. Twenty-four hours' notice of a special meeting will be given. The members present at any regular or special meeting shall constitute a quorum.

Dean of the College of Engineering and Applied Science. The dean of the college shall be its administrative head. The dean shall be responsible for the enforcement of admission requirements and for the general efficiency of the college and its departments and programs, and has overall responsibility for budgetary planning and allocation of funds, space and other resources, faculty assignments and workloads, recommendations on personnel actions, planning, accountability and reporting (in accordance with the Laws of the Regents Article 4.A.2). The dean shall enforce rules and regulations of the college. The dean shall confer with the department chairs about departmental needs. The dean shall make regular reports to the provost of the Boulder campus, and to the faculty of the college.

The Dean of the College of Engineering and Applied Science reports to the Provost. The Provost leads the Division of Academic Affairs at the University of Colorado Boulder. The Division of Academic Affairs is responsible for administering the academic programs and policies of the Boulder campus, and for providing intellectual leadership for excellence in teaching, scholarship, and creative work. The division recruits faculty, deans, and other academic leaders, and allocates resources to ensure high-quality teaching, research and creative work, and service. The Provost reports to the Chancellor, who in turn reports to the President of the University of Colorado.

Table 6-1. Faculty Qualifications – *Architectural Engineering*

The full CEAE roster is shown below since all faculty votes on curriculum issues regardless of the program. The table is organized by program starting with AREN followed by CVEN whose various faculty contribute to AREN. Last is EVEN.

Faculty Name	Highest Degree Earned- Field and Year	Rank [1]	Type of Academic Appointment[2] T, TT, NTT	FT or PT[3]	Years of Experience			Professional Registration/ Certification	Level of Activity[4] H=high, M, L= low		
					Govt./Ind. Practice	Teaching	This Institution		Professional Organizations	Professional Development	Consulting/summer work in industry
Amadei, Bernard	PhD Civil Engineering, 1982	P	T	FT	1	35	29	PE Europe	H	H	M
Balaji, Rajagopalan	PhD Stochastic Hydrology & Water Resources, 1995	P	T	FT	0	20	17		H	H	L
Beamer, C. Walter IV*	PhD Civil Engineering, 2005	I	NTT	FT	10	5	5		L	M	M
Bielefeldt, Angela	PhD Civil Engineering, 1996	P	T	FT	1	21	21	PE CO	H	H	L
Chinowsky, Paul	PhD Civil Engineering, 1991	P	T	FT	3	23	15		H	H	M
Corotis, Ross	PhD Civil Engineering, 1971	P	T	FT	1	46	23	PE CO,IL,MD	H	H	M
Dashti, Shideh	PhD Geoengineering, 2009	AST	TT	FT	0	6	6		L	M	L
Goodrum, Paul	PhD Civil Engineering, 2001	P	T	FT	3	16	5	PE KY	H	L	L
Hallowell, Matthew	PhD Construction Eng & Mgmt, 2008	ASC	T	FT	5	9	9		H	M	L
Hearn, George	DES Civil Engineering 1989	ASC	T	FT	10	28	28	PE CO,NY	M	L	M
Henze, Gregor	PhD Civil Engineering, 1995	P	T	FT	4	18	9	PE NE	M	L	M
Hubler, Mija	PhD Civil & Environ Engineering, 2013	AST	TT	FT		2	2		M	M	L
Javernick-Will, Amy	PhD Civil Engineering, 2009	ASC	T	FT	7	7	7		H	M	L
Krarti, Moncef	PhD Civil Engineering, 1987	P	T	FT	3	26	26	PE CO	H	H	M
Liel, Abbie	PhD Civil & Env. Engineering, 2008	ASC	T	FT	0	9	9	PE CA	M	H	M
Molenaar, Keith	PhD Civil Engineering, 1997	P	T	FT	7	20	18		H	H	M

Morris, Matthew	MS Civil Engineering, 2002	I	NTT	FT	14	8	5	PE [CO]	M	L	M
Pak, Ronald	PhD Applied Mechanics, 1985	P	T	FT	1	32	32		H	H	L
Pfeffer, William (Tad)	PhD Geophysics, 1987	P	T	FT	9	19	18		H	H	L
Pourahmadian, Fatemah	PhD Civil Engineering, 2016	AST	TT	FT	0.5	0.5	0.5		L	L	L
Regueiro, Richard	PhD Civil & Environ Engrg, 1998	ASC	T	FT	7	12	12		M	H	L
Saouma, Victor	PhD Civil Engineering, 1980	P	T	FT	0	33	33		M	M	L
Sideris, Petros	PhD Civil Engineering, 2012	AST	TT	FT	0	5	4	PE[G]FE [MI]	H	M	L
Song, Jeong-Hoon	PhD Theoretical Appl Mechanics, 2008	AST	TT	FT					H	L	L
Srubar, Wil V.	PhD Civil Engineering, 2013	AST	TT	FT		3	3		M	M	L
Vasconez, Sandra	MS Lighting 2000; MA Art Hist. 2005	I	NTT	FT	14	10	10		L	L	L
Xi, Yunping	PhD Structural Engineering, 1991	P	T	FT	3	21	20		M	H	L
Zhai, Zhiqiang	PhD Building Technology, 2003	P	T	FT	2	14	14		H	H	M
Zhang, Yida	PhD Civil & Environ Engineering, 2016	AST	TT	FT	0	1	1		L	L	L
Znidarcic, Dobroslav	PhD Civil Engineering, 1982	P	T	FT	0	35	31		L	L	L
Water and Environmental Engineering											
Cook, Sherri	PhD Environmental Engineering, 2014	AST	TT	FT	0	2	2		M	M	L
Corwin, Chris	PhD Civil Engineering, 2010	I	NTT	FT	13	3	3	PE [CO]	L	M	M
Crimaldi, John	PhD Civil & Environm Engrg, 1998	P	T	FT	4	18	18		L	M	L
Gooseff, Michael	PhD Civil Engineering, 2001	ASC	T	FT					H	M	L
Hernandez, Mark	PhD Environmental Engrg, 1994	P	T	FT	8	22	22	PE [CA]	H	M	L
Kasprzyk, Joseph	PhD Civil Engineering, 2013	AST	TT	FT					M	M	L
Linden, Karl	PhD Civil & Environm Engrg, 1997	P	T	FT	1	22	12		M	H	M
Livneh, Ben	PhD Civil Engineering, 2012	AST	TT	FT					L	M	L
McKnight, Diane	PhD Environmental Engrg, 1979	P	T	FT	17	21	21		H	H	L
Montoya, Lupita	PhD Civil & Env. Engineering, 1999	AST	TT	FT	1	14	7		M	H	L
Neupauer, Roseanna	PhD Hydrology, 2000	ASC	T	FT	0	17	12	PE[VA, NM]	H	H	L
Rajaram, Harihar	ScD Civil Engineering, 1991	P	T	FT	0	18	18		L	H	L
Ren, Zhiyong (Jason)	PhD Civil & Environ Engineering, 2008	ASC	T	FT	2	9	4		H	M	L

Rosario-Ortiz, Fernando	D.Env. Environ Science & Eng, 2006	ASC	T	FT	4	9	9		H	H	M
Ryan, Joseph	PhD Civil & Environm Engrg, 1992	P	T	FT	3	24	24		M	H	M
Silverstein, JoAnn	PhD Civil Engineering, 1982	P	T	FT	2	35	35	PE CO	H	M	L
Summers, R. Scott	PhD Environmental Eng & Sci, 1986	P	T	FT	2	29	18		M	H	M
Walker, Mike	PhD Chemical Engineering, 2012	I	NTT	FT	4	3	3		M	H	L

1. Code: P = Professor ASC = Associate Professor AST = Assistant Professor I = Instructor A = Adjunct O = Other
2. Code: TT = Tenure Track T = Tenured NTT = Non Tenure Track
4. The level of activity, high, medium or low, reflects an average over the year prior to the visit plus the two previous years.

* No longer at this institution

*Table 6-2. **Faculty Workload Summary** – Architectural Engineering*

The full CEAE roster is shown below since all faculty votes on curriculum issues regardless of the program. The table is organized by program starting with AREN followed by CVEN whose various faculty contribute to AREN. Last is EVEN.

Faculty Member (name)	PT or FT[1]	Classes Taught (Course No./Credit Hrs.) Term and Year[2]	Program Activity Distribution[3]			% of Time Devoted to the Program[5]
			Teaching	Research or Scholarship	Other[4]	
Amadei, Bernard	FT	CVEN 3698 Engineering Geology, 3 cr, F 2016 CVEN 4/5837 Sp Tpc – Syst App Global Engrg, 3 cr, S 17 CVEN 5929 Sustainable Community Dev 2, 3 cr, S 2017 CVEN 5939 SCD Practicum, 3 cr, S 2017	25	40	35	5
Balaji, Rajagopalan Department Chair	FT	CVEN 6393 Water Resources Seminar, 1 cr, F/S 2016/17 CVEN 6833 Advanced Data Analysis, 3 cr, F 2016 CVEN 5454 Statistical Methods for Nat/Eng Sys, 3 cr, S 17	40	40	20	20
Beamer, C. Walter IV *	FT	AREN 3540 Illumination 1, 3 cr, F 2016 AREN 4580/5830 Daylighting, 3 cr, F 2016 CVEN 5830 Sp Tpc – Bldg Energy Sys, 1 of 3 cr, F 2016 [resigned from CU effective January 2017]	55	20	25	95
Bielefeldt, Angela	FT	AREN 1316 Intro to Arch. Eng., 2 cr, F 2016 CVEN 1317 Intro to Civil & Env Eng., 2 cr, F 2016 CVEN 4897 Prof Issues in Civil Eng, 2 cr, F 2016 SUST 2800 Sp Tpc: Intro Sust, 1 cr, F 2016	34	33	33	30
Chinowsky, Paul	FT	*Admin Role – Assoc Vice Provost Student Success*	15	25	60	10
Corotis, Ross	FT	Fall SABBATICAL CVEN 5565 Life-cycle Engineering, 3 cr, S 2017	25	50	25	40
Dashti, Shideh	FT	CVEN 4/5728 Foundation Engineering, 3 cr, F 2016 CVEN 5818 Geotech Earthquake Engrg, 3 cr, S 2017	40	40	20	5
Goodrum, Paul	FT	CVEN 5286 Design Construction Operations, 3 cr, F 2016 CVEN 3256 Construction Equipment & Mths, 3 cr, S 2017 CVEN 5836 Sp Tpc – Discrete Event & BIM, 3 cr, S 2017	40	40	20	50
Hallowell, Matthew	FT	CVEN 3256 Construction Equipment & Mthds, 3 cr, F 2016 CVEN 5226 Quality and Safety, 3 cr, F 2016	25	60	15	50

Faculty Member (name)	PT or FT[1]	Classes Taught (Course No./Credit Hrs.) Term and Year[2]	Program Activity Distribution[3]			% of Time Devoted to the Program[5]
			Teaching	Research or Scholarship	Other[4]	
		CVEN 3246 Introduction to Construction, 3 cr, S 2017				
Hearn, George	FT	CVEN 4555 Reinforced concrete Design, 3 cr, F 2016 CVEN 5575 Advanced Steel Design, 3 cr, F 2016 CVEN 4545 Steel Design, 3 cr, S 2017	53	27	20	50
Henze, Gregor	FT	AREN 4/5890 Sustainable Building Design, 3 cr, F 2016 AREN 4/5010 HVAC System Modeling Control, 3 cr, S 17 AREN 4/5110 HVAC Design, 3 cr, S 2017	40	40	20	95
Hubler, Mija	FT	CVEN 3161 Mechanics of Materials 1, 3 cr, F 2016 *Family Leave spring 2017*	40	40	20	40
Javernick-Will, Amy	FT	SABBATICAL – full academic year	25	60	15	50
Krarti, Moncef	FT	AREN 4570/5830 Electrical Systems, 3 cr, F 2016 CVEN 5830 Sp Tpc – Bldg Energy Systems, 3 cr, F 2016 AREN 5020 Building Energy Audits, 3 cr, S 2017	25	60	15	95
Liel, Abbie	FT	CVEN 4/5525 Matrix Structural Analysis, 3 cr, F 2016 CVEN 5835 Sp Tpc – Risk Landsc Ind Seism, 3 cr, F 2016 CVEN 3227 Probability Statistics and Decision, 3 cr, S 17	40	40	20	30
Molenaar, Keith	FT	AREN 4056 Project Management 1, 3 cr, F 2016 *CEAS Associate Dean for Graduate Programs*	20	30	50	50
Morris, Matthew	FT	AREN 2050 Building Materials and Systems, 3 cr, F 2016 CVEN 3246 Introduction to Construction, 3 cr, F 2016 CVEN 5836 Sp Tpc – CEM Fundamentals, 3 cr, F 2016 AREN 4606 Project Management 2, 3, S 2017 CVEN 4899 Civil Engrg Senior Project Design, 4, S 2017	80	0	20	55
Pak, Ronald	FT	CVEN 5798 Dynamics of Soils/Foundations, 3 cr, F 2016 CVEN 3708 Geotechnical Engineering 1, 3 cr, S 2017 CVEN 5131 Continuum Mechanics & Elasticity, 3 cr, S 17	40	40	20	20
Pfeffer, William (Tad)	FT	FALL SABBATICAL CVEN 2012 Introduction to Geomatics, 3, S 2017	25	60	15	30
Pourahmadian, Fatemah	FT	STARTED JANUARY 2017 CVEN5831 Sp Tpc: Wave-Based Methods&Appl, 3, S2017	40	40	20	5

Faculty Member (name)	PT or FT[1]	Classes Taught (Course No./Credit Hrs.) Term and Year[2]	Program Activity Distribution[3]			% of Time Devoted to the Program[5]
			Teaching	Research or Scholarship	Other[4]	
Regueiro, Richard	FT	CVEN 3708 Geotechnical Engineering 1, 3 cr, F 2016 CVEN 7511 Comp Finite Inelast Multiph Mech, 3 cr, F2016 CVEN 5788 Computational Modeling in Geotech, 3 cr, S17	40	40	20	20
Saouma, Victor	FT	CVEN 7161 Fracture Mechanics, 3 cr, S 2017 CVEN 3525 Structural Analysis, 3 cr, S 2017	25	60	15	20
Sideris, Petros	FT	CVEN 2121 Analytical Mechanics 1, 3 cr, F 2016 CVEN 5111 Intro Structural Dynamics, 3 cr, F 2016 CVEN 5835 Sp Tpc – Exper Methods Str Eng, 3 cr, S 2017	40	40	20	20
Song, Jeong-Hoon	FT	CVEN 4/5511 Finite Element Analysis, 3 cr, F 2016 CVEN 3111 Dynamics, 3 cr, S 2017	40	40	20	30
Srubar, Wil V.	FT	AREN 4/5830 Sp Tpc – Sustain. Matls & Str, 3 cr, F 2016 AREN 4/5830 Sp Tpc – Forensic Engineering, 3 cr, F 2016 CVEN 4565 Timber Design, 3 cr, S 2017	40	40	20	70
Vasconez, Sandra	FT	AREN 4530 Advanced Lighting Design, 3 cr, F 2016 AREN 4830 Sp Tpc – Arch. Lighting Design, 3 cr, F 2016 AREN 4550 Illimunation II, 3 cr, S 2017 CVEN 5830 Sp Tpc – Illumination II, 3 cr, S 2017	70	0	30	95
Xi, Yunping	FT	CVEN 4/5161 Adv Mechanics of Materials 1, 3 cr, F 2016 CVEN 4535 Construction Materials, 1 or 3 cr, F 2016 CVEN 3161 Mechanics of Materials 1, 3 cr, S 2017 AREN 4317 Architectural Engineering Design, 1 cr S 2016	40	40	20	30
Zhai, Zhiqiang	FT	AREN 3010 Mechanical Sys for Buildings, 3 cr, F 2016 CVEN 5830 Sp Tpc – Bldg Energy Systems, 3 cr, F 2016 AREN 2120 Fluid Mechanics & Heat Transfer, 3 cr, S 2017	40	40	20	95
Zhang, Yida	FT	CVEN 5708 Soil Mechanics, 3 cr, F 2016 CVEN 7718 Engineering Properties of Soils, 3 cr, S 2017	40	40	20	10
Znidarcic, Dobroslav	FT	CVEN3718 Geotechnical Engineering 2, 3 cr, S 2017 CVEN 5748 Design of Earth Structures, 3 cr, S 2017	40	40	20	20
Water and Environmental Engineering						
Cook, Sherri	FT	CVEN 5534 Wastewater Treatment, 3 cr, F 2016	40	40	20	5

Faculty Member (name)	PT or FT[1]	Classes Taught (Course No./Credit Hrs.) Term and Year[2]	Program Activity Distribution[3]			% of Time Devoted to the Program[5]
			Teaching	Research or Scholarship	Other[4]	
		CVEN 5834 Sp Tpc – Environm Sustainability, 3 cr, F 2016 CVEN 4834 Sp Tpc – Sustainability Princip Eng, 3 cr, S 17				
Corwin, Chris	FT	CVEN 3414 Fundls Environm Eng, 3 cr, F/S 2016/17 CV/EVEN 4464 Environm Engrg Processes, 3 cr, F 2016 CVEN 3424 Water/WW treatment, 3 cr, S 2017 CV/EV4434 Env Engrg Design, 4 cr, S 2017	80	0	20	5
Crimaldi, John	FT	CVEN 5313 Environm Fluid Mechanics, 3 cr, F 2016 CVEN 3313 Fluid Mechanics, 3 cr, S 2017	25	50	25	5
Gooseff, Michael	FT	CVEN 5333 Physical Hydrol/Hydroclimatol, 3 cr, F 2016 CVEN 5833 Sp Tc – Init. Academic Career, 1 cr, F 2016 CVEN 4/5833 Sp Tpc – Open Channel Hydraulics, 3 c, S 17 CVEN 5833 Sp Tpc – Surface Water Qual Model, 3 cr, S 17	40	40	20	5
Hernandez, Mark	FT	AREN 2110 Thermodynamics, 3 cr, F 2016 CVEN 5484 Applied Microbiology & Toxicol., 3 cr, S 2017 EVEN 1001 Environmental Engineering 101, 3 cr, S 2017	25	60	15	20
Kasprzyk, Joseph	FT	CVEN 5423 Water Resources Engrg, 3 cr, F 2016 CVEN 4333 Engineering Hydrology, 3 cr, S 2017 CVEN 5393 Water Resources Develop/Mgmt, 3 cr, S 2017	40	40	20	5
Linden, Karl	FT	FALL SABBATICAL CV/EVEN 4/5834 Sp Tpc - WASH	20	60	20	5
Livneh, Ben	FT	CVEN 4333 Engineering Hydrology, 3 cr, F 2016	25	60	15	5
McKnight, Diane	FT	*On loan to NSF*	10	20	70	5
Montoya, Lupita	FT	CVEN 4/5554 Fundamentals of Air Quality, 3 cr, F 2016 AREN 2110 Thermodynamics, 3 cr, S 2017 COEN 1410 Sust Community Design, 3 cr, S 2017	40	40	20	30
Neupauer, Roseanna	FT	CVEN 3323 Hydraulic Engineering, 3 cr, F 2016 CVEN 4/5353 Groundwater Engineering, 3 cr, F 2016 CVEN 4/5383 Groundwater Modeling, 3 cr, S 2017	40	40	20	5
Rajaram, Harihar	FT	CVEN 5537 Numerical Methods in Civil Eng, 3 cr, F 2016 CVEN 6383 Flow & Transport Porous Media, 3 cr, F 2016	40	40	20	5

Faculty Member (name)	PT or FT[1]	Classes Taught (Course No./Credit Hrs.) Term and Year[2]	Program Activity Distribution[3]			% of Time Devoted to the Program[5]
			Teaching	Research or Scholarship	Other[4]	
		SPRING 2017 ON SABBATICAL				
Ren, Zhiyong (Jason)	FT	CVEN 5614 Bioenergy & Bioresource Recov, 3 cr, F 2016 CVEN 4/5834 Environmental Microbiology, 3 cr, S 2017 CVEN 5834 Sp Tpc – Emerg Tech: Microb Elctchm, 3, S17	40	40	20	5
Rosario-Ortiz, Fernando	FT	CVEN 4404 Water Chemistry, 3 cr, F 2016 CVEN 4414 Water Chemistry Lab, 1 cr, F 2016 CVEN 5424 Environm Organic Chemistry, 3 cr, S 2017	25	60	15	5
Ryan, Joseph	FT	EVEN 4100 Environml Sampling & Analysis, 3 cr, F 2016 CVEN 5404 Environm Engrg Chemistry, 3 cr, F 2016 CV/EVEN 4424 Environm Organic Chemistry, 3 cr, S 2017	40	40	20	5
Silverstein, JoAnn	FT	CVEN 4/5147 Civil Engineering Systems, 3 cr, F 2016 CVEN 5834 Sp Tpc – Small System W/WW Tmt, 3 cr, S 17	30	40	30	5
Summers, R. Scott	FT	EVEN 1000 Introduction to Environm. Engrg, 1 cr, F 2016 CVEN 5464 Environm Engrg Processes, 3 cr, F 2016 CVEN 5524 Water Treatment, 3 cr, S 2017	25	40	35	5
Walker, Mike	FT	CV/EVEN 4/5434 Environmental Engrg Design, 4 cr, S17 EVEN 4830 Sp Tpc – Env Eng Process Model, 3 cr, F 2016 MCEN 3032 Thermodynamics 2, 3 cr, F/S 2016/17	80	0	20	5

1. FT = Full Time Faculty or PT = Part Time Faculty, at the institution
2. For the academic year for which the Self-Study Report is being prepared.
3. Program activity distribution should be in percent of effort in the program and should total 100%.
4. Indicate sabbatical leave, etc., under "Other."
5. Out of the total time employed at the institution. Most faculty are less than 100% to the Architectural Engineering program due to time devoted to Civil Engineering (CVEN) or Environmental Engineering (EVEN) students via course instruction and/or advising.

* No longer at this institution

CRITERION 7. FACILITIES

A. Offices, Classrooms and Laboratories

The CEAE department is housed primarily in the Engineering Center, where the main office, undergraduate advisor, and most faculty offices are located. All architectural engineering faculty offices and research space along with offices used by Teaching Assistants to hold office hours are located in the Engineering Center.

The majority of the undergraduate architectural engineering classes are offered in centrally-scheduled classrooms in the Engineering Center and the Fleming Building. Working with the campus IT organization, the college ensures that the open computer labs in the engineering center are configured with software tools needed by engineering students.

The CEAE program has three classrooms for which it controls scheduling: ECCE 1B41 (up to 49 students), ECCE 1B43 (up to 25 students), ECCE 1B52A (up to 20 students). Undergraduate courses and office hours are held in ECCE 1B41 and ECCE 1B43. Only office hours have been held in ECCE 1B52A (which is a classroom space within the structural engineering laboratory). ECCE 1B41 was recently extensively renovated (Spring 2016) to allow teaching simultaneously a local group of students and off-site students. This classroom includes state of the art A/V equipment including two 80" monitors and 2- 6' erasable black boards on the east wall and a 50" monitor on the west wall. Architectural engineering has access to these rooms.

The CEAE Department on behalf of the AREN program maintains specialized teaching laboratories for undergraduate courses in building mechanical systems, lighting systems, mechanics and structural engineering. Undergraduate teaching laboratories feature state-of-the-art equipment such as a novel small-scale geotechnical centrifuge, two independently controlled test rooms for the indoor thermal environment and HVAC systems (under renovation), a lighting demonstration and test room with a moveable ceiling system, computer-controlled material testing equipment. In addition, laboratories have enough small instruments and supplies dedicated to courses with laboratory components to permit simultaneous hands-on laboratory experiments and independent data collection by 4-6 student teams working simultaneously in both the CEAE laboratories and the College's Integrated Teaching and Learning Laboratory (ITLL).

a) Building Systems Laboratory: Up until 2015, the Larson Building Systems laboratory consisted of a full-size commercial HVAC system, four representative commercial building zones, a system for producing repeatable and controllable loads on the HVAC system, and sophisticated data acquisition and control systems. Activities at the Laboratory included evaluation and testing of control algorithms and hardware for HVAC components and systems, interactions between multiple control functions of HVAC systems, the dynamic interactions between building thermal response and HVAC system controls, ventilation control for indoor air quality, and HVAC system diagnostics. The Larson laboratory was a dual-purpose facility for research and teaching about building mechanical systems. In teaching, it was used primarily by students in AREN 3130 Building Energy Laboratory and AREN 4010 HVAC System Controls. The larger equipment in the lab has been disposed of to make room for current state-of-the art technologies. A plan for renovation is underway.

b) Lighting Laboratory: The Lighting Laboratory is a learning and research space for lighting students in the AREN program. The lab has a dynamic ceiling such that the height can be adjusted through wallbox control gear, allowing for a wide range of academic and research exploration. Although the lab has full wall north facing windows, there are blackout curtains installed to eliminate external light when it is undesirable as with certain types of research projects. In addition, this lab houses a goniophotometer. This apparatus is used to measure the intensity of light leaving a luminaire at various vertical and horizontal angles. From this information, the photometric light distribution of the luminaire is derived, and quantities such as total lumen output, luminaire luminance, zonal lumen summary and other information that is included in a photometric report can be computed. Students use the goniophotometer in classes such as AREN 3540 Illumination I and AREN 4130 Optical Design. This piece of equipment will be updated in 2017. The lab also houses a small lighting sphere, which allows testing of lumen output of small LED luminaires and LED chips. The sphere is used mainly by graduate students. In addition to the main lab space there is studio space. This space is used primarily for lighting research. The lab has an extensive aluminum open ceiling grid that allows for quick electrical and physical connection of light sources and luminaires for research. In addition, a series of custom 4 lamp indirect luminaires fill the lower room cavity and are controlled by Lutron Ecosystem with Quantum Software. For lighting design oriented classes such as AREN 4550 Illumination II and AREN 4350 Advanced Lighting Design, students have access to theatrical-type and programmable color-changing luminaires to do mock-ups and study lighting effects.

c) Structural engineering and materials laboratory: There are laboratory components in mechanics of materials I (CVEN 3161) and advanced mechanics of materials (CVEN 4161), and laboratory demonstrations and experiments are carried out both in the ITLL and in the structures laboratory in the CE wing of the Engineering Center. The Department has a site in the NSF-funded George E. Brown Jr., Network for Earthquake Engineering Systems, the Fast Hybrid Test Facility, which has enabled major equipment upgrades in the structures laboratory, which in turn will benefit undergraduate students in courses with demonstrations as well as opportunities for hands-on experiments. There are 110 kip and 1,000 kip Universal Testing machines with automated data acquisition, and facilities for fabrication of concrete and steel structural elements and sensors for testing (http://www.colorado.edu/ceae/research/structural-engineering-structural-mechanics/facilities).

d) Sustainable Infrastructure Materials Laboratory (SIMLab): The SIMLab is a departmental laboratory facility that supports teaching and research activities related to innovative construction materials. Because this is a new laboratory, it has not been used by undergraduate students yet, but it will begin supporting AREN and CVEN undergraduate courses in the near future. It is equipped with ovens, microbalances, fume hoods, glove boxes, and other standard laboratory equipment that support polymer-, foam-, and cement-based materials experiments at the laboratory scale. Additional soft materials characterization equipment include a Fourier-Transform Infrared (FT-IR) Spectrometer, an X-ray Diffraction (XRD) system, a thermogravimetric analyzer (TGA), nano-scale mechanical testing equipment, Raman and mass spectroscopy, environmental chambers with temperature and moisture controls, X-ray computed microtomography, a dynamic mechanical analyzer (DMA), and an atomic force microscope (AFM). Activities in the SIMLab also utilize university-wide shared experimental facilities in the Integrated Teaching and Learning Laboratory (ITLL) and the Chemical and

Biological Engineering Biotechnology Laboratories for physicochemical characterization of soft and hard materials. Micrography resources (e.g., SEM, TEM) are also available as part of this facility.

e) Surveying-Geomatics laboratory: Plane Surveying (CVEN 2012) is taken by all students in Civil and Architectural Engineering. In 2004 the curriculum was broadened to incorporate GPS hardware and software and GIS software in a course that will be renamed Geomatics. Laboratory work, field measurements, and computer lab assignments comprise the majority of the course work by student teams. Sufficient surveying instruments are available for six student crews to work in the field simultaneously. These include traditional transits, theodolites and levels. Modern instruments used are EDM, total stations, and a digitized level. There are six PCs and a plotter to allow each student crew to download and analyze field data immediately. The lab also has bench space for minor repairs and adjustments to equipment. In addition, GPS and GIS software are available on the Bechtel Lab (see below) server for both in-class instruction and student projects.

The students also rate the overall quality of the facilities on the graduating senior survey. The facilities are rated on a scale of 1 = poor, 2= marginal, 3=fair, 4=good, and 5=excellent. Results are summarized below. All ratings are 3 or higher, which is adequate. The weakest ratings are for classrooms and the lobby, over which the department has no control.

Facilities Ratings on the Graduating Senior Survey (average of AREN respondents)

Year	2015-2016	2014-2015	2013-2014	2012-2013	2011-2012
Department experimental labs	3.35	3.68	3.17	3.23	3.86
Classrooms	2.90	3.21	3.20	2.74	3.53
ITLL	4.25	4.26	4.17	4.12	4.38
Idea Forge	4.20				
Engineering Library	3.35	3.74	3.57	3.36	4.06
Engineering Lobby	2.76	3.08	2.90	2.71	3.39

B. Computing Resources

Campus-wide/Institutional Computing Resources

The majority of campus-wide computing resources are provided by the Office of Information Technology (OIT), which provides CU-Boulder with innovative, customer-focused IT support and core IT services. Under the leadership of the Office of the Associate Vice Chancellor for IT and CIO, OIT partners and collaborates with academic, research, and administrative units in order to create a robust, best-in-class IT environment.

Computing resources are provided by OIT as well as colleges, departments, institutes, centers, etc. OIT provides coordinated, centralized IT support as well as core IT services in areas such as academic technologies, communication technologies, enterprise IT services, infrastructure, Research Computing and IT security.

Networking
The University of Colorado has a robust, enterprise-level network that serves both wired and wireless Internet access to nearly every corner of the campus, as well as providing VPN opportunities for off-campus connections.

- Wired connectivity – 1 Gigabit/secs Ethernet, 13 distribution routers, 700 switches, servicing ~23,000 hardwire attached devices
- Wireless connectivity – 802.11a/b/g/n/ac, 85,000 registered wireless devices
- VPN connectivity
- Institutional network backbone – 10 Gigabit/sec Ethernet and multiple 10 Gigabit/sec Internet connectivity.
- ScienceDMZ – 80 GigaBit/sec core with no firewalls and 10 Gigabit/sec Internet connectivity managed jointly by Research Computing and OIT networking

Teaching and Learning Spaces
Students, faculty, and staff have access to a variety of OIT Technology Enhanced Learning Spaces. OIT maintains over 200 technology-equipped classrooms campus wide, which includes most (but not all) College of Engineering and Applied Science's classrooms. Each technology-equipped classroom and lecture hall contains at minimum a video display (LCD or Data Projector), audio reinforcement, and wireless networking capability. Classroom sizes range from 12 to 375 seats. Most classrooms on campus have an audience response system, CU iClicker. All OIT supported spaces have an assigned CU iClicker frequency posted.

Computer Labs
There are forty-two centrally-managed labs on campus. Eight of them are in Engineering buildings. The University maintains a three or four year hardware replacement schedule for most workstations. Software on the machines is upgraded every semester with new or updated versions of important Engineering software packages. The hours of availability and access vary according to the policies of individual buildings and departments. However, most Engineering labs are open 24 hr./day, 7days/week to students in the College of Engineering.

Engineering Labs
There are eight centrally-managed labs in the Engineering complex. These labs are configured with similar workstation hardware and software in all locations. Current configurations and software availability can be found on the OIT website: http://webdata.colorado.edu/labs/map/ (Click on individual labs to view load sets.)

Open student engineering lab locations and resources include the following rooms:

- ECCE 141 (CadLab)
- ECCE 152 (Soils)
- ECCR 143 (APPM)
- ECCR 235
- ECCR 239
- ECCR 252
- ECES 107
- JCSB A205

In addition to a much larger set of software available in Engineering labs, the following engineering-related software is also installed on many Open Student Engineering Labs

A variety of software compilers	LabView
Abaqus	Mathcad with Prime
Ansys	Mathematica
ArcGIS	MATLAB
AspenONE Suite	OriginPro
AutoCAD	R
EES (Engineering Equation Solver)	Revit
EQS	SAS
IDL	SolidWorks
JMP PRO	

Classrooms

OIT maintains Technology Enhanced Learning Spaces.

Smart Classrooms (S) – 0 to 155 seats.

These classrooms contain the features listed below:

- Digital image display, projection screen or video monitor
    - Laptop inputs could include VGA, HDMI and\or MiniDisplay
- Most rooms have DVD players
- Content audio reinforcement, wall or ceiling speakers
- UCB Wireless and UCB Guest wireless connectivity
- iClicker frequency assigned
    - Not all rooms are assigned a base station
- Manual writing surface such as chalkboard or dry erase board
- Student seat and table types vary greatly from room to room
    - Rooms with tables could be fixed or modular with modular chairs
    - Rooms without tables have student seats which could be fixed or modular style seating with armchair writing surfaces
- All rooms are supplied with an instructor table/lectern
    - This may range from a large lectern, small lectern, table-top lectern or a table
- AV room control (source routing) system
    - Button controllers
    - Remote handheld monitor control (only few LCD TV monitor rooms)

Large Lecture Halls (L) – Over 155 seats.

These classrooms contain the features listed below:

- ADA accessible lectern with height adjustment
- Digital image display, projection screen(s) or video monitor(s)
    - Laptop inputs could include VGA, HDMI and\or MiniDisplay
- Minimum of DVD players, some have Blu-Ray

- Content audio reinforcement
- Multiple wireless microphones for voice audio reinforcement
    - Minimum of one handheld and one lapel microphone
- Assisted listening technology for hard of hearing compliancy
    - Full-room T-coil hearing loop or
    - Individual listening receiver systems
- Document camera
- UCB Wireless and UCB Guest wireless connectivity
- iClicker frequency assigned
    - Not all rooms are assigned a base station
- Manual writing surface such as chalkboard or dry erase board
- Student seats are fixed with armchair writing surfaces
- Lecture capture features available by request
- Some rooms are equipped with software-based Video Conference capability through USB connection using a user supplied laptop
- Minimum of one pan/tilt/zoom video camera with multiple pre-set camera selections
- Audio Visual room control system
    - Interactive multiple video source routing touch panel (Crestron)

Distance Learning Spaces (D) – 10 to 100 seats.
These classrooms contain the features listed below:

- ADA accessible lectern with height adjustment
- Dedicated lectern Windows-based computer
- Multiple digital image displays, projection screens and/or video monitors
    - Primary lecture content
    - Secondary lecture content
    - Rear wall confidence LCD monitor
    - Laptop inputs include VGA, HDMI and MiniDisplay
- DVD player
- Content audio reinforcement
- Multiple wireless microphones for voice audio reinforcement
    - Minimum of one handheld and one lapel microphone
- Assisted listening technology for hard of hearing compliancy
    - Full-room T-coil hearing loop or
    - Individual listening receiver systems
- Document camera
- UCB Wireless and UCB Guest wireless connectivity
- iClicker frequency assigned
    - Not all rooms are assigned a base station
- Manual writing surfaces such as chalkboard, dry erase board and interactive LCD monitor
- Student seats are fixed or modular with fixed or modular tables or armchair writing surfaces
- Lecture capture features available by request
- Hardware-based Video Conference/Synchronous Participation capability through codec

- Multiple pan/tilt/zoom video cameras with multiple pre-set camera selections
- Audio Visual room control system
    - Interactive multiple video source routing touch panel (Crestron)
- Operator supported for distance education courses only
- Redundant lecture capture system
- WACOM annotation over content
- Audience microphones for recording purposes only
- Some rooms have stage lighting for recording
- USB connectivity for the dedicated PC and the Laptop input to allow annotation to either device from the WACOM or Touch LCD monitors where available

Computer Labs (Lab) – 6 to 50 seats.
These classrooms contain the features listed below:

- Some rooms are outfitted with **Smart Classroom (S)** technology
- PC or Macintosh computing devices with a single display

Additional Administrative Systems

Additionally, administration of the campus is supported by a central portal (my.cu.edu), a learning management system (Desire2Learn), and various database software applications. This includes, but is not limited to: web presentation and content services through Google Apps for Education, course schedules, grades, billing information, employment listings, Registrar forms, announcements, news, and events, online file access, e-mail, calendaring, the college catalog, financial aid, online-registration, student academic records, and Faculty Report of Professional Activity (FRPA) information. Our library system uses technology that includes a digital catalog with 300 citation indexes, full-text databases, 23 academic, public and special libraries, 20 million books, journals DVDs, CDs, videos, and is linked to thousands of libraries across the world.

Academic Technologies
Besides ubiquitous Internet connectivity and laboratory space, students are provided with many other computing services and software. Students are offered 2 walk-in desktop support centers for software and hardware support. Teaching and learning technologies include Desire2Learn, CUClickers, Lynda.com, Google Apps for Education, Microsoft 365, and some Lecture Capture possibilities. Captioning guidelines and consultation are provided to all campus constituents while media captioning is provided to meet accommodation requests.

Faculty members using technologies in the classroom are supported by both dispatched and walk-in desktop support, robust phone and email support, and a team of Technology Learning Assistants who provide 1:1 support and workshops for teaching and learning technology use in the classroom.

Additionally, the College of Engineering and Applied Science is served along with the larger campus by the Academic Technology Design Team, a group consisting of media, universal, and learning designers, social media experts, and data analytics professionals. College leaders partner with the ATDT to define strategic and complex learning problems and pilot solutions through the creative application of new technologies. Three of the showcase campus projects were partnerships with the College of Engineering and Applied Science, including the launch of two Coursera engineering MOOCs (one from the Department of Computer Science), the ambitious redesign of Introduction to Engineering, and forward-looking flipped redesign of a senior/graduate level statistics course.

CEAE Department Computing Facilities

The CEAE Department has access to two large computing facilities for use by Civil and Architectural Engineering courses and individual students, the CAD laboratory (described above, ECCE 141), which is maintained by the Office of Information Technology (OIT) and the Bechtel laboratory (ECCE 157 and ECCE 161) which is controlled by the Department and maintained via a contract to OIT. The computers and peripheral hardware in the CAD lab are replaced approximately every three years. Both rooms have laser printers (color laser in Bechtel) and student print jobs are subsidized by the Department. All these computers are Auto-CAD/Revit workstations and contain general spreadsheet, word processing and Internet access software. The drawing class (AREN 1027) is taught in the CAD lab. The Bechtel lab contains professional-level software in classes, as well as general software, including those shown in the table below. Undergraduate required courses that periodically use the Bechtel lab include: CVEN 1317 Introduction to Architectural Engineering, AREN 2120 Fluid Mechanics & Heat Transfer, CVEN 3161 Mechanics of Materials II, AREN 3540 Illumination I, AREN 4317 Architectural Design; proficiency courses such as: AREN 4550 Illumination II, AREN 4560 Optical Design, AREN 4010 HVAC Design, AREN 4317 Architectural Engineering Design, and electives such as AREN 4580 Daylighting, AREN 4606 Project Management 2.

Priority for both the CAD-Lab and Bechtel Lab computing facilities is undergraduate classroom use, with use by individual students and student teams from Civil and Architectural Engineering heavy during non-teaching hours. The Department has contracted with OIT to maintain the Bechtel Lab.

ECCE 157 houses the Bechtel Computer Aided Design Laboratory (West). This facility is accessible to CEAE students via card-swipes programmed to their Buff One ID cards, 24 hours/day, 7 days/week. The lab includes 29 Dell Precision T3500, Intel Xeon/6GB, E520, 2.27 GHz with Windows 7 operating systems, and numerous applications including: Abaqus, ACI, Adobe Dreamweaver, ArcGIS, AutoCAD 2011, AutoCAD Civil 3D, Revit Architecture, BioWin, Caterpillar FPC, DesignBuilder, F-Chart APSS, FLOWNETz, GeoStudio, GW Chart (MODFLOW GUI), HEC-HMS Hydrologic Modeling System, HEC-RAS River Analysis System , HYDRUS-1D 4.14, Mathcad 14, Mathematica 7, Matlab R2010a, McTrans HCS+ 5.2, MT3DMS 4.3 , Plaxis 2D, Plaxis 3D Foundation 2.1, Plaxis 3D Tunnel 2.4 , Processing Modflow 5.3.1 , R 2.11.x , RETScreen International, Storm Water Management Model, 5.0, TESS TRNSYS 16, Trane TRACE 700 v6.2 , US EPA BIOCHLOR 2.2 , US EPA BIOSCREEN 1.4 , US EPA EPANET 2.00.12 , US EPA LandGEM 3.02 , US EPA REMChlor 1.0 , Visual MINTEQ 3.0, VisualDOE 4 , West Point Bridge Designer 2015.

ECCE 161 Bechtel Computer Aided Design Laboratory (East) includes 33 workstations that generally mirror those in Bechtel West. Access to the lab is identical to Bechtel West.

Example of specific software used primarily by the different sub-groups within AREN engineering are listed in the table below.

Examples of software used primarily by different civil engineering groups

Type	Programs	Locations
Lighting	Excel, Matlab, Mathematica, Notepad, AGI32, Visual 2016, Licaso, Rhino, Diva, Daysim, Radiance, Photopia	Bechtel Lab, except for Licaso
Mechanical	EQUEST, EnergyPlus, DesignBuilder, Homer, Sam, Phoenix, beopt, Trane Trace 700, Matlab Simulink, EES	Bechtel Lab
CEM	Primavera P6, Trimble WinEst, Bluebeam	Bechtel Lab
Geotechnical	PLAXIS, SEEP_W, SIGMA_W, SLOPE_W	Bechtel Lab
Geomatics / surveying	Quicksurf; Horizon Solutions – Plane Surveying, GPS software; ARCVIEW 3.3 and ARCGIS 9.0	CAD lab Bechtel lab
Structural Engineering	ALGOR, SAP90, SAP 2000 (nonlinear), SODA, FEAP, ABAQUS, Linear Stress and Vibrations	Bechtel lab
Miscellaneous	West Point Bridge Designer (CVEN 1317); Math tools: Mathematica, MatLab, SPSS	Bechtel Lab All computing labs

On the graduating senior survey, AREN students rate the quality of the computer facilities on a scale of 1 = poor, 2= marginal, 3=fair, 4=good, and 5=excellent. Results are summarized below. All ratings for both campus centrally controlled (OIT) computing facilities and departmental computing facilities were adequate, at 3.08 and higher.

Graduating Senior Survey Average Ratings for Computer Facilities

	2015-2016	2014-2015	2013-2014	2012-2013	2011-2012
OIT computer facilities	3.33	3.74	3.14	3.27	4.00
Department computer facilities	3.68	3.59	3.08	3.47	4.13

C. Guidance

The Department provides students with guidance on the use of the computing tools, resources, and labs discussed in this section via a variety of means. In courses where students will be using laboratory facilities (e.g. Mechanics of Materials, Illumination II), the instructor and/or teaching assistants (TAs) describe the relevant equipment to students. Important health and safety requirements and precautions are described. Safe equipment use is monitored during the laboratory sessions by the TA and/or faculty. User guides and/or instructions for each laboratory and necessary equipment are provided to the students. The students work with the laboratory equipment during supervised laboratory times, with immediate access to teaching assistants and/or faculty to answer their questions.

The primary methods of guidance include leveraging University-wide OIT training resources, semester-length tooling courses, online and video documentation, extracurricular training sessions, and peer-tutoring. Each method is discussed in greater detail below. Many of the computer resources leveraged by the Department are provided by the University-wide Office of Information Technology (OIT). OIT provides training and guidance for such resources to students directly via their website, walk-in support desk, and phone and email support center. OIT provides a range of support service to AREN students, staff, and faculty including:

- Campus Single-Sign-On (SSO) and Directory (LDAP) Support
- OSX and Windows end-user software licensing, installation, and training
- Email, contacts, and calendaring support (Google Apps or Microsoft Exchange)
- Classroom technology upkeep and training
- Backup services, hosted servers, etc.
- Wireless, wired, and VPN network access
- Phone and telecommunication services

Beyond the general IT support provided by OIT, the department also has a designated individual for desktop support.

D. Maintenance and Upgrading of Facilities

Larson Building Systems Laboratory

The Larson Building Systems laboratory has served the AREN program well for 40 years. However, in order to enhance the research and teaching capacity, attract students and faculty, and provide hands-on education, a plan to modernize it is in the works. This will be a $400,000 renovation, which CU will cover. The CEAE Department will provide $15,000 annually for its maintenance.

CEAE Departmental Experimental Laboratories

The faculty who teach courses using the undergraduate teaching laboratories monitor the equipment used and generally perform basic maintenance. The department collects student fees, and the money is used to maintain, repair, and replace the laboratory equipment, when needed. The relevant course instructor simply informs the department chair of any needs, and makes the necessary purchases or contracts for needed service. Instructors can also request new equipment as they keep laboratory experiences up-to-date with current practice. Major equipment requirements are often cost-shared between the College (via a request for funding to the Engineering Excellence Fund) and the Department. One example of recent updates to equipment is the CVEN 2012 Introduction to Geomatics course, which purchased a variety of new equipment specified by Prof. Tad Pfeffer.

OIT Controlled Computing Facilities

The computer hardware in the centrally-managed computer labs are configured to meet the high-end demands of the software specific to Engineering disciplines. The labs are outfitted with workstation-class hardware that provides the necessary CPU, memory and GPU to support these applications. The hardware is purchased with a 3-year warranty, and the machines are refreshed at the end of the three years to ensure that the labs can stay current with the demands of new and updated software. All the hardware is managed centrally using management tools like Microsoft SCCM and AppSense. These tools allow us to deploy software, manage the user environment, and monitor the security and performance of the machines. Microsoft security updates are applied weekly after-hours to ensure they do not impact the availability of the machines during classes or while students are using the machines. In addition, because these machines are used in multi-user environments, we ensure that changes made by previous users are not maintained across logins. This ensures a consistent and familiar environment for the students and faculty that use them. The machines are all configured with antivirus software to protect the students and other machines from viruses, and logins and application usage data is tracked to help us make decisions about software licensing and machine availability.

E. Library Services

The Leonard Gemmill Engineering, Mathematics & Physics Library[2], opened in 1992, is an 18,000 square foot facility. In 2016, during fall semester approximately 242,945 user visits were recorded, and during spring semester approximately 227600 user visits were recorded. The library is open 83 hours per week when fall and spring semesters are in session and 40 hours per week during the summer session. Additionally, it provides 24/7 access to a substantial electronic collection. Additionally, college students have access to collections in four other libraries on campus, one of them being Norlin Library, which houses the science collection, as well as regional and world-wide interlibrary loan services free of charge.

Three paraprofessional and two professional librarians, as well as several trained student assistants, are available to answer reference questions in several modalities. Research help is available by dropping by the circulation desk or making an appointment with a subject specialist, as well as by telephone, email, and synchronous chat services. Typically, these services are fully staffed from eight to five pm, with chat service available into the evening hours. Further, librarians in the sciences department, which serves computers science, are available to provide in-class information literacy instruction, online tutorials, and workshops. We offer course-integrated instruction, designed around finding information resources for particular assignments or projects in a class, as well as workshop series known as Science Learner's Lunches, which focus on information literacy skills needed for lifelong learning, as well as associated technology skills.

The Gemmill Library spaces are designed to facilitate student success and academic engagement. The Gemmill provides 22 OIT-managed computers with a full range of office, design, and statistical-analysis software for students, faculty and staff, as well as several public

[2] For more information on the Gemmill Library, please see http://www.colorado.edu/libraries/libraries/engineering-math-physics-library

computers with more limited software. Printers and two scanners are available, as well as a large screen designed to facilitate group work. Seven study rooms are available for group study; four are reservable in advance and three are available for drop in use. A library instruction room, Math 150, can accommodate up to 20 people for libraries classes, group study and student events. This room, with its large presentation screen and modular furniture, is available for student group study whenever it is not in use for library instruction or by affiliate events (which could include events or tutoring sponsored by the computer science department). The Gemmill strives to develop spaces that are flexible and promote student learning; the upper floor featuring movable furniture is available for collaborative work and discussion, while the lower floor is a quiet area for individual study.

The libraries continue our efforts to provide access to important collections, particularly electronic collections and discovery platforms, as budgets remain tight. The Gemmill Library provides over 155,000 print monographs and 100,000 microform technical reports. Access to online materials includes bibliographic indexes, such as *Compendex* and *INSPEC* on the *Engineering Village* platform, as well as searchable full text providers, such as *IEEE Xplore* and *ACM Digital Library.* A comprehensive list of electronic tools and databases is available[3]. These journals, and engineering and computer science handbooks and manuals from many publishers, are available 24 hours per day from any location via proxy access. Book purchase requests can be submitted to any member of the Library staff, or by using an online form[4] . The vast majority of monograph suggestions are purchased. Moreover, the libraries use a patron driven acquisition model that allows us to provide access to a wide variety of e-books, and instantly purchase those that our campus community uses.

The Gemmill Library is committed to building an evidence-based, user-centered library. Various assessments gathered by the Library (including an international benchmark survey known as *LibQUAL+*) over the last 10-12 years have led to several completed and planned changes. *LibQUAL+* feedback, for example, was used to instigate and guide the redesign of the libraries web sites. It also led to the provision of a proxy service for off-campus access in addition to the VPN. Other assessment data has led to the Library reconfiguring its space to provide flexible study areas. As journals shift to electronic access and bound journals were moved to an off-campus space with 24-hour turnaround scanning, this opened space for student study. We turned to students to discover how best to shape this new space: nearly every year, the Gemmill Library works with an upper-division technical writing and design course project team to assess space use, user needs, and more. This feedback is quickly turned around and applied to the library's spaces. Recent changes have included adding wheels to existing furniture, providing more whiteboards, and adding chalkboard walls, for example. We gather and respond to feedback from students but also attend to the larger institutional context. The Head of the Engineering Library sits on the College's Undergraduate and Graduate Education Councils and uses information gathered from those councils to help guide library decision-making, as well. In short, this library is envisioned as one where students can access information, information professionals, faculty, productivity tools, and one another in one facility; a place where ABET criteria regarding engineering tools and lifelong learning skills can be pursued.

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[3] See http://libguides.colorado.edu/az.php?a=all

[4] Accessible at http://www.colorado.edu/libraries/services/suggest-library-purchase

F. Overall Comments on Facilities

All of the classrooms, offices, labs, equipment, and facilities that are housed within university buildings conform to standard fire, safety, building, and health codes.

The Environmental Health and Safety (EH&S) department at the University of Colorado at Boulder (http://www.colorado.edu/ehs) provides comprehensive environmental, health and safety services to minimize health and safety impacts to the campus and the greater Boulder community. EH&S accomplishes this through training, emergency planning, consultation and partnership with members of the campus community as well as with local, state and federal agencies. Environmental Health and Safety provides regular training programs for UCB faculty, staff and students. These classes are mandatory for those who handle, manage or come into contact with potentially hazardous materials. EH&S has a substance disposal service in which hazardous waste or expired chemicals are removed from laboratories and disposed of according to state and federal regulations, ensuring a safe laboratory environment.

Facilities Management at the University of Colorado at Boulder (http://www.colorado.edu/facilitiesmanagement/) further ensures a safe working environment. The Mission of Facilities Management is "To plan for and provide a physical and operational environment that supports the University of Colorado at Boulder's mission of education, research and outreach." One of the core values of Facilities Management is "A safe environment" and Facilities Management supports this value by providing waste removal, custodial services, pest management, recycling, the fire alarm and fire sprinkler systems, landscaping, snow removal, and safe steam and electricity generation. All of these support services contribute to the overall safety of students in the program.

The Engineering Center is generally open Monday-Thursday from 7 a.m. to 1 a.m., Friday from 7 a.m. to 10 p.m. and Saturday and Sunday 8 a.m. to 10 p.m. The Discovery Learning Center (DLC) is open Monday-Friday from 7 a.m. to 7 p.m.; and the Integrated Teaching and Learning Lab (ITLL) is open Monday-Thursday 8 a.m. to 11 p.m., Friday 8 a.m. to 5 p.m., and Sunday 1 p.m. to 11 p.m.

CRITERION 8. INSTITUTIONAL SUPPORT

1. Leadership

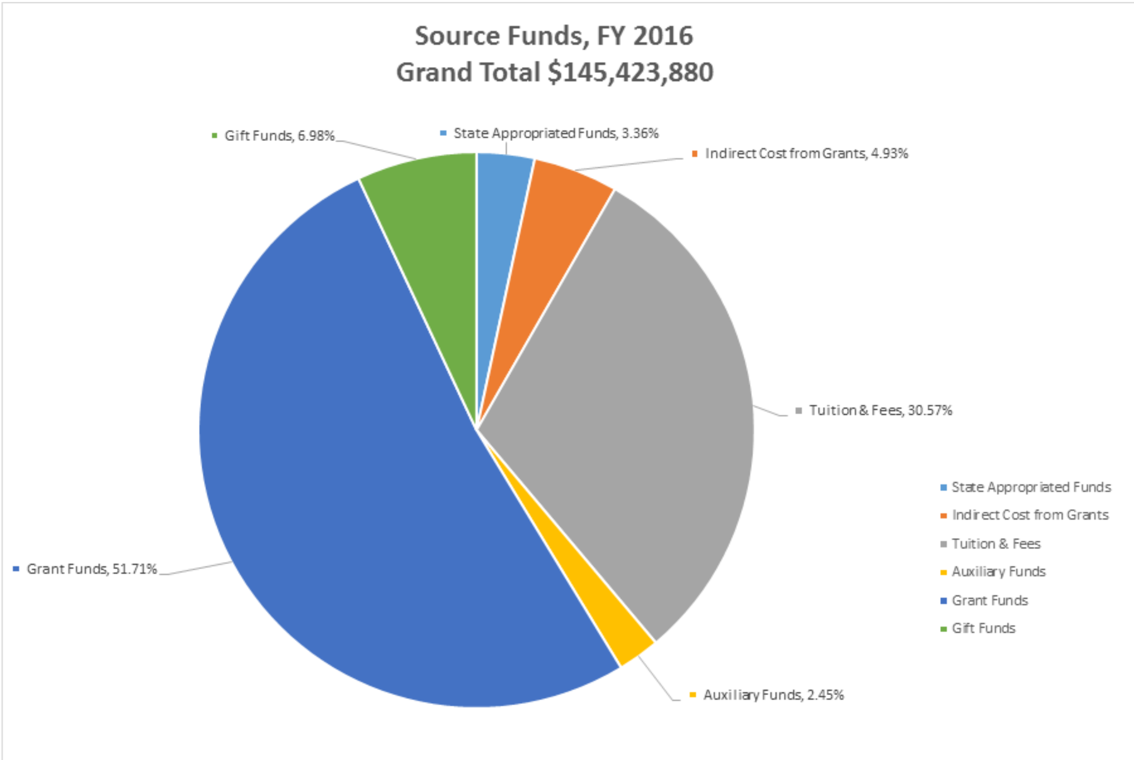
The CEAE department is the sole home for the architectural engineering Bachelor's degree; it also is the sole home of the civil engineering Bachelor's degree and supports the environmental engineering degree (which is a college-wide program with various affiliated faculty that is administratively supported by CEAE). Faculty members in the CEAE department are represented in six traditional civil/architectural engineering groups for administrative purposes:

- building systems (devoted to architectural engineering)
- construction engineering & management (with equal commitment to civil and architectural engineering),
- environmental (with commitment to civil and environmental engineering),
- geotechnical (fully devoted to civil engineering),
- structural engineering & mechanics (with equal commitment to civil and architectural engineering),
- water resources (committed to civil engineering, and some support environmental engineering)

The CEAE department has a democratic governance structure with collaborative planning and decision-making. The Department chair is elected by the faculty, with final appointment by the Dean; until now the Dean has not gone against the wishes of the faculty. The department chair is the chief administrative officer. The CEAE Department is led by the Chair and the Executive Committee. Professor Keith Molenaar was elected in 2010 and served one 4-year term until 2014. Professor Balaji Rajagopalan was elected in 2014 and is still serving. Faculty members in the CEAE department are represented in six traditional civil/architectural engineering groups for administrative purposes: building systems, construction engineering & management, environmental, geotechnical, structural engineering & mechanics, and water resources. The sub-group nominates a member for the executive committee, who is then approved (or not) by a vote of the entire CEAE faculty for a three-year term. CEAE faculty are also assigned to standing committees which are considered sub-committees of the Executive Committee: Curriculum (chaired by the Associate Chair for Undergraduate Education), Graduate (chaired by the Associate Chair for Graduate Education), Facilities, Personnel (Promotion) and Operations. Ad hoc committees can be formed by the faculty to serve special purposes. Current ad hoc committees include Awards, Mentoring, Research, and Computing. Rostered instructors and research professors are voting members of the faculty and serve on the standing committees of the department, including the Executive Committee. The faculty governance structure is one of the strengths of the department. The representative structure of each sub-discipline area on the executive committee ensures that all faculty have a voice in the direction of the program. The leadership structure is adequate to ensure the direction, continuity, and quality of the architectural engineering program.

2. Program Budget and Financial Support

The expenditures by the College of Engineering and Applied Science for FY16 were $145.4 M from the following sources:

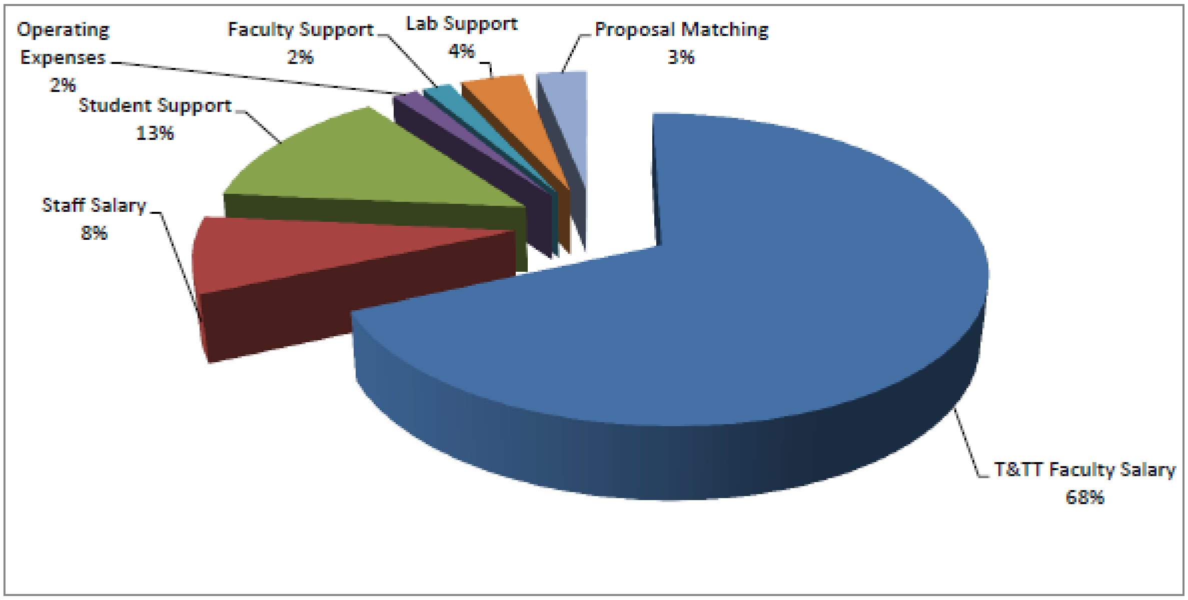


The College distributes the general fund budget (monies from tuition and fees, state funds, and indirect costs from grants) to the departments and programs in specific categories (ex., faculty salaries, staff salaries, TA stipends, operating funds) using well-defined formulas, established by the dean with advice from and discussion with the department chairs. These formulas are based on input data such as enrollments, student credit hours, and research expenditures.

The Department receives its budget from the College of Engineering and Applied Science through (1) allocation of faculty positions, (2) funds to cover staff and teaching assistant salaries and operating expenses, and (3) recovery of indirect costs from grants and contracts. In addition, the Department has several gift endowments totaling approximately $2.5 million, which generate about $100,000 per year in income for support of educational equipment and student activities. The staff, teaching assistant, and operating budgets are determined based primarily on student credit hour (SCH) generation, the number of undergraduate and graduate students in the Department's programs, and the number of faculty in the Department. Funds for additional teaching support are added when the SCH generation per faculty member exceeds the College average. The CEAE department chair and staff, with inputs from the Executive Committee, creates budget based upon teaching, research, and administrative needs. The budget is presented to the Executive Committee for approval each fall with updates throughout the year as necessary.

A portion (approximately 15%, plus 8% embedded in staff salaries) of the indirect costs recovery (ICR) from faculty's sponsored research activities is returned to the Department to augment its operating budget. In addition, the endowments to the Department also produce an income stream that is used for purposes specified in the original donations, such as acquisition of instructional equipment, funding of student scholarships, and funding of named lecture series.

Breakdown of the Department expenditures for FY2016 were $6.9 M from the sources shown below.



Funding of senior instructors and lecturers has increased 68% from $313,142 in 2010 to $524,434 in 2016. Although resources have been strained largely due to increasing student enrollment in our courses, they continue to be sufficient to enable us to meet our student outcome goals.

3. *Staffing*

The CEAE department has an excellent staff to support the architectural engineering program, consisting of an administrative manager, an undergraduate advisor/program coordinator for Architectural Engineering, a graduate program coordinator, an office receptionist/program assistant, one accounting professional, an accounting technician and a web design specialist; a part-time communications specialist also serves the program. As well, the undergraduate advisors/program coordinators for Civil Engineering can fill-in when the Architectural Engineering advisor is absent. Part-time student assistants are hired on an as-needed basis to assist with special activities demanding more staff time.

The Department has a contract with the University's Office of Information Technology (OIT) to provide desktop support to faculty and staff, and to its Bechtel Lab Computer Lab. This OIT contract is equivalent to approximately a half-time position. The Department supports the Laboratory positions through its operating budget. The OIT contract is supported through program fees.

The staff budget allocation from the College has increased by 94% ($268,872 in 2010 to $ 522,329 in 2017), as a reflection of the overall growth in research expenditures and student enrollment. The Department hopes to add staff in coming years to accommodate growth in student enrollment.

The Department participates in the College's Staff Excellence Program. This program funds - (i) opportunities for staff training and professional development, (ii) performance-recognition awards, (iii) a peer-mentoring program, and (iv) engagement in social events and college activities. The Department financially supplements the College's program to assist in professional development for the staff. Professional development and training strengthens staff members' capabilities to take on additional responsibilities, (e.g. the latest upgrade of the Human Resources and Financial Systems, CU Marketplace, CU-SIS student information system, and the new graduate application system). Staff are also given the opportunity to enroll in job-related or career enhancing classes on campus, taking advantage of the tuition benefit of 9 credit hours per academic year. Staff arrange work time, if necessary, with their supervisor, to take these classes.

4. *Retention*

The Dean, with advice from and discussion with the department chairs, assigns new and replacement (losses due to retirements, resignations, etc.) faculty lines to departments. Each department is required to produce a recruiting plan for each faculty line for which the department will be searching. The department is responsible for advertising for the position, forming the search committee, selecting candidates for interviews, etc. In some cases, the search will be for an interdisciplinary faculty member. In those cases, the search committee will have members from several departments. Detailed information about the procedures for faculty hiring are found at http://www.colorado.edu/engineering-facultystaff/hiring.
When the department has selected its preferred faculty hire, the Dean must then approve the individual. Note that if a faculty is being hired with tenure, the individual must be reviewed through the entire standard tenure process (review by primary unit, first level review, Dean, Vice Chancellor's Advisory Committee, and eventually approved by the Regents).

To retain current qualified faculty, the University benchmarks its salary and benefits against peer institutions. Per the availability of the raise pool determined for the campus each year, raises are awarded based on merit, as established by annual ratings in research, service, and teaching. The CEAE Department, in coordination with the College and University, can also offer a retention package if a faculty member has a competing offer from another university. Retention packages vary, but typically include salary increases, student support, lab space or other items to entice the faculty to stay. Raises can also be awarded if a faculty member demonstrates that their salary lags behind peers in CEAE with similar merit ratings.

5. *Support of Faculty Professional Development*

The University offers excellent opportunities to grow one's teaching abilities through the Faculty Teaching Excellence Program (FTEP; http://www.colorado.edu/ftep/). FTEP has two programs targeted specifically at helping new tenure-track faculty: the New Assistant Professor Program and the Early Career Faculty Program: Faculty Learning Communities. FTEP offers a variety of workshops and seminar events open to any faculty member each semester. They also offer one-on-one consultations such as classroom learning interviews, videotape consultation, and teaching portfolio consultations. FTEP coordinates the President's Teaching Scholars Program to promote the scholarship of teaching and learning; CEAE participants have included Matt Hallowell (2013) and Lupita Montoya (2011). FTEP coordinates the President's Teaching Scholars Program (PTSP), of which two CEAE faculty are members (Roseanna Neupauer and Hari Rajaram).

The College supports the professional development of faculty through the Faculty Excellence Program (see http://www.colorado.edu/engineering-facultystaff/awards-incentives/college-awards/faculty-excellence-program), which provides a number of financial support opportunities. This program includes:

- Dean's Faculty Fellowships - Selected faculty members are given one semester off from teaching a course, to focus on a major initiative in research and scholarly work or development of substantial educational materials or initiatives
- Dean's Seed Funds for Novel Ideas - Discretionary funds up to $10,000 provide seed support for new ideas, and are matched 1:1 by the department or program
- Dean's Performance Awards - $5,000 awards are given for top performance in categories such as research, teaching, professional progress, and overall performance of junior faculty, based on the annual performance evaluations for the prior calendar year
- Matching funds for research grants, laboratory renovation funds, and travel to funding agencies are supported
- Sabbatical Supplement Program - This program offers an additional 20% of the academic-year salary to faculty members taking full-year sabbaticals, on top of the normal 50% of the academic-year salary that they receive on sabbatical. The department then retains the remaining 30% of the academic-year salary, and the faculty member is responsible for raising (or foregoing) 30% of her or his salary. In addition, the Dean will provide $4000 in discretionary funds for research, travel, etc. to each faculty member who successfully applies for this program. http://www.colorado.edu/engineering-facultystaff/sabbatical-supplement-program

The Department encourages professional development through the attendance of conference and workshops. Data are collected on faculty attendance of these events through the annual reporting and evaluation process. If faculty members are not participating in these events, it is noted by the chair. New faculty members have significant start-up packages with moneys designated for travel and professional development. Senior faculty members typically raise their own funds for travel to these events, but they can also make request of the Department or College on a case-by-case basis. For example, the department paid for the ABET assessment coordinator to attend the Spring ABET symposium. All faculty members are encouraged to use the significant on-campus resources for professional development as well.

PROGRAM CRITERIA

The program criteria for architectural engineering programs include requirements for both curriculum and faculty. Each of these requirements and how the CU Architectural Engineering program fulfills the requirement are explained below.

1.1 The curriculum must demonstrate that graduates can apply mathematics through differential equations, calculus-based physics, and chemistry.

All Architectural Engineering students in the BS program take 32 credits of math and basic sciences, including three semesters (12 credits) of calculus, one semester of differential equations and linear algebra (4 credits), two semesters of calculus-based physics (8 credits), and one semester of basic chemistry with a laboratory (5 credits). [These courses are shown on the block diagram in section 5.A and associated Table 5-1.]

Performance in subsequent engineering courses both depends on and reinforces students' basic knowledge in mathematics, physics, and chemistry. Calculus and differential equations (APPM 1350, 1360, 2350, 2360) and Physics 1 (PHYS 1110) are prerequisites for the fundamental engineering science courses (thermodynamics, analytical mechanics 1, fluid mechanics & heat transfer). These courses are in turn pre-requisites for the various AREN fundamentals courses, which in turn are pre-requisites for proficiency courses and AREN/CVEN technical elective courses.

Measures of students' attainment of proficiency in math and basic science depends on internal measures such as student work in architectural engineering courses requiring application of these fundamentals, and on external measures such as the Fundamentals of Engineering (FE) Examination. As described above in section 4B for student outcome 1, our direct and indirect evidence indicates adequate student fulfillment of this outcome.

1.2 The four basic architectural engineering curriculum areas are building structures, building mechanical systems, building electrical systems, and construction/construction management. Graduates are expected to reach the synthesis (Design) level in one of these areas…

All AREN students select one concentration area from among these four AREN areas; students take two three-credit proficiency course focused on design, two three-credit concentration courses that may be design or technical in nature. Technical-elective-related courses provide depth within each of the four basic AREN curriculum areas.

1.3 …the application level in a second area…

The current curriculum requires all AREN students to select two AREN areas from which to take a proficiency course. The proficiency level courses map to the application level. One proficiency area is built on as the concentration area (described above).

1.4 …and the comprehension level in the remaining two areas.

There are five fundamental courses that all AREN students are required to take that cover all four areas of AREN as shown below:

Area	**Fundamental Courses (comprehension)**
Building structures	CVEN 3525-3 Structural Analysis
Building mechanical systems	AREN 3010-3 Mechanical Systems
Building electrical systems	ECEN 3030-3 Electrical Circuits AREN 3540-3 Illumination 1
Construction/construction management	CVEN 3246-3 Introduction to Construction

1.5 The engineering topics required by the general criteria shall support the engineering fundamentals of each of these four areas at the specified level.

The five fundamental courses are supported by the following required general engineering topics:

Engineering Fundamentals	**Pre-Requisite General Engineering Courses**
CVEN 3525-3 Structural Analysis	CVEN 3161-3 Mechanics of Materials I
AREN 3010-3 Mechanical Systems	AREN 2110-3 Thermodynamics, AREN 2120-3 Fluid Mechanics & Heat Transfer, AREN 2050-Engineering Systems for Buildings
ECEN 3030-3 Electrical Circuits	APPM 2360-3 Intro Differential Equations
AREN 3540-3 Illumination 1	APPM 2350-3 Calculus III for Engineers, COEN 1300-4 Intro to Engineering Computing
CVEN 3246-3 Introduction to Construction	Restricted to students with 57-180 credits (Junior or Senior)

1.6 Graduates are expected to discuss the basic concepts of architecture in a context of architectural design and history.

All AREN students are required to take 2 courses (6 credits) of the history and theory of architecture (ENVD 3114 and 3134). In addition, they must take ARCH 4010 Architectural Design, a 5-credit course on architectural design that precedes and feeds into the AREN 4317 capstone design course. Syllabi for these courses are found in Appendix E.

1.7 The design level must be in a context that:

a. Considers the systems or processes from other architectural engineering curricular areas

The AREN4317 senior capstone is a project-based course aimed at having students synthesize and apply the knowledge acquired in previous courses. Only students in their fourth year may take this course and they must have taken the fundamentals or architectural engineering as pre-requisites:

- AREN 3010: Mechanical Systems for Buildings
- ECEN 3030: Electrical Circuits
- AREN 3246: Introduction to Construction
- CVEN 3525: Structural Analysis
- AREN 3540: Illumination I
- ARCH 4010: Architecture Appreciation and Design
-

Students must petition entrance to the course if they don't meet a requirement.

In addition, since students are divided in teams whereby each discipline is represented. Students hoping to lead their own discipline should meet their respective proficiency course, that is:

- CVEN 3256 Construction Equipment & Methods
- AREN 4550 Illumination 2 or AREN 4570 Electrical Systems
- AREN 4110 HVAC Design
- CVEN 4545 Steel Design or 4555 Reinforced Concrete

Students may need to be paired in a group with another person of the same discipline if deficiencies are encountered. Students may also volunteer to do a different discipline. An example of this is with the HVAC discipline. In the last few years, there have not been enough HVAC students in the class and in order to form a complete group (with all four disciplines) students choose to work on HVAC.

b. Works within the overall architectural design,

The AREN curriculum is designed so that all students take a 10-credit design experience in their senior year. Five of those credits are spent in Environmental Design where students learn architectural principles and design. Students also design a building (typically 15,000 to 30,000 ft. sq. commercial building) which they will bring to the engineering design class. It is to these buildings that students apply architectural engineering processes and systems.

c. Includes communication and collaboration with other design or construction team members

Students work in teams for the duration of the course. The teams are multidisciplinary as all four architectural engineering tracks are represented. Collaboration within the teams is not only encouraged but necessary in particular during the schematic and design development phases as students need to coordinate with each other to ensure a cohesive design and one that meets specific constraints like LEED, codes, budgets, and equipment placement. Lectures, workshops, and assignments related to LEED, value engineering and clash detection help ensure communication and collaboration between team members.

d. Includes computer-based technology and considers applicable codes and standards

   Starting with the programming phase, students begin their re-acquaintance with the codes and standards that govern their buildings. Specific discipline lectures by industry professionals kick off this process. In the conceptual phase, students explore and synthesize in their reports the codes and standards that apply to their respective disciplines. In the schematic students are asked to provide some kind of corroboration that they are meeting the most relevant codes and standards. By the design developing phase, students use software to perform calculations to demonstrate compliance.

e. Considers fundamental attributes of building performance and sustainability

   Students receive specific assignments per discipline that helps them develop, from the ground up, systems that will be functional and sustainable. Students are required to show, not only that their buildings meet codes and standards, but that these also comply with minimum standards of care, function, and comfort. Lectures on these topics are provided by industry professionals. In addition, students are assigned professional mentors who review their work, provide feedback and share with them current techniques and practices related to building performance and sustainability.

2.1 Faculty Qualifications to Teach Design

"The program shall demonstrate that those faculty members teaching courses that are primarily design in content are qualified to teach the subject matter by virtue of education and experience or professional licensure." (ABET, EAC, 2017-2018… p. 9-10)

For the capstone design course in AREN, a team of 4 faculty routinely teach the course. For the last 9 years, the course has been coordinated and led by Sandra Vásconez who is a Senior Instructor in the Department. While she is not a licensed Professional Engineer or Registered Architect, she has extensive experience with lighting design since 1998. As manager of program development at the Lighting Research Center at Rensselaer Polytechnic Institute, she was heavily involved in research, testing, and design projects with the lighting industry. She was the manager of the DELTA (Demonstration and Evaluation of Lighting Technologies and Applications) Program. As such, she published 8 lighting studies demonstrating best-practices and lessons learn in lighting design. From 2004-2007, she worked on design and installation of museum exhibits at a lighting design firm in Boulder, CO. She continued to freelance in this area until 2010. Other instructors vary somewhat each term. Each term the course includes a minimum of 1 instructor who is a licensed PE. Instructors are summarized below:

AREN 4317 Instructors

Term	Instructor Team
Fall 2012	Molenaar (CEM), Brandemuehl (HVAC PE), Krarti (electrical PE) Vásconez (lighting), Xi (structures)
Fall 2013	Kaminsky (CEM), Zhai (HVAC), Krarti (electrical PE) Vásconez (lighting), Xi (structures)
Fall 2014	Molenaar (CEM), Henze (HVAC PE), Beamer (electrical) Vásconez (lighting), Xi (structures)
Fall 2015	Arneson (CEM), Zhai (HVAC), Krarti (electrical PE) Vásconez (lighting), Xi (structures)
Spring 2016	Albattah (CEM), Currie (HVAC), Krarti (electrical PE) Vásconez (lighting), Xi (structures)
Spring 2017	Arneson (CEM), Currie (HVAC), Jadaan (structures) Krarti (electrical PE) Vásconez (lighting)

For the instructors who are not PEs (as noted in the table above), design experience is summarized below with more detail provided in the individual resumes in Appendix B (full-time faculty). CVs for Ph.D students are provided in the supplemental materials available during the site visit.

Mohammed Albattah, Ph.D. Student – graduated in 2016

Experience in construction management in Saudi Arabia (AlSuwaidi Industrial Services Co. LTD) and the United States (HOAR Construction). Responsible for project site visits to check accuracy of drawings and equipment accessibility, pricing of construction change orders and to develop competitive bids for new projects and coordinate sub-contractors.

Erin Arneson, Ph.D. Student – present

Worked as an architect and construction project manager for over 7 years at an international design firm in Seattle, WA. Specifically, worked on commercial retail projects, both renovation and new shell construction. Coordinated projects during: early contract phase (negotiating and reviewing tenant leases for clients); construction documents (conceptual drawings thru permit drawings); project bid and schedule reviews; project financials (RFIs, change orders, submittals, billings); on-site management; and Closeout.

Walter Beamer, Ph.D., CEAE Senior Instructor

Spent 6 years in the architectural lighting design field working for Robert Singer Lighting Associates (Aspen, CO) and Light'n Up (Washington, DC). Lighting projects ranged from small homes to high-end multimillion dollar homes all over the country, he also worked with museum projects, and memorials in Washington, DC. Dr. Beamer spent 6 years in the architectural acoustics industry as an acoustics consultant with Kirkegaard Associates (Boulder, CO) and then Shen Milsom & Wilke (Denver, CO). His acoustics projects ranged in scale from single family homes to sky scrapers, churches to performing arts complexes, high-end hotels to college campuses, and his work took him to the Middle East and Asia.

Samuel Currie, Ph.D. Student - present

Extensive experience using energy modeling to inform design decisions, including in the design of a net-zero energy laboratory for Purdue University's biology department and a building integrated photovoltaic/thermal collector as part of ongoing research at Purdue University. Additionally, Mr. Currie has designed and built several software applications to aid architects and engineers in the design of Title 24, Part 6 compliant buildings and performed consulting work for the California Energy Commission and investor owned utility companies in California on implementation aspects of the energy code.

Dhafer Jadaan, Ph.D. Student - present

Structural designer at the Reconstruction Department, University of Anbar 2006- 2014. Consultant engineer at the Provincial Reconstruction Team-American Army- Iraq: June 2013-Dec 2013.

Jessica Kamisnky, Ph.D. Student - graduated in 2013

Six years working for CH2M HILL as a staff engineer. Performed traffic analyses, travel demand modelling, preliminary pipeline design, and some preliminary wastewater treatment plant design. Significant hydraulic pipeline work (building computerized network models for a major urban utility)

Keith Molenaar, Ph.D., CEAE Professor

Practitioner and researcher in engineering design and construction. Designated Design-Build Professional from the Design-Build Institute of America (DBIA) and serves as the Chair of the national DBIA Design-Build Certification Board. Worked on design and in design support services for Architectural Research Consultants. Work examples: Denver Performing Arts Center Renovation, Sunspot Lodge and Lutheran Medical Center Emergency Room and Surgery Center Expansion. Has worked on 48 funded research projects, many of which support design and involve the design of experiments. Keeps an active consulting practice. Works on preconstruction services and design for major infrastructure and science projects including the Panama Canal Expansion, the San Francisco-Oakland Bay Bridge, the ITER Fusion Generator and the Long Baseline Neutrino facility.

Yunping Xi, Ph.D., CEAE Professor

Worked as structural engineer at Beijing Central Research Inst. of Building and Construction and Beijing Design Institute of Building and Construction. In these institutions participated in many projects designing high-rise apartment buildings, a middle school, a movie theater, and rehabilitation projects for steel mills. Conducts research and evaluation projects related to highway bridges, DIA radar control building, and containment structures of nuclear power plants.

John Zhai, Ph.D., CEAE Professor

Combined degree in Mechanical Engineering and Architecture with both research and practice interest and experience in sustainable building design. Leads the evaluation and development of a few building systems and associated code developments sponsored by ASHRAE (such as for active chilled beam system, hospital and data center ventilation systems etc.). Serves as full-time senior fellow and project manager for RMI, participating/leading over 10 design and retrofit projects in 2011. Recently, has served as green building consultant for several major projects in China, such as the 452m tall Suzhou International Finance Square project, designed by KPF.

The instructors for other proficiency and concentration courses in the curriculum with large design elements are shown below.

Proficiency:

Course	AREN 4110 HVAC Design	AREN 4550 Illumination II	AREN 4570 Electrical Systems for Buildings	CVEN 3256 Constr Equip & Methods	CVEN 4545 Steel Design	CVEN 4555 Reinforced Concrete Design
Instructor	Brandemuehl (PE) Henze (PE) Zhai	Vasconez	Krarti (PE) Billington (PE)	Goodrum (PE) Hallowell Novak	Hearn (PE)	Hearn (PE) Nguyen

Concentration:

Course	AREN 4550 Illumination II	AREN 4570 Electrical Systems for Buildings	AREN 4570 Luminous Transfer	AREN 4830 Computer Simulation of Building System	AREN 4890 Sustainable Building Design	CVEN 4545 Steel Design	CVEN 4555 Reinforced Concrete Design
Instructor	Vasconez	Krarti (PE) Billington (PE)	Jongewaard	Krarti (PE)	Henze (PE)	Hearn (PE)	Hearn (PE) Nguyen

A brief summary of the design experience for individuals without a PE license who have not been described already above is provided here.

Matthew Hallowell, PhD

President and lead engineer at Modular Design solutions in Corvalis, OR; Structural engineer at Penn Lyon Homes in Selinsgrove, PA; Project engineer at Pine Tree Engineering in Bath, ME (highway design)

Lan Nguyen, PhD

Earned her PhD in structural engineering from CU in 2014. Worked as a structural engineer at Aero Solutions LLC from 2011-2013, including designing tower structural elements such as foundations and upgrades for stability. As a graduate research assistant she design reinforced concrete frames and masonry shear wall panels. She served as an Adjunct

Instructor for the Reinforced Concrete Design class in fall 2014. She has since earned her P.E. license

Ryan Novak, MS

Project manager for Erdman and project industrial manager for UOP within a design-build delivery system (oversaw the design, fabrication, and installation of variety of mechanical product lines)

Mark Jongewaard, MS

Extensive experience in lighting software development, lighting and optical analysis, illumination optical design and training. Broad experience in lighting analysis and algorithm development influenced the calculation modules in all of LTI's products including Photopia, Lumen-Micro and Lumen Designer. Works on optical design projects and is a training seminar instructor. Maintains close personal relationships with the R&D departments of lighting manufacturers around the world. Responsible for 10 patents from various optical design projects.

2.2 It must demonstrate that the majority of the faculty members teaching architectural design courses are qualified to teach the subject matter by virtue of professional licensure, or by education and design experience.

The ARCH 4010 Architectural Design course is taught by faculty from the College of Architecture and Planning, which has ample experience with design and teaching. The CVs for these instructors will be provided in the supplemental materials available during the site visit.

Year	Instructors
Fall 2012	Amir Alrubaiy – Master of Architecture, Master of Landscape Architecture Don Russell – Licensed Architect
Fall 2013	Justin Bellucci – BA Environmental Design, MS Civil Engineering Marcus Farr, Master of Architecture, LEEP AP
Fall 2014	Shawhin Roudhari, P.E., LEED AP Justin Bellucci – BA Environmental Design, MS Civil Engineering Kevin Kemp, Licensed Architect
Fall 2015	Shawhin Roudhari, P.E., LEED AP Justin Bellucci – BA Environmental Design, MS Civil Engineering
Fall 2016	Shawhin Roudhari, P.E., LEED AP Justin Bellucci – BA Environmental Design, MS Civil Engineering

Shawhin Roudhari = 2006 PE California; 200 LEED Accredited Professional

APPENDICES

Appendix A – Course Syllabi

Course descriptions are provided for each of the following courses in the AREN program. Each course could be required for graduation, depending on the track pursued within the program.

APPM 1350 Calculus 1 for Engineers
APPM 1360 Calculus 2 for Engineers
APPM 2350 Calculus 3 for Engineers
APPM 2360 Introduction to Differential Equations with Linear Algebra
ARCH 4010 Architectural Design
AREN 1027 Engineering Drawing
AREN 1316 Introduction to Architectural Engineering
AREN 2050 Building Materials and Systems
AREN 2110 Thermodynamics
AREN 2120 Fluid Mechanics and Heat Transfer
AREN 3010 Mechanical Systems for Buildings
AREN 3540 Illumination 1
AREN 4110 HVAC Design 1
AREN 4317 Architectural Engineering Design
AREN 4506 Project Management 1
AREN 4550 Illumination 2
AREN 4560 Luminous Radiative Transfer
AREN 4570 Building Electrical Systems Design 1
AREN 4606 Project Management 2
AREN 4830 Computer Simulation of Building Systems
AREN 4890 Sustainable Building Design
CHEM 1211 General Chemistry for Engineers
CHEM 1221 Engineering General Chemistry Lab
CHEN 1310 Introduction of Engineering Computing
CVEN 2012 Introduction to Geomatics
CVEN 2121 Analytical Mechanics 1
CVEN 3161 Mechanics of Materials 1
CVEN 3246 Introduction to Construction
CVEN 3256 Construction Equipment and Methods
CVEN 3525 Structural Analysis
CVEN 4161 Mechanics of Materials 2
CVEN 4545 Steel Design
CVEN 4555 Reinforced Concrete Design
ECEN 3030 Electrical/Electronic Circuits for Non-Majors
ENVD 3114 History and Theory of Environmental Design: Buildings
ENVD 3134 History and Theory of Environmental Design: Precincts
GEEN 1400 Engineering Projects
PHYS 1110 General Physics 1
PHYS 1120 General Physics 2
WRTG 3030 Writing on Science and Society

APPM 1350 - Calculus 1 for Engineers

Course Syllabus

1. **Course number and name**
   APPM 1350 - Calculus 1 for Engineers
2. **Credits and contact hours**
   4 credit hours/4 contact hours
3. **Instructor's or course coordinator's name**
   Coordinator: Anne Dougherty
4. **Textbook, title, author, and year**
   Essential Calculus 2nd edition, James Stewart, 2013
   a. **other supplemental materials**
      WebAssign online homework system (requires subscription)
5. **Specific course information**
   a. **brief description of the content of the course (catalog description)**
      Topics in analytical geometry and calculus including limits, rates of change of functions, derivatives and integrals of algebraic and transcendental functions, and applications of differentiation and integration. Students with credit in APPM 1350 may not receive credit for MATH 1080, 1081, 1090, 1100, 1300, 1310, or ECON 1088
   b. **prerequisites or co-requisites**
      Requires prerequisite course of APPM 1235 or MATH 1021 or MATH 1150 or an ALEKS math score or 76% or greater.
   c. **indicate whether a required, elective, or selected elective (as per Table 5-1) course in the program.**
      required
6. **Specific goals for the course**
   a. **specific outcomes of instruction, ex. The student will be able to explain the significance of current research about a particular topic.**
      (1) Understand the concepts, techniques and applications of differential and integral calculus, and (2) improve problem solving and critical thinking.
   b. explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course.
7. **Brief list of topics to be covered**
   Limit of a Function; Continuity; Derivatives and Rates of Change; Basic Differentiation Formulas; Chain Rule; Implicit Differentiation; Related Rates; Linear Approximations and Differentials; Maximum and Minimum Values; Mean Value Theorem; Curve Sketching; Optimization Problems; Newton's Method; Antiderivatives; Areas and Distances; Definite Integral; Fundamental Theorem of Calculus; Substitution Rule; Inverse Functions; Natural Logarithmic Function; Exponential Functions; Exponential Growth and Decay; Inverse Trigonometric Functions; Hyperbolic Functions; Indeterminate Forms and l'Hospital's Rule

APPM 1360 - Calculus II for Engineers

Course Syllabus

1. **Course number and name**
   APPM 1360 - Calculus II for Engineers
2. **Credits and contact hours**
   4 credit hours/4 contact hours
3. **Instructor's or course coordinator's name**
   Coordinator: Brian Zaharatos
4. **Textbook, title, author, and year**
   Essential Calculus 2nd edition, James Stewart, 2013
   a. **other supplemental materials**
      WebAssign online homework system (requires subscription)
5. **Specific course information**
   a. **brief description of the content of the course (catalog description)**
      Continuation of APPM 1350. Focuses on applications of the definite integral, methods of integration, improper integrals, Taylor's theorem, and infinite series. Credit not granted for this course and MATH 2300.
   b. **prerequisites or co-requisites**.
      Requires prerequisite course of APPM 1345 or APPM 1350 or MATH 1300 (minimum grade C-)
   c. **indicate whether a required, elective, or selected elective (as per Table 5-1) course in the program.**
      required
6. **Specific goals for the course**
   a. **specific outcomes of instruction, ex. The student will be able to explain the significance of current research about a particular topic.**
      1) Understand the concepts, techniques, and applications of differential and integral calculus, (2) to understand sequences and series, and (3) to improve problem solving and critical thinking
   b. explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course.
7. **Brief list of topics to be covered**
   Integration by Parts; Trigonometric Integrals and Substitutions; Partial Fractions; Improper Integrals; Areas between Curves; Volumes; Volumes by Cylindrical Shells; Arc Length; Applications of Integration to Physics and Engineering; Differential Equations; Sequences; Series; The Integral and Comparison Tests; Other Convergence Tests; Power Series; Representing Functions as Power Series; Taylor and Maclaurin Series; Parametric Curves; Calculus with Parametric Curves; Polar Coordinates; Areas and Lengths in Polar Coordinates.

APPM 2350. Calculus 3 for Engineers

Course Syllabus

1. **Course number and name:**
   APPM 2350. Calculus 3 for Engineers
2. **Credits and contact hours**
   Total Credits: 4 *Lecture 50-minutes 3x/week; Recitation 50 min 1x/wk*
3. **Instructor's or course coordinator's name**
   Adam Norris, course coordinator
4. **Text book, title, author, and year**
   Essential Calculus, Second Edition (w/Enhanced WebAssign). James Stewart, ISBN 9781133425823
   a. **other supplemental materials**
      - WebAssign. https://www.webassign.net/colorado/login.html
      - Desire2Learn (D2L) https://learn.colorado.edu/
5. **Specific course information**
   a. **brief description of the content of the course (catalog description)**
      Covers multivariable calculus, vector analysis, and theorems of Gauss, Green, and Stokes. Credit not granted for this course and MATH 2400..
   b. **prerequisites or co-requisites**
      APPM 1360 or MATH 2300
   c. **indicate whether a required, elective, or selected elective (as per Table 5-1) course in the program.**
6. **Specific goals for the course**
   a. **Specific outcomes of instruction. ex: the student will be able to explain the significance of current research about a particular topic.**
      This course extends the ideas of single-variable calculus (e.g. differentiation, integration, optimization) to functions of several variables.
   b. **explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course.**
7. **Brief list of topics to be covered**
   Vectors in the Plane; Cartesian (Rectangular) Coordinates and Vectors in Space; Dot Products; Cross Products; Lines and Planes in Space; Cylinders and Quadric Surfaces; Vector-Valued Functions and Space Curves; Arc Length and the Unit Tangent Vector T; Curvature, Torsion, and the TNB Frame; Functions of Several Variables; Limits and Continuity; Partial Derivatives; Differentiability, Linearization, and Differentials; The Chain Rule; Directional Derivatives, Gradient Vectors, and Tangent Planes; Extreme Values and Saddle Points; Lagrange Multipliers; Taylor's Formula; Double Integrals; Areas, Moments, and Centers of Mass; Double Integrals in Polar Form; Triple Integrals in Rectangular Coordinates; Cylindrical and Spherical Coordinates; Triple Integrals in Cylindrical and Spherical Coordinates; Substitutions in Multiple Integrals; Line Integrals; Vector Fields, Work, Circulation, and Flux; Path Independence, Potential Functions, and Conservative Fields; Green's Theorem in the Plane; Surface Area and Surface Integrals; Stoke's Theorem; The Divergence Theorem and a Unified Theory.

APPM 2360. Differential Equations with Linear Algebra

Course Syllabus

1. **Course number and name**
   APPM 2360. Differential Equations with Linear Algebra
2. **Credits and contact hours**
   Total Credits: 4 *Lecture 50-minutes 3x/week; Recitation 50 min 1x/wk*
3. **Instructor's or course coordinator's name**
   Nicholas Featherstone. James Meiss, Congming, Li, and Stephen Beckeer
4. **Text book, title, author, and year**
   Differential Equations and Linear Algebra, by Farlow, Hall, McDill, & West, 2nd edition.
   a. **other supplemental materials**
      1. https://www.colorado.edu/amath/course-pages/fall-2016/appm2360 for general info, homework assignments, past exams, tutoring options, pre-exam review sessions, exam rooms and times, and office hours.
5. Desire2Learn (D2L) https://learn.colorado.edu for grades, homework solutions, and submitting projects
   Specific course information
   a. **brief description of the content of the course (catalog description)**
      Introduces ordinary differential equations, systems of linear equations, matrices, determinants, vector spaces, linear transformations, and systems of linear differential equations. Credit not granted for this course and both MATH 3130 and 4430.
   b. **prerequisites or co-requisites**
      APPM 1360 or MATH 2300
   c. **indicate whether a required, elective, or selected elective (as per Table 5-1) course in the program.**
6. **Specific goals for the course**
   a. **Specific outcomes of instruction. ex: the student will be able to explain the significance of current research about a particular topic.**
      Explain the importance of ordinary differential equations in science and engineering, identify appropriate analysis methods, and develop mathematical thinking with the exposure to abstract vector spaces. Categorize types of differential equations (ordinary/partial, linear/nonlinear, separable). Qualitative methods: construct and interpret direction fields and phase planes. Analytic methods: solve separable first-order equations, and inhomogeneous linear second-order equations. Laplace transform: know when to recommend the Laplace transform method, and to how to compute solutions to second-order. equations using the method. Linear algebra: explain the concept of a vector space, determine whether a given set of vectors are linearly independent, compute eigenvalues and eigenvectors, apply the methods of linear algebra to a system of linear differential equations
   b. **explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course.**

7. **Brief list of topics to be covered**
Solutions and Direction Fields; Separation of Variables; Approximation Methods' Picard's Theorem; Linear Equations; Solving First-Order Linear Equations; Growth and Decay; Mixing and Cooling; Nonlinear Logistic Equations; Systems of Equations; Matrices; Systems of Linear Equations; Matrix Inverse; Determinants; Vector Spaces; Basis and Dimension; Eigenvalues; Harmonic Oscillator; Real Characteristic Roots; Complex Characteristic Roots; Undetermined Coefficients; Variation of Parameters; Forced Oscillations; Conservation and Conversion' Laplace Transform; Solving Des with Laplace Transform; Step Function and Delta Function' Liner Systems with Real Eig.; Linear Systems w/Non-real Eig; Stability and Liner Classification

Course Syllabus

1. **Course number and name**
   ARCH 4010, Architectural Appreciation & Design Studio

2. **Credits and contact hours**
   5 Credits, Monday, Wednesday: 3:00 pm to 5:30 pm

3. **Instructor's or course coordinator's name**
   Justin Bellucci and Shawhin Roudbari

4. **Text book, title, author, and year**
   N/A (select chapters from several books, listed below, were used)
   a. **other supplemental materials**
      readings: Simon Unwin, *Analyzing Architecture*, 2009; Francis Ching, *Architecture: Form, Space, Order*, 2011; Christine Sauer, *Made of: new material sourcebook for architecture and design,* 2010; Ivan Margolius, *Architects + Engineers = Structures*, 2002; Marianne Keeler and Bill Burke, *Fundamentals of Integrated Design for Sustainable Building*.

5. **Specific course information**
   a. **brief description of the content of the course (catalog description)**
      Introduces basic processes and principles of architectural design. Provides a basis for understanding and evaluating architecture

   b. **prerequisites or co-requisites**
      Seniors in AREN

   c. **indicate whether a required, elective, or selected elective (as per Table 5-1) course in the program.**

6. **Specific goals for the course**
   a. **Specific outcomes of instruction. ex: the student will be able to explain the significance of current research about a particular topic.**

      Broadly, this class aims to train you in (a) fundamentals of design and architecture; (b) methods of analysis and research in architecture; and (c) techniques and tools for communicating design. Specifically, these aims correspond to the following outcomes:

      Familiarity with elements of architecture
      An understanding of material and tectonics
      Exposure to innovations in integration of architecture with systems and structures
      Exposure to precedent research
      An understanding of ordering systems in design
      Practice in the design process and design thinking

Exposure to basics of site and user analysis
Schematic design development
Drawing and model making
Presentations, posters, and technical drawings

b. **explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course.** *(leave blank if you are unsure)*

7. **Brief list of topics to be covered**
   Elements of architecture; precedent research; ordering systems; site analysis; concept development; technical drawings; tectonics; diagram; poster board; user analysis; drawing; physical model; materials; modeling; presentation; program design; sketch models; digital 3D model; systems and structures; design; process; program development

Course alpha, number, title	**AREN 1027 Engineering Drawing**
Required or elective	Required for all students in degree program
Course description	Students learn linetypes, symbols, drawing and dimensioning standards by generating drawings using drafting instruments and computer-aided-drafting. Drawings start with basic sketching, hand drafting and continue through 3-D solid modeling on Revit. Print reading includes interpretation of site, foundation, floor and roof plans as well as elevations and sections.
Prerequisite(s)	None
Textbook(s) and/or other required material	The LIFT student USB package. Included Templates, Revit Building Blocks, and Example files Optional: The Creativity Code: The Power of Visual Thinking **ISBN-13:** 978-0997927528
Class/Lab schedule	Total Credits: 3 *Lecture 75-minutes 2x/week; Lab 110 min 1x/wk*
Instructor	Alex Gore and Lance Cayko
Topics covered	• Alphabet of lines. • Drawing symbols • Lettering and text • Drawing and dimensioning standards • Drawing notes and tables on working drawings • Sketches, geometric construction, working drawings, 3D models • Drawing problems on computer using both basic and advanced setup, drawing, editing, attributes and dimensioning commands • Working drawings including format and site, foundation, floor, roofing plans and section and detail drawings • Notes and tables on working drawings • Printing and plotting
Course learning objectives	1. Draw and dimension working drawings using proper format 2. Draw a 3D solid model of a structure 3. Read and interpret working drawings

Relationship of course to program outcomes

Program Outcome	Emphasis
1. an ability to apply knowledge of mathematics, science, and engineering	Small
2. an ability to design and conduct experiments	**Large**
3. an ability to analyze and interpret data	Small
4. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic,	Medium

	environmental, social, political, ethical, health and safety, manufacturability, and sustainability	
	5. an ability to function on multi-disciplinary teams	None
	6. an ability to identify, formulate, and solve engineering problems	None
	7. an understanding of professional and ethical responsibility	Small
	8. an ability to communicate effectively through writing and drawings	**Large**
	9. an ability to communicate effectively through oral presentations	Small
	10. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	None
	11. a recognition of the need for, and an ability to engage in life-long learning	Medium
	12. a knowledge of contemporary issues	Small
	13. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	**Large**
	14. an ability to explain basic concepts in management, business, public policy, and leadership	Small
Contribution to the professional component	60% Engineering Science 40% Engineering Design	
Person(s) who prepared this description	Alex Gore	
Date of Preparation	2/07/2017	

Course number, name	**AREN 1316 Introduction to Architectural Engineering**	
Credits and contact hours	2-credits, two 50-min lectures per week	
Instructor(s)	Prof. Angela R. Bielefeldt, PhD, PE	
Textbook, Other materials	No textbook required Readings from: ASCE Civil Engineering Body of Knowledge for the 21st Century (2008), ASCE 2013 Report Card for America's Infrastructure, LEED v4 User Guide (2013), The ASCE Code of Ethics: Principles, Study, and Application (2011)	
Course description	Surveys the broad subject of architectural engineering and professional practice. Includes the subdisciplines of structures, construction, electrical, lighting, and HVAC. Discusses professional ethics, important skills for engineers, and the engineering design process as it fulfills multiple objectives.	
Prerequisite(s)	None	
Required or elective	Required for all students in degree program	
Course learning objectives	1. describe what architectural engineering is, what you may do as a architectural engineer, and the skills required to be an architectural engineer 2. understand the process to gain the skills required to be an engineer and successfully graduate with a degree in architectural engineering from CU 3. explain the importance of professional licensure (PE) for architectural engineers 4. apply the professional codes of engineering ethics to evaluate situations you may encounter in your career 5. define sustainability, describe its importance to engineering, and identify aspects of sustainability in architectural engineering projects	
Relationship of course to program outcomes	<u>Program Outcome</u>	<u>Emphasis</u>
	1. an ability to apply knowledge of mathematics, science, and engineering	Small
	2. an ability to design and conduct experiments	None
	3. an ability to analyze and interpret data	None
	4. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	Small
	5. an ability to function on multi-disciplinary teams	Small
	6. an ability to identify, formulate, and solve engineering problems	None

	7. an understanding of professional and ethical responsibility	**Large**
	8. an ability to communicate effectively through writing and drawings	Small
	9. an ability to communicate effectively through oral presentations	None
	10. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	Medium
	11. a recognition of the need for, and an ability to engage in life-long learning	Medium
	12. a knowledge of contemporary issues	Small
	13. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	None
	14. an ability to explain basic concepts in management, business, public policy, and leadership	None
List of topics covered	Overview of architectural engineering and sub-disciplines Compare/contrast architectural engineering with civil engineering Sustainable design Ethics and professional licensure Design and teamwork Process to earn an architectural engineering degree and build relevant skills	
Contribution to the professional component	90% Professional skills 10% Engineering Design	
Prepared by:	Angela Bielefeldt, 10/31/2016	

Course number, name	**AREN 2050 Building Systems and Materials**
Credits and contact hours	3-credits, two 1.25-hour lectures per week
Instructor(s)	Senior Instructor Matt Morris, P.E.
Textbook, Other materials	Allen, Edward and Iano, Joseph (2009). Fundamentals of Building Construction Materials and Methods, 5th Edition. Wiley, Inc. Hoboken, NJ. ISBN 978-0-470-07468-8 Example construction drawings
Course description	Covers the broad subject of building materials and systems. Includes a practical approach to assembly details, methods of construction, codes, foundations, steel, concrete, masonry, cladding, doors and windows, interiors, finishes, mechanical, plumbing, electrical, life safety and conveyance. Includes investigation of an existing facility along with a team presentation trends in commercial building construction.
Prerequisite(s)	Restricted to students with 27-180 credits (Sophomores, Juniors or Seniors) Civil (CVEN) or Architectural (AREN) or GEEN (General) or Applied Mathematics (AMEN) majors only.
Required or elective	Required for all students in AREN degree program, elective for CVEN
Course learning objectives	1. Identify the numerous building components, materials and systems 2. Understand the sequence and relationship between building assemblies 3. Develop industry vocabulary

Relationship of course to program outcomes

Program Outcome	Emphasis
1. an ability to apply knowledge of mathematics, science, and engineering	Small
2. an ability to design and conduct experiments	None
3. an ability to analyze and interpret data	Small
4. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	Medium
5. an ability to function on multi-disciplinary teams	Small
6. an ability to identify, formulate, and solve engineering problems	Small
7. an understanding of professional and ethical responsibility	Small
8. an ability to communicate effectively through writing and drawings	Medium
9. an ability to communicate effectively through oral presentations	Medium

	10. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	Medium
	11. a recognition of the need for, and an ability to engage in life-long learning	Medium
	12. a knowledge of contemporary issues	Medium
	13. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	Medium
	14. an ability to explain basic concepts in management, business, public policy, and leadership	Small
List of topics covered	Daily current events Planning and construction sequencing Building codes Soils, earthwork, utilities Retaining systems, deep & shallow foundations Concrete, reinforcement, formwork Grade beams, foundation walls Structures - Cast-in-place, precast concrete, steel, tilt-up, masonry MEP rough-in Enclosure Interior partitions and framing Indoor air quality, thermal comfort and HVAC systems/equipment Plumbing systems/equipment Electrical systems/equipment Life safety systems/equipment Conveyance systems MEP trim, startup, testing, commissioning, certificate of occupancy Prefabrication Reading drawings	
Contribution to the professional component	10% Engineering Design 90% Engineering Science	
Prepared by:	Matt Morris, 10/31/2016	

Course number, name	**AREN 2110 Thermodynamics**
Credits and contact hours	3-credits, three 50-min lectures per week
Instructor(s)	Prof. Lupita D. Montoya, PhD
Textbook, Other materials	Cengel, Yunus A., John Cimbala, Robert H. Turner, Fundamentals of Thermal-Fluid Sciences, 4th Edition McGraw-Hill, 2012.
Course description	Explores fundamental principles of thermodynamics, including first and second law of thermodynamics, thermophysical properties, power and refrigeration cycles, gas mixtures and psychrometrics. Approved for arts and sciences core curriculum: natural science. Restricted to AREN, CVEN or EVEN, GEEN, AMEN or EVENCVEN Concurrent Degree majors only.
Prerequisite(s)	Requires a prereq course of PHYS 1110 (min grade C-) and a prereq or coreq course of APPM 1360 or MATH 2300 (min grade C-).
Required or elective	Required for all students in degree program

Course learning objectives

1. Analyze energy transfer and transformation in systems using fundamental concepts of properties of materials, work, heat, internal energy, entropy, equilibrium, and relations derived from the First and Second Laws of Thermodynamics.
2. Apply principles to simple compressible systems used in a variety of applications that sustain modern society – heating, cooling, electric and mechanical power generation.
3. Learn the methods to measure thermodynamic properties and estimate values for properties using property tables and relations.
4. Perform thermodynamic analysis of engineering devices and systems such as piston-cylinders, compressors, turbines, pumps, heat exchangers, heat engine cycles, and refrigeration cycles using energy, materials, and entropy relations.
5. Apply thermodynamic concepts in Civil, Environmental & Architectural Engineering such as sustainable energy technologies, energy conservation, and maintaining the global environment

Relationship of course to program outcomes

Program Outcomes	Emphasis
1. an ability to apply knowledge of mathematics, science, and engineering	Large
2. an ability to design and conduct experiments	None
3. an ability to analyze and interpret data	Small

	4. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	None
	5. an ability to function on multi-disciplinary teams	None
	6. an ability to identify, formulate, and solve engineering problems	**Large**
	7. an understanding of professional and ethical responsibility	None
	8. an ability to communicate effectively through writing and drawings	Small
	9. an ability to communicate effectively through oral presentations	None
	10. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	Small
	11. a recognition of the need for, and an ability to engage in life-long learning	Small
	12. a knowledge of contemporary issues	Small
	13. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	**Large**
	14. an ability to explain basic concepts in management, business, public policy, and leadership	None
List of topics covered	Basic concepts in thermodynamics (e.g., system, state, equilibrium, cycle); Energy, energy transfer and general energy analysis; Properties of pure substances; Energy analysis of closed systems; Mass and energy analysis of control volumes; First and second law of thermodynamics; Entropy; Power and refrigeration cycles.	
Contribution to the professional component	100% Engineering Science	
Prepared by:	Lupita D. Montoya, 11/01/2016	

Course number, name	**AREN 2120 Fluid Mechanics and Heat Transfer**
Credits and contact hours	3-credits, two 75-min lectures per week
Instructor(s)	Prof. Zhiqiang (John) Zhai, PhD
Textbook,	Cengel, Y.A., Cimbala, J.M., and Turner, R.H. Fundamentals of Thermal-Fluid Sciences, 4th Edition, McGraw-Hill, 2011, ISBN-10: 0077422406 | ISBN-13: 978-0077422400.
Other materials	Series of handouts for lecture summaries and homework assignments
Course description	This course explores fundamental principles of fluid mechanics and heat transfer. Topics include fluid statics, momentum and energy conservations; laminar and turbulent viscous flows; conduction, convection and radiation heat transfer. Emphasizes topics and problems that are important to Architectural Engineers including flow of fluids in pipes and ducts, heat transfer in buildings and building systems.
Prerequisite(s)	APPM 2350 or MATH 2400, and AREN 2110 or GEEN 3852 or MCEN 3012 or ASEN 2002; Requires corequisite course of APPM 2360
Required or elective	Required for all students in degree program
Course learning objectives	The course has two basic objectives: (i) to teach the fundamentals of engineering fluid mechanics and heat transfer and (ii) to present selected applications related to building energy systems. Throughout the class we will emphasize topics and problems that are important to Architectural Engineers including flow of fluids in pipes and ducts, heat transfer in buildings and building systems. Additionally, the class will touch on some broader issues of which students, as engineers, should be aware. Among these are such topics as the need for sustainability in building design and ethical implications of standard design, the cost and benefits of high efficiency buildings, and growing concern for indoor air quality (i.e. sick building syndrome).

Relationship of course to program outcomes

Program Outcome	Emphasis
1. an ability to apply knowledge of mathematics, science, and engineering	**Large**
2. an ability to design and conduct experiments	Small
3. an ability to analyze and interpret data	Medium
4. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	Medium
5. an ability to function on multi-disciplinary teams	Small

	6. an ability to identify, formulate, and solve engineering problems	**Large**
	7. an understanding of professional and ethical responsibility	Medium
	8. an ability to communicate effectively through writing and drawings	Medium
	9. an ability to communicate effectively through oral presentations	Medium
	10. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	**Large**
	11. a recognition of the need for, and an ability to engage in life-long learning	**Large**
	12. a knowledge of contemporary issues	**Large**
	13. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	**Large**

List of topics covered

Fluid Mechanics:

- Compute energy flow and loss of fluids in pipes
- Compute required pumping power and pump heating
- Compute head and power loss during pumping
- Identify the differences between laminar and turbulent flow
- Compute laminar flow profiles in pipes
- Compute Reynolds number for flow over plates and in pipes
- Compute laminar and turbulent drag coefficients and head loss in pipes
- Compute minor losses in laminar and turbulent flow

Heat Transfer

- Compute thermal conduction through plates, cylinders and spheres
- Compute thermal conduction through uniform and composite structures
- Compute transient heat conduction in lumped systems
- Compute forced convection coefficients over plates and in pipes
- Compute natural convection coefficients over plates and in pipes
- Compute radiation emissions from gray bodies
- Compute radiation transmission through partially absorbing materials
- Compute view factors for common geometries

Compute radiation between elements of an enclosure

Contribution to the professional component: 80% Engineering Science
20% Engineering Design

Prepared by: Zhiqiang (John) Zhai, 11/16/2016

Course number, name	**AREN 3010 Mechanical Systems for Buildings**
Credits and contact hours	3-credits, two 75-min lectures per week
Instructor(s)	Prof. Zhiqiang (John) Zhai, PhD
Textbook,	Principles of Heating, Ventilation, and Air Conditioning in Buildings (1st Edition), John W. Mitchell, James E. Braun, 2012.
Other materials	Advanced Energy Design Guide for Small to Medium Office Buildings. ASHRAE, 2011; ANSI/ASHRAE/USGBC/IES Standard 189.1-2014 Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings. ASHRAE, 2014
Course description	This is a required entry course for AREN on the basic design of buildings and their systems to meet the requirements of designing a comfortable and healthy building. The course examines critical elements such as psychrometrics, thermal comfort, indoor environment quality, solar conditions, envelope heat transfer, building heating and cooling loads, and HVAC components and systems.
Prerequisite(s)	AREN 2120 Fluid Mechanics and Heat Transfer; AREN 2050 Engineering Systems for Buildings
Required or elective	Required for all students in degree program
Course learning objectives	(1) The ability to identify the criteria, metrics, and mechanisms for a comfortable and healthy indoor environment. The criteria and metrics are determined by human physiology, but for practical design purposes, are also dictated by building codes and standards. (2) The ability to identify and analyze the characteristics of weather, building construction, and building operations as they define the requirements for comfortable and healthy indoor environment. (3) The ability to analyze the heating, ventilating, and air conditioning requirements of residential and small commercial buildings. Given the need to maintain a comfortable and healthy indoor environment, you will be able to determine HVAC loads (i.e., the requirements) as a function of a building's physical characteristics, its use, and its climatic location. The analyses will be performed by applying basic engineering knowledge with hand calculations and computer simulation. (4) The ability to select and size basic heating and cooling equipment to meet HVAC requirements. This ability requires knowledge of alternative HVAC equipment performance, the interactions among system components, and the interactions of the system with the building loads. (5) The ability to evaluate the impact of building design decisions on HVAC equipment size and cost, annual HVAC energy

	consumption and cost, and environmental impact of energy consumption on power plant emissions	
Relationship of course to program outcomes	<u>Program Outcome</u>	<u>Emphasis</u>
	1. an ability to apply knowledge of mathematics, science, and engineering	Large
	2. an ability to design and conduct experiments	Small
	3. an ability to analyze and interpret data	Large
	4. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	Large
	5. an ability to function on multi-disciplinary teams	Medium
	6. an ability to identify, formulate, and solve engineering problems	Large
	7. an understanding of professional and ethical responsibility	Medium
	8. an ability to communicate effectively through writing and drawings	Large
	9. an ability to communicate effectively through oral presentations	Medium
	10. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	Large
	11. a recognition of the need for, and an ability to engage in life-long learning	Medium
	12. a knowledge of contemporary issues	Large
	13. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	Large
	14. an ability to explain basic concepts in management, business, public policy, and leadership	Small
List of topics covered	Sustainable building design Building thermal system principles Building envelope and mechanical systems and design Building outdoor and indoor design conditions Thermal comfort and indoor air quality HVAC process and psychrometrics, load calculation and system sizing	
Contribution to the professional component	60% Engineering Science 40% Engineering Design	

Course number, name	**AREN 3540: Illumination 1**
Credits and contact hours	3-credits, Three 50-min lectures per week
Instructor(s)	Sr. Instructor C. Walter Beamer IV, PhD
Textbook, Other materials	Recommended Text: Illuminating Engineering: From Edison's Lamp to the LED, Second Edition, Joseph B. Murdoch
Course description	This course is about the fundamentals of illumination and lighting systems. The emphasis is on the technical foundations for the generation and distribution of light. This course is a basic fundamentals course that focuses on the physics of illumination with respect to lighting technology and the quantitative aspects of lighting design. For those students interested in a technically intensive career in lighting this course will be the basis for all illumination calculations. For those students more interested in the lighting design for buildings, this course will give them the technical knowledge necessary to effectively create installed lighting systems that meet the design expectations.
Prerequisite(s)	Engineering Computing, Calculus III
Required or elective	Required for all students in degree program
Course learning objectives	Upon completion of this course, the successful student will have: 1. The ability to discuss lighting using professional terminology. 2. A complete understanding of lighting fundamentals including light spectrum and the 5 fundamental units of photometry. 3. A thorough knowledge of light generation technology, including their positives, negatives, spectral characteristics, and likely failure mechanisms. 4. The ability to predict light reflection, transmission, and diffraction through physical media. 5. The ability to manipulate photometric data and derive photometric reports from luminous intensity data. 6. The ability to apply engineering calculations to lighting problems in order to verify design goals are met and to better understand the effect of the building environment on the flow of light. 7. An understanding of the basic considerations of the lighting design process.

Relationship of course to program outcomes	Program Outcome	Emphasis
	1. an ability to apply knowledge of mathematics, science, and engineering	**Large**
	2. an ability to design and conduct experiments	None

	3. an ability to analyze and interpret data	Small
	4. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	Small
	5. an ability to function on multi-disciplinary teams	None
	6. an ability to identify, formulate, and solve engineering problems	**Large**
	7. an understanding of professional and ethical responsibility	Small
	8. an ability to communicate effectively through writing and drawings	Small
	9. an ability to communicate effectively through oral presentations	None
	10. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	None
	11. a recognition of the need for, and an ability to engage in life-long learning	Small
	12. a knowledge of contemporary issues	Small
	13. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	Medium
	14. an ability to explain basic concepts in management, business, public policy, and leadership	None
List of topics covered	Electromagnetic spectrum, Visual evaluation of EMR, The lumen, Solid angle, The 5 lighting metrics, Flux transfer methods, Reflectance and transmittance properties of materials, Basic luminous radiative transfer, Form factors, Configuration factors, Lumen method.	
Contribution to the professional component	80% Engineering Science 20% Engineering Design	
Prepared by:	Walter Beamer, 10/31/2016	

Course number, name	**AREN 4110 HVAC System Design**
Credits and contact hours	3-credits, two 75-min lectures per week
Instructor(s)	Prof. Gregor P. Henze, Ph.D., P.E.
Textbook, Other materials	Mitchell, J.W., and J.E. Braun. 2012. Heating, Ventilating, and Air-Conditioning, First Edition. John Wiley & Sons, New York McQuiston, F.C., J.D. Parker, and J.D. Spitler. 2005. Heating, Ventilating, and Air Conditioning: Analysis and Design, Sixth Edition. John Wiley & Sons, New York. ASHRAE. 2013. Handbook: Fundamentals, American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc., Atlanta. ASHRAE. 2012. Handbook: HVAC Systems and Equipment, American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc., Atlanta.
Course description	The overall objective of this course is to prepare students for professional practice in the area of mechanical systems design for commercial buildings. Upon completion of the course, students will possess the skills to calculate heating, cooling, and ventilation requirements, design and evaluate conventional HVAC systems to meet these requirements in the context of codes and standards, and design and evaluate low-energy systems for sustainable buildings.
Prerequisite(s)	AREN 3010 Mechanical Systems for Buildings
Required or elective	Elective for students in the mechanical systems option in AREN
Course learning objectives	1. Develop methods for energy-conscious design of HVAC systems in commercial buildings based on a thorough understanding of component and system performance 2. Develop broad desire to achieve optimal energy efficiency in the context of prevailing codes and standards. 3. Understand heating, cooling, and ventilating requirements in commercial buildings 4. Understand HVAC equipment, including the primary equipment for providing heating and cooling in buildings and the secondary air and water distribution system equipment 5. Understand the role of HVAC systems and building energy use in integrated and sustainable building design including economic impact of HVAC design decisions on both the initial costs of the building and the continuing operating costs 6. Apply codes, standards, and sustainable design guidelines in the design of building HVAC systems

Program Outcome | Emphasis

Relationship of course to program outcomes	**1. an ability to apply knowledge of mathematics, science, and engineering**	**Large**
	2. an ability to design and conduct experiments	None
	3. an ability to analyze and interpret data	None
	4. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	**Large**
	5. an ability to function on multi-disciplinary teams	Small
	6. an ability to identify, formulate, and solve engineering problems	Medium
	7. an understanding of professional and ethical responsibility	None
	8. an ability to communicate effectively through writing and drawings	Small
	9. an ability to communicate effectively through oral presentations	None
	10. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	Medium
	11. a recognition of the need for, and an ability to engage in life-long learning	Medium
	12. a knowledge of contemporary issues	Small
	13. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	Medium
	14. an ability to explain basic concepts in management, business, public policy, and leadership	None
List of topics covered	Overview of HVAC system, Building heating and cooling loads Psychrometric applications, Heat exchangers and cooling coils Ventilation and ASHRAE Std. 62, Air and water distribution system Room airflow and diffusers, Radiant heating and cooling Cooling towers, Chillers, Thermal energy storage Ground source heat pumps, Underfloor air distribution	
Contribution to the professional component	30% Engineering Science 70% Engineering Design	
Prepared by:	Gregor Henze, 1/30/2017	

Course number, name	**AREN 4317Architectural Engineering Design**
Credits and contact hours	5-credits, two 75-min lectures and one 1-hr. 50-min. lab per week
Instructor(s)	Sandra L. Vásconez, MS, LC
Textbook, Other materials	None
Course description	Provides a capstone experience to AREN students. Students design a modest commercial building and complete an integrated engineering design of the building systems executed for the conceptual, schematic, and design development phases. Students' teams work on structural, mechanical, electrical/lighting, and construction engineering management design. Each stage produce a professional-quality design document. Faculty and industry mentors participate in the teaching and evaluation of designs.
Prerequisite(s)	ARCH 4010, AREN 3010, AREN 3540, CVEN 3246, CVEN 3525, ECEN 3030 (all minimum grade C-).
Required or elective	Required
Course learning objectives	1. Integrate the technical sub-disciplines of structural, mechanical, lighting and electrical, and construction engineering management to create a professional-level solution to a 12,000 to 15,000 square-foot building. 2. Gather relevant data; understand "client" needs (as defined by AE faculty and industry mentors); identify budgetary, environmental and ethical constraints; and identify and use applicable regulations, codes and standards. 3. Create feasible alternative designs--where appropriate, and carry out value engineering analysis. 4. Prepare increasingly detailed designs and construction planning that satisfies project's constraints while also conforming to relevant codes and regulations and established sustainable practices. 5. Prepare design documentation including design rationale and intent, design details and integrated project planning, scheduling and construction cost analysis to support each design stage. 6. Communicate effectively both through oral presentations and written reports/drawings the design intent, proposed solutions, and engineering details. 7. Work in multi-disciplinary teams and in interdisciplinary formats as appropriate during different phases of the project. 8. Realize the importance of obtaining professional credentials and engaging in life-long learning throughout their careers as engineers.

9. Understand professional and ethical responsibilities students must exercise as students and as future practicing engineers.

	Program Outcome	Emphasis
Relationship of course to program outcomes	**1. an ability to apply knowledge of mathematics, science, and engineering**	**Large**
	2. an ability to design and conduct experiments	None
	3. an ability to analyze and interpret data	None
	4. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	**Large**
	5. an ability to function on multi-disciplinary teams	**Large**
	6. an ability to identify, formulate, and solve engineering problems	**Large**
	7. an understanding of professional and ethical responsibility	Small
	8. an ability to communicate effectively through writing and drawings	**Large**
	9. an ability to communicate effectively through oral presentations	Medium
	10. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	Medium
	11. a recognition of the need for, and an ability to engage in life-long learning	Small
	12. a knowledge of contemporary issues	Medium
	13. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	**Large**
	14. an ability to explain basic concepts in management, business, public policy, and leadership	None
List of topics covered	Engineering: LEED, BIM, quality control, building/energy codes, VE, sustainability, professional standards of care, case studies, written specifications, FE prep Professional development: leadership, ethics, life-long learning, time management, presentation skills, owning a company	
Contribution to the professional component	50% Engineering Science 50% Engineering Design	
Prepared by:	Sandra Vasconez, 10/31/2016	

Course number, name	**AREN 4506 Preconstruction Estimating and Scheduling**
Credits and contact hours	3-credits, three 75-min lectures per week
Instructor(s)	Prof. Keith Molenaar, PhD, DBIA Assoc. Prof. Amy Javernick-Will, PhD
Textbook, Other materials	Hinze, Jimmie. "Construction Planning and Scheduling- 4th edition." Pearson, New Jersey. Holm, Schaufelberger, Griffin and Cole. "Construction Cost Estimating: Process & Practices" Peason, New Jersey
Course description	This course provides an overview of pre-construction scheduling and estimating for building and engineering projects. We will explore project management methods with an emphasis on techniques for estimating and scheduling projects throughout the design process. We will apply lecture and reading materials to solve basic engineering problems. We will use computer programs, including Primavera and WinEst, to perform complex schedules and estimates. The course will culminate in a group project that will simulate a construction bid for a design and construction project on the University of Colorado campus.
Prerequisite(s)	CVEN 3246 Introduction to Construction
Required or elective	Elective in AREN and CVEN degrees
Course learning objectives	1. Identify the concepts and phases of project management and pre-construction planning. 2. Describe and differentiate between types of construction estimates and the role they play in the project process. 3. Explain the fundamental concepts, tools and techniques to organize and develop estimates. 4. Perform estimates, including conceptual and detailed estimates for building construction. 5. Apply WinEst and the RS Means cost database to perform estimates throughout design. 6. Describe and create a work breakdown (WBS) for a project. 7. Describe and differentiate between relationship types when ordering activities in a project plan. 8. Calculate the early start, early finish, late start and late finish for activities and the early/late finish, total float and free float for a project using the critical path method (CPM). 9. Apply Primavera P6 to schedule complex design and construction activities. 10. Create project schedules, including cost-loaded schedules, by applying the materials from the class to a project.

Program Outcome	Emphasis

Relationship of course to program outcomes	1. an ability to apply knowledge of mathematics, science, and engineering	Medium
	2. an ability to design and conduct experiments	None
	3. an ability to analyze and interpret data	Medium
	4. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	Small
	5. an ability to function on multi-disciplinary teams	Small
	6. an ability to identify, formulate, and solve engineering problems	Medium
	7. an understanding of professional and ethical responsibility	Small
	8. an ability to communicate effectively through writing and drawings	Medium
	9. an ability to communicate effectively through oral presentations	Medium
	10. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	Small
	11. a recognition of the need for, and an ability to engage in life-long learning	Small
	12. a knowledge of contemporary issues	Small
	13. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	Medium
	14. an ability to explain basic concepts in management, business, public policy, and leadership	Medium
List of topics covered	Project management Estimating techniques (conceptual, assemblies and cost-based) Computer estimating methods (RSMeans and WinEst) Subcontractor bid analysis Scheduling techniques (bar charts and critical path method) Computer scheduling methods (Primavera P6) Project cash flow analysis	
Contribution to the professional component	90% Engineering Science 10% Engineering Design	
Prepared by:	Keith Molenaar, 10/9/2016	

Course number, name	**AREN 4550 Illumination II**
Credits and contact hours	3-credits, three 50-min lectures
Instructor(s)	Sandra L. Vasconez, MS, LC
Textbook, Other materials	Required: *Designing with Light, The Art, Science, and Practice of Architectural Lighting Design*, Jason Livingston, 2014. Other: Architectural Lighting Magazine – Selected Articles; *Architectural Lighting, Designing with Light and Space*, Herve Descottes with Cecilia E. Ramos; *The Architecture of Light*, Sage Russell; IES/ASHRAE 90.1 – Lighting Section; *IESNA Lighting Handbook*, 10th ed., David DiLaura, et.al. (editor); LD+A Magazine – Selected Articles; Lighting Research Center Web site
Course description	Studies the fundamentals of architectural illumination. Introduces and applies basic principles and vocabulary to elementary problems in the lighting of environments for the performance of visual work and the proper interaction with architecture.
Prerequisite(s)	AREN 3540
Required or elective	Required
Course learning objectives	1. Identify fundamental aspects of color vision and use that knowledge to appraise how light/lighting can be applied in architectural settings to improve visual comfort and performance. 2. Acquire the lighting vocabulary used in architectural lighting so that even if a student chose not to work with lighting and lighting systems in their professional career, they still have the understanding required to work with lighting architectural engineers. 3. Apply the lighting design process and basic lighting techniques to simple architectural lighting problems. 4. Design simple yet practical architectural lighting solutions. This means selecting the appropriate lighting equipment that will achieve a desired lighting effect. The student will: a. Understand performance characteristics of lamps, ballasts, and controls. b. Understand how these components perform within a lighting system. c. Select and specify luminaries d. Verify through lighting calculations photometric objectives as well as the light levels required to meet specific design goals.

	e. Select basic lighting controls strategies and devices. Explore the integration of daylighting with electrical lighting through the use of controls. f. Present and describe desired lighting effects through sketches and produce lighting-layouts using standard formats and symbols. g. Develop a personal philosophy of lighting design, albeit this philosophy will evolve throughout the student's lighting career	
Relationship of course to program outcomes	Program Outcome	Emphasis
	1. an ability to apply knowledge of mathematics, science, and engineering	Small
	2. an ability to design and conduct experiments	None
	3. an ability to analyze and interpret data	None
	4. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	**Large**
	5. an ability to function on multi-disciplinary teams	Small
	6. an ability to identify, formulate, and solve engineering problems	Small
	7. an understanding of professional and ethical responsibility	Small
	8. an ability to communicate effectively through writing and drawings	**Large**
	9. an ability to communicate effectively through oral presentations	None
	10. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	Small
	11. a recognition of the need for, and an ability to engage in life-long learning	Small
	12. a knowledge of contemporary issues	Medium
	13. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	**Large**
List of topics covered	The lighting design profession, communicating design ideas, visual performance, accent illuminance ratios, light and color, Visual, AGI32, Psychology of light, lamps, luminaires and cutsheets, controls, design process, luminaire specification, design documentation, codes and sustainability.	
Contribution to the professional component	10% Engineering Science 90% Engineering Design	
Prepared by:	Sandra Vasconez, 10/21/2016	

Course number, name	**AREN 4560: Luminous Radiative Transfer**
Credits and contact hours	3-credits, Three 50-min lectures per week
Instructor(s)	Sr. Instructor C. Walter Beamer IV, PhD
Textbook	Recommended Text: Thermal Radiation Heat Transfer ,Fifth Edition, John R. Howell, Robert Siegel, M. Pinar Menguc
Course description	It is a study of the interaction of light and architecture. The nature of this interaction is described by a process usually referred to as "radiative transfer"; that is, the transfer of electromagnetic energy by radiative means. The descriptor "luminous" is added to indicate that the interactions studied are limited to those involving that part of the electromagnetic spectrum responsible for the sense of vision. This descriptor also indicates that the result of this interaction is ultimately assessed by visual perception, in its various forms. The mathematical models that have been developed to describe this interaction are presented. Their use for the analysis of lighting systems and architecture is demonstrated. Additionally, these models are used to help design lighting systems and architecture. The mathematical models are given utility by being cast into computer programs that are used to solve various lighting and architectural problems.
Prerequisite(s)	Engineering Computing, Calculus III, AREN 3540 Illumination 1
Required or elective	Technical Elective
Course learning objectives	The learning objectives of this course are: 1. To give you a comfortable **understanding of the** physical (photometric) **basis** for radiative transfer. 2. To give you an understanding of the concepts which **define and describe** radiative transfer. 3. To give you an **understanding of the mathematics which describe** radiative transfer. 4. To give you **practice at using the mathematics** to solve real lighting and architectural problems involving radiative transfer. 5. To give you the **skill of evaluating an architectural/lighting problem**, extracting the essential radiative transfer involved, and producing architectural/lighting solutions.

<u>Program Outcome</u> <u>Emphasis</u>

Relationship of course to program outcomes	**1. an ability to apply knowledge of mathematics, science, and engineering**	**Large**
	2. an ability to design and conduct experiments	Small
	3. an ability to analyze and interpret data	Small
	4. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	Small
	5. an ability to function on multi-disciplinary teams	None
	6. an ability to identify, formulate, and solve engineering problems	**Large**
	7. an understanding of professional and ethical responsibility	None
	8. an ability to communicate effectively through writing and drawings	Small
	9. an ability to communicate effectively through oral presentations	None
	10. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	None
	11. a recognition of the need for, and an ability to engage in life-long learning	Small
	12. a knowledge of contemporary issues	Small
	13. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	Medium
	14. an ability to explain basic concepts in management, business, public policy, and leadership	None
List of topics covered	MATLAB programming, Basic file I/O, Numerical methods for surface and contour integrals, Advanced luminous radiative transfer, Form factors, Configuration factors, Blocking algorithms, Simple raytracing, Rendering luminous scenes, 3D modeling.	
Contribution to the professional component	95% Engineering Science 5% Engineering Design	
Prepared by:	Walter Beamer, 12/6/2016	

Course number, name	**AREN 4570 Building Electrical Systems**
Credits and contact hours	3-credits, two 75-min lectures per week
Instructor(s)	Prof. Moncef Krarti, PhD, PE
Textbook, Other materials	No textbook required, a series of handouts are provided Readings from: National Electrical Code. National Fire Protection Agency, 2014.
Course description	The design procedures for electrical distribution systems suitable for residential and commercial buildings are provided throughout the course. In particular, the main safety requirements from NEC are highlighted and used to design electrical systems for both dwellings and small commercial buildings.
Prerequisite(s)	ECEN 3030: Electrical Circuits
Required or elective	Required for all Lighting/Electrical students in AREN degree program
Course learning objectives	1. Review the electrical circuit fundamentals. 2. Be familiar with operation and characteristics of motors and transformers. 3. Know the various protection devices used in electrical distribution systems. 4. Design an electrical system for a residential building and a small office building according to the requirements of the National Electrical Code (NEC). 5. Design energy efficient electrical systems for commercial buildings.

Relationship of course to program outcomes	Program Outcome	Emphasis
	1. an ability to apply knowledge of mathematics, science, and engineering	Medium
	2. an ability to design and conduct experiments	None
	3. an ability to analyze and interpret data	None
	4. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	**Large**
	5. an ability to function on multi-disciplinary teams	Small
	6. an ability to identify, formulate, and solve engineering problems	Small
	7. an understanding of professional and ethical responsibility	Medium
	8. an ability to communicate effectively through writing and drawings	**Large**

	9. an ability to communicate effectively through oral presentations	Small
	10. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	Medium
	11. a recognition of the need for, and an ability to engage in life-long learning	Medium
	12. a knowledge of contemporary issues	Small
	13. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	Medium
	14. an ability to explain basic concepts in management, business, public policy, and leadership	None
List of topics covered	Overview of basic electrical circuits for AC and DC circuits. Review of basic components of electrical distribution systems for buildings. Review National Electrical Code (NEC) safety requirements Design procedures for electrical systems for buildings	
Contribution to the professional component	30% Engineering Science 70% Engineering Design	
Prepared by:	Moncef Krarti, 11/8/2016	

Course number, name	**AREN 4506 Preconstruction Estimating and Scheduling**
Credits and contact hours	3-credits, three 75-min lectures per week
Instructor(s)	Prof. Keith Molenaar, PhD, DBIA Assoc. Prof. Amy Javernick-Will, PhD
Textbook, Other materials	Hinze, Jimmie. "Construction Planning and Scheduling- 4th edition." Pearson, New Jersey. Holm, Schaufelberger, Griffin and Cole. "Construction Cost Estimating: Process & Practices" Peason, New Jersey
Course description	This course provides an overview of pre-construction scheduling and estimating for building and engineering projects. We will explore project management methods with an emphasis on techniques for estimating and scheduling projects throughout the design process. We will apply lecture and reading materials to solve basic engineering problems. We will use computer programs, including Primavera and WinEst, to perform complex schedules and estimates. The course will culminate in a group project that will simulate a construction bid for a design and construction project on the University of Colorado campus.
Prerequisite(s)	CVEN 3246 Introduction to Construction
Required or elective	Elective in AREN and CVEN degrees
Course learning objectives	1. Identify the concepts and phases of project management and pre-construction planning. 2. Describe and differentiate between types of construction estimates and the role they play in the project process. 3. Explain the fundamental concepts, tools and techniques to organize and develop estimates. 4. Perform estimates, including conceptual and detailed estimates for building construction. 5. Apply WinEst and the RS Means cost database to perform estimates throughout design. 6. Describe and create a work breakdown (WBS) for a project. 7. Describe and differentiate between relationship types when ordering activities in a project plan. 8. Calculate the early start, early finish, late start and late finish for activities and the early/late finish, total float and free float for a project using the critical path method (CPM). 9. Apply Primavera P6 to schedule complex design and construction activities. 10. Create project schedules, including cost-loaded schedules, by applying the materials from the class to a project.
	Program Outcome — Emphasis

Relationship of course to program outcomes	1. an ability to apply knowledge of mathematics, science, and engineering	Medium
	2. an ability to design and conduct experiments	None
	3. an ability to analyze and interpret data	Medium
	4. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	Small
	5. an ability to function on multi-disciplinary teams	Small
	6. an ability to identify, formulate, and solve engineering problems	Medium
	7. an understanding of professional and ethical responsibility	Small
	8. an ability to communicate effectively through writing and drawings	Medium
	9. an ability to communicate effectively through oral presentations	Medium
	10. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	Small
	11. a recognition of the need for, and an ability to engage in life-long learning	Small
	12. a knowledge of contemporary issues	Small
	13. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	Medium
	14. an ability to explain basic concepts in management, business, public policy, and leadership	Medium
List of topics covered	Project management Estimating techniques (conceptual, assemblies and cost-based) Computer estimating methods (RSMeans and WinEst) Subcontractor bid analysis Scheduling techniques (bar charts and critical path method) Computer scheduling methods (Primavera P6) Project cash flow analysis	
Contribution to the professional component	90% Engineering Science 10% Engineering Design	
Prepared by:	Keith Molenaar, 10/9/2016	

Course number, name	**AREN 4830 Computer Simulation for Building Energy Systems**	
Credits and contact hours	3-credits, two 75-min lectures per week	
Instructor(s)	Prof. Moncef Krarti, PhD, PE	
Textbook, Other materials	No textbook required, a series of handouts are provided Readings from: ASHRAE handbooks and engineering manuals of DOE-2 and EnergyPlus computer tools.	
Course description	Overview of basic heating and cooling thermal load calculation methods as well as modeling techniques of building energy systems. In particular, energy analysis tools are introduced to assess the impact of various energy efficiency measures and control strategies on the thermal performance of both residential and commercial buildings.	
Prerequisite(s)	AREN 3010: Mechanical Systems for Buildings	
Required or elective	Required for Mechanical students in AREN degree program	
Course learning objectives	1. Introduce advanced energy modeling techniques including time-domain and frequency-domain analysis to determine heating and cooling loads in buildings. 2. Conduct building energy analysis using the state-of-the-art building simulation program DOE-2 and EnergyPlus. 3. Introduce commercially available software such as eQUEST, EnergyPlus, Design Builder, and BEOpt. 4. Perform parametric and optimization analyses to evaluate the effects of various design features and/or operational parameters in building energy use.	
Relationship of course to program outcomes	<u>Program Outcome</u>	<u>Emphasis</u>
	1. an ability to apply knowledge of mathematics, science, and engineering	Medium
	2. an ability to design and conduct experiments	None
	3. an ability to analyze and interpret data	None
	4. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	Medium
	5. an ability to function on multi-disciplinary teams	Small
	6. an ability to identify, formulate, and solve engineering problems	Small
	7. an understanding of professional and ethical responsibility	Medium
	8. an ability to communicate effectively through writing and drawings	Medium

	9. an ability to communicate effectively through oral presentations	Small
	10. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	Medium
	11. a recognition of the need for, and an ability to engage in life-long learning	Small
	12. a knowledge of contemporary issues	Small
	13. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	Medium
	14. an ability to explain basic concepts in management, business, public policy, and leadership	None
List of topics covered	Overview of modeling methods and techniques of building energy systems Hands-on practice to use whole-building energy simulation tools commonly used in thermal analysis of residential and commercial buildings. Review effective energy efficiency measures to improve thermal performance of buildings. Perform parametric and optimization analysis to design building energy systems.	
Contribution to the professional component	90% Engineering Science 10% Engineering Design	
Prepared by:	Moncef Krarti, 2/17/2017	

Course number, name	**AREN 4890 Sustainable Building Design**
Credits and contact hours	3-credits, two 75-min lectures per week
Instructor(s)	Prof. Gregor P. Henze, Ph.D., P.E.
Textbook, Other materials	Advanced Building Technologies for Sustainability Asif Syed, ISBN: 978-0-470-54603-1, Wiley & Sons, Inc. Advanced Energy Design Guide for Small to Medium Office Buildings Free download at ASHRAE: https://www.ashrae.org/standards-research--technology/advanced-energy-design-guides/50-percent-aedg-free-download.
Course description	Project and presentation based course that focuses on building performance analysis by simulation based on a series of lectures discussing energy efficiency technologies applied in best-practice buildings in Germany. Through the use of building simulation programs, students will examine relevant design parameters and their influence on the efficiency of these design strategies and technologies as well as on the overall energy consumption of a building. The simulations are related to a high-performance office building and will aim at optimizing the architectural design concept. Besides energy performance, a special focus will be placed on thermal comfort and indoor air quality evaluation including their integration in building simulation platforms.
Prerequisite(s)	AREN 3010 Mechanical Systems for Buildings AREN 4110 HVAC System Design
Required or elective	Elective for students in the mechanical systems option in AREN
Course learning objectives	1. Evaluate building performance analysis by simulation 2. Analyze energy and climate conscious design (super insulation, ventilation concepts, passive cooling strategies) as well as integrated energy concepts 3. Examine relevant design parameters and their influence on the efficiency of these design strategies and technologies as well as on the overall energy consumption of a building 4. Identify, understand and successfully synthesize architectural and engineering principles of climate and energy conscious design to create a highly comfortable indoor climate 5. Understand to which extent the design concepts can be transferred into different climates 6. Experience strategies of abstraction and reduction of problems to use the appropriate tool or model for the respective question and to use them in the most effective way 7. Attain proficiency for the use of simulation to explore novel energy efficiency technologies for buildings

Relationship of course to program outcomes	Program Outcome	Emphasis
	1. an ability to apply knowledge of mathematics, science, and eng.	Medium
	2. an ability to design and conduct experiments	None
	3. an ability to analyze and interpret data	None
	4. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	**Large**
	5. an ability to function on multi-disciplinary teams	**Large**
	6. an ability to identify, formulate, and solve engineering problems	Medium
	7. an understanding of professional and ethical responsibility	None
	8. an ability to communicate effectively through writing and drawings	Small
	9. an ability to communicate effectively through oral presentations	**Large**
	10. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	Medium
	11. a recognition of the need for, and an ability to engage in life-long learning	Medium
	12. a knowledge of contemporary issues	Small
	13. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	**Large**
	14. an ability to explain basic concepts in management, business, public policy, and leadership	None
List of topics covered	Climate/micro-climate parameters and their relevance for climate-conscious design, Building simulation in design practice, Introduction to OpenStudio, Innovative heat insulation technologies and passive solar energy use, Ventilation in winter and summer, Comfort requirements and impact on design strategies and HVAC concepts, Passive cooling – solar and internal loads, heat storage capacity of buildings, night ventilation, ground-to-air heat exchangers, cooling with thermally activated building systems	
Contribution to the professional component	20% Engineering Science 80% Engineering Design	
Prepared by:	Gregor Henze, 1/30/2017	

CHEN 1211 – General Chemistry for Engineers

Course Syllabus

8. **Course number and name:** CHEN 1211 – General Chemistry for Engineers
9. **Credits and contact hours**
   4 credit hours/4 contact hours
10. **Instructor's or course coordinator's name**
    Michael Shirts
11. **Textbook, title, author, and year**
    McMurry and Fay, Chemistry 6th ed., Prentice Hall, 2012
    a. **other supplemental materials**
       iClickers
       Sapling Learning subscription
       D2L
12. **Specific course information**
    a. **brief description of the content of the course (catalog description)**
       One-semester lecture and recitation course designed to meet the general chemistry requirement for engineering students. Topics include stoichiometry; thermodynamics; gases, liquids, and solids; equilibrium; acids and bases; bonding concepts; kinetics; reactions; and materials science. Examples and problems illustrate the application of chemistry to engineering sub-disciplines. Department enforced prereqs., one year of high school chemistry or CHEM 1021 (min. grade C-) and high school algebra. Not recommended for students with grades below B- in CHEM 1021. Credit not granted for this course and CHEM 1113/1114, 1251, or 1351.
    b. **prerequisites or co-requisites**
       Recommended co-req. CHEM 1211
    c. **indicate whether a required, elective, or selected elective (as per Table 5-1) course in the program.**

13. **Specific goals for the course**
    a. **specific outcomes of instruction, ex. The student will be able to explain the significance of current research about a particular topic.**
       After completing the work in this course, students will be able to
       - Provide meaningful and quantitative answers for the questions:
         - What is the nature of matter?
         - How can we predict the properties of matter, and how is the periodic table helpful?
         - What makes chemicals react, and why do reactions go in a particular direction?
         - How can we quantify changes in chemical reactions?
       - Solve quantitative engineering problems more easily problem solving
       - Better appreciate of the richness of chemistry and its influence on your life.

b. **explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course.**

14. Brief list of topics to be covered

- Atomic Structure
- Compounds, Balancing Equations
- Yield, Limiting Reactants, Solutions
- Percent Composition, Combustion Analysis
- Reactions In Aqueous Media
- Bases, Redox Reactions
- Redox Reactions
- Atomic Structure
- Atomic Structure
- Electron Configuration
- Ionic Bonds
- Lewis Dot Structures, Resonance, Formal Charge
- Resonance, Formal Charge, Vsepr
- Valence Bond And Hybridization
- Intro To Thermochemistry
- Hess's Law, Calculating Heats Of Reaction
- Entropy, Gibb's Free Energy, Gas Laws
- Dalton's Law, Kinetic Theory, Real Gases
- Intermolecular Forces
- Phase Changes, Vapor Pressure
- Solids, Phase Diagrams
- Reaction Rates And Orders, Initial Rates
- Integrated Rate Laws, Half-Lives, Mechanisms
- Rate Laws, Arrhenius Equation, Catalysis
- Equilibrium Constants
- Equilibrium Concentrations, Le Chatelier
- More Lechatelier
- Kinetics, Intro To Acids And Base Equilibria
- Ph, Weak Acid/Base Equilibria
- Percent Dissociation, Polyprotic Acids, Salts, Lewis Acids
- Neutralization, Common Ions, Buffers
- Buffers Continued
- Titrations
- Titrations Continued, Solubility
- Solubility, Precipitation
- Entropy And Probability
- Entropy And Thermodynamics
- Free Energy
- Free Energy And Chemical Equilibrium

Course alpha, number, title	**CHEM 1221 Engineering General Chemistry Lab**
Required or elective	Required for all students in degree program
Course description	One hour recitation in which concepts and problems are re-emphasized, homework is collected, and quizzes are given. Three hour lab in which students perform experiments designed to illustrate chemical concepts discussed in CHEN 1211. Also introduction to basic techniques in chemical measurements and synthesis.
Prerequisite(s)	One year high school chemistry or minimum grade of C- in CHEM 1001 or 1021; high school algebra. Coreq., CHEN 1211.
Textbook(s) and/or other required material	There is no textbook but there is a laboratory manual.
Class/Lab schedule	Total Credits: 2 *Recitation 50-minutes 1x/week; lab 3 hrs 1x/wk*
Instructor	Douglas Gin
Topics covered	• Chemical reactions of copper • How acidic is your vinegar? • Atomic Spectroscopy • Ionic and covalent compounds • Enthalpy changes in chemical reactions • identifying an unknown metal from determination of its molar mass • Avogadro's number • Freezing point depression • Kinetics of reactions of the ferroin complex • Equilibrium Studies of the Iron(III) Thiocyanate reaction
Course learning objectives	• to learn how a chemist thinks and works • to discuss difficult points in small recitation classes • to develop experimental skills • to learn how to carefully observe and measure
Relationship of course to program outcomes	<u>Program Outcome</u> **1. an ability to apply knowledge of mathematics, science, and engineering — Large** **2. an ability to design and conduct experiments — Large** **3. an ability to analyze and interpret data — Large** 4. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic,

environmental, social, political, ethical, health and safety, manufacturability, and sustainability N/A

5. an ability to function on multi-disciplinary teams N/A
6. an ability to identify, formulate, and solve engineering problems N/A
7. an understanding of professional and ethical responsibility N/A
8. an ability to communicate effectively through writing and drawings N/A
9. an ability to communicate effectively through oral presentations N/A
10. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context N/A
11. a recognition of the need for, and an ability to engage in life-long learning N/A
12. a knowledge of contemporary issues N/A
13. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice N/A
14. an ability to explain basic concepts in management, business, public policy, and leadership N/A

Contribution to the professional component: 100% Math and Basic Science

CHEN 1310 – Introduction to Computing for Engineers

Course Syllabus

1. **Course number and name**
   CHEN 1310 – Introduction to Computing for Engineers
2. **Credits and contact hours**
   3 credit hours/3 contact hours
3. **Instructor's or course coordinator's name**
   Charlie Nuttelman
4. **Textbook, title, author, and year***:*

   Optional:

   Engineering with Excel, Fourth Addition. Larsen, Ronald W. Pearson Prentice Hall

   Matlab for Engineers, Third Edition. Moore, Holly. Pearson Prentice Hall.

   a. **other supplemental materials**
      Subscription to Top Hat (www.tophat.com)
      MatLab

5. **Specific course information**
   a. **brief description of the content of the course (catalog description)**
      Introduces the use of computers in engineering problem solving, including elementary numerical methods. Teaches programming fundamentals, including data and algorithm structure, and modular programming. Software vehicles include Excel/VBA and Matlab. Formerly GEEN 1300 and COEN 1300.
   b. **prerequisites or co-requisites**
      APPM 1340, 1345, or 1350, or MATH 1300
   c. **indicate whether a required, elective, or selected elective (as per Table 5-1) course in the program.**

6. **Specific goals for the course**
   a. specific outcomes of instruction, ex. The student will be able to explain the significance of current research about a particular topic.

   b. explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course.
7. **Brief list of topics to be covered**

Course number, name	**CVEN 2121: Analytical Mechanics 1 (Statics)**
Credits and contact hours	3-credits, three 50-min lectures per week
Instructor(s)	Assist. Prof. Petros Sideris, PhD, E.I.T
Textbook, Other materials	*Engineering Mechanics – Statics* by R. C. Hibbeler, 14th Edition, Prentice Hall/ Pearson. Supplemental notes provided by the instructor
Course description	Application of mechanics to the study of static equilibrium of rigid and elastic bodies. Topics include composition and resolution of forces; moments and couples; equivalent force systems; free-body diagrams; equilibrium of particles and rigid bodies; forces in trusses and beams; frictional forces; first and second moments of area; moments and products of inertia
Prerequisite(s)	PHYS 1110, APPM 2350
Required or elective	Required for all students in degree program
Course learning objectives	1) Calculate the resultant forces and moments in 2D and 3D systems. 2) Draw free-body diagrams for particles and rigid bodies. 3) Solve particle and rigid body problems using the principle of static equilibrium. 4) Analyze 2D trusses using methods of joints and methods of sections. 5) Calculate internal forces in a beam and plot axial-force, shear-force and bending-moment diagrams. 6) Calculate the location of the center of gravity and the centroid of a given shape/volume. 7) Calculate moment of inertia for an area/volume over a given rotational axis.

Relationship of course to program outcomes

Program Outcome	Emphasis
1. an ability to apply knowledge of mathematics, science, and engineering	**Large**
2. an ability to design and conduct experiments	None
3. an ability to analyze and interpret data	None
4. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	None
5. an ability to function on multi-disciplinary teams	None

	6. an ability to identify, formulate, and solve engineering problems	**Large**
	7. an understanding of professional and ethical responsibility	Small
	8. an ability to communicate effectively through writing and drawings	Medium
	9. an ability to communicate effectively through oral presentations	None
	10. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	Medium
	11. a recognition of the need for, and an ability to engage in life-long learning	Medium
	12. a knowledge of contemporary issues	Small
	13. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	Medium
	14. an ability to explain basic concepts in management, business, public policy, and leadership	None
List of topics covered	1. Introduction (Concepts, Units, Calculations, Analysis Procedures) 2. Force Vectors 3. Equilibrium of a Particle 4. Systems of Forces and Moments 5. Equilibrium of a Rigid Body 6. Structural Analysis of Trusses 7. Internal Axial/Shear Forces and Moments 8. Centroids & Centers of Gravity 9. Moments of Inertia 10. Friction	
Contribution to the professional component	100% Engineering Science	

Prepared by: Petros Sideris, 10/08/2016

Course number, name	**CVEN3161 Mechanics of Materials I**	
Credits and contact hours	3-credits, three 50-min lectures per week	
Instructor(s)	Prof.Yunping Xi, PhD, Full Professor	
Textbook, Other materials	Roy R. Craig, Jr. (2000) "Mechanics of Materials", John Wiley & Sons, New York	
Course description	Addresses concepts of stress and strain; material properties, axial loading, torsion, simple bending, and transverse shear; analysis of stress and strain; and deflections of beams. Includes selected experimental and computational laboratories.	
Prerequisite(s)	CVEN 2121 Analytical Mechanics 1. CVEN 2360 Introduction to Differential Equations with Linear Algebra	
Required or elective	Required for all students in degree program	
Course learning objectives	1. The ability to find analytical solution of a single structural member under different loading conditions, such as tension, compression, torsion, and bending. The analytical solution includes selection of cross section and examination of safety of a structural member. 2. The ability to analyze stress and strain states and find the principal stresses and strains. 3. The ability to establish stress-strain relation of brittle and ductile materials based on hands-on experience of tensile, compressive, and torsional testing of various construction materials. 4. The ability to analyze test data and write laboratory reports.	
Relationship of course to program outcomes	Program Outcome	Emphasis
	1. an ability to apply knowledge of mathematics, science, and engineering	**Large**
	2. an ability to design and conduct experiments	Medium
	3. an ability to analyze and interpret data	Large
	4. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	Small
	5. an ability to function on multi-disciplinary teams	None
	6. an ability to identify, formulate, and solve engineering problems	Medium
	7. an understanding of professional and ethical responsibility	Small
	8. an ability to communicate effectively through writing and drawings	**Large**
	9. an ability to communicate effectively through oral presentations	Small

	10. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	Small
	11. a recognition of the need for, and an ability to engage in life-long learning	Medium
	12. a knowledge of contemporary issues	Small
	13. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	**Large**
	14. an ability to explain basic concepts in management, business, public policy, and leadership	Small
List of topics covered		
Contribution to the professional component	80% Engineering Science 20% Engineering Design	
Prepared by:	Yunping Xi, 11/10/2016	

Course number, name	**CVEN 3246 Introduction to Construction**	
Credits and contact hours	3-credits, two 75-min lectures per week	
Instructor(s)	Prof. Matthew R. Hallowell, PhD	
Textbook, Other materials	Knutson, K., Schexnayder, C., Fiori, C. and Mayo, R. (2004). "Construction management fundamentals 2nd edition" McGraw Hill, New York, NY.	
Course description	Broad view of concerns, activities, and objectives of people involved in construction: the owner, architect/engineer, contractor, labor, and inspector. Interactive gaming situation relates these people to the construction contract, plans/specifications, estimates/bids, scheduling, law, and financial management. Students with a Business School Real Estate emphasis may be considered for this course.	
Prerequisite(s)	None	
Required or elective	Required for all students in degree program	
Course learning objectives	1. Describe the roles of key project players 2. Select an appropriate project delivery method for a construction project 3. Estimate the cost of a basic structure or roadway 4. Calculate the equivalence of a series of economic investments 5. Schedule a series of construction tasks using the critical path method 6. Analyze a balance sheet 7. Identify the requisite elements of a contract 8. Identify and analyze project risks 9. Identify and assess hazards on construction projects	
Relationship of course to program outcomes	<u>Program Outcome</u>	<u>Emphasis</u>
	1. an ability to apply knowledge of mathematics, science, and engineering	None
	2. an ability to design and conduct experiments	None
	3. an ability to analyze and interpret data	None
	4. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	Medium
	5. an ability to function on multi-disciplinary teams	Small
	6. an ability to identify, formulate, and solve engineering problems	None
	7. an understanding of professional and ethical responsibility	Medium

	8. an ability to communicate effectively through writing and drawings	Small
	9. an ability to communicate effectively through oral presentations	Small
	10. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	Medium
	11. a recognition of the need for, and an ability to engage in life-long learning	Small
	12. a knowledge of contemporary issues	Medium
	13. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	None
	14. an ability to explain basic concepts in management, business, public policy, and leadership	Medium
List of topics covered	Project contracts Project delivery strategies Introduction to basic risk analysis Project controls Engineering economics Productivity measurement Hazard recognition and construction safety	
Contribution to the professional component	90% Engineering Science 10% Engineering Design	
Prepared by:	Matthew Hallowell, 11/1/2016	

Course number, name	**CVEN 3256 Construction Equipment and Methods**
Credits and contact hours	3-credits, three 50-min lectures per week
Instructor(s)	Paul M. Goodrum, PhD, PE and Matthew R. Hallowell, PhD
Textbook, Other materials	Peurifoy, R., Schexnayder, C., Shapira, A., and Schmidt, R. (2010). Construction Planning, Equipment, and Methods. 8th Edition. McGraw-Hill. Readings regarding construction formwork design from: Nunnally, S. W., Construction Methods and Management, 6th Ed., Prentice-Hall, 2003. Additional Material & References will also be used.
Course description	Integrated study of construction equipment, methods, and economics. Topics include equipment productivity, equipment selection, and construction engineering design within economic constraints. Examples include earthmoving, concrete formwork, and temporary construction.
Prerequisite(s)	CVEN 3246 – Introduction to Construction Engineering
Required or elective	Elective and can be taken as a proficiency course in construction engineering and management
Course learning objectives	1. Understand the different measurements and assessment techniques of productivity 2. Understand how to estimate earthwork volumes 3. Understand how to estimate production rates of excavators, tractors, dozers, and scrapers 4. Understand how to determine safe lifting capacities of cranes 5. Understand how to estimate production rates of loaders and haulers 6. Understand the methodology and how to estimate production rates of compaction and finishing 7. Understand the methodology of rock excavation 8. Understand the methodology of concrete construction 9. Understand the methodology of timber construction 10. Understand the methodology of steel construction 11. Understand the design procedures of temporary support systems including formwork design, scaffolding, and shoring.

Relationship of course to program outcomes

Program Outcome	Emphasis
1. an ability to apply knowledge of mathematics, science, and engineering	**Large**
2. an ability to design and conduct experiments	None
3. an ability to analyze and interpret data	Medium
4. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic,	**Large**

	environmental, social, political, ethical, health and safety, manufacturability, and sustainability	
	5. an ability to function on multi-disciplinary teams	Small
	6. an ability to identify, formulate, and solve engineering problems	Medium
	7. an understanding of professional and ethical responsibility	Medium
	8. an ability to communicate effectively through writing and drawings	Medium
	9. an ability to communicate effectively through oral presentations	Medium
	10. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	Small
	11. a recognition of the need for, and an ability to engage in life-long learning	Low
	12. a knowledge of contemporary issues	Medium
	13. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	Medium
	14. an ability to explain basic concepts in management, business, public policy, and leadership	Medium
List of topics covered	1. Construction Productivity 2. Construction Modeling 3. Earthwork Fundamentals 4. Tractors, Dozers, and Rippers 5. Construction Equipment Economics 6. Scrapers and Excavators 7. Cranes and Heavy Lift Planning 8. Loaders and Haulers 9. Compaction and Finishing 10. Rock Excavation 11. Asphalt & Concrete Paving 12. Foundation Systems 13. Concrete Construction 14. Timber Construction 15. Steel Construction 16. Formwork Design	
Contribution to the professional component	70% Engineering Science 30% Engineering Design	

Course number, name	**CVEN 3525 Structural Analysis**
Credits and contact hours	3-credits, two 75-min lectures per week
Instructor(s)	Prof. Victor Saouma, PhD
Textbook, Other materials	Hibbeler R.C., *Structural Analysis*, Prentice Hall, 9th ed. Various Handouts, papers.
Course description	This introductory course will provide the technical foundation to properly understand the analysis of statically determinate (simple) and indeterminate (complex) structures such as cables, trusses, frames, arches. Whereas emphasis will be on 2D structures, students will also be exposed to some 3D cases. Techniques of analysis include flexibility (hand calculation) and stiffness (computer based) methods. They will also be exposed to a widely used commercial program for the analysis of structure, and will be encouraged to program in Matlab and use Mathcad for their assignments. There will be at least one presentation by a Structural Engineer who will discuss the challenges of the profession.
Prerequisite(s)	Cven 3161
Required or elective	prerequisite to CVEN-4545 (Steel Design), CVEN-4555 (Reinforced Concrete Design), CVEN-4525 Matrix Analysis
Course learning objectives	Acquire abilities to 1. Apply knowledge of mathematics, science, and engineering 2. Identify, formulate, and solve engineering problems. 3. Communicate effectively through writing and drawings 4. Use the techniques, skills, and modern engineering tools necessary for engineering practice

Relationship of course to program outcomes	Program Outcome	Emphasis
	1. an ability to apply knowledge of mathematics, science, and engineering	Large
	2. an ability to design and conduct experiments	None
	3. an ability to analyze and interpret data	None
	4. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	Small
	5. an ability to function on multi-disciplinary teams	None
	6. an ability to identify, formulate, and solve engineering problems	**Large**
	7. an understanding of professional and ethical responsibility	None

	8. an ability to communicate effectively through writing and drawings	Small
	9. an ability to communicate effectively through oral presentations	None
	10. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	Medium
	11. a recognition of the need for, and an ability to engage in life-long learning	Medium
	12. a knowledge of contemporary issues	None
	13. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	**Large**
	14. an ability to explain basic concepts in management, business, public policy, and leadership	None
List of topics covered	Analysis of statically indeterminate 2D and 3D structures; Flexibility method. Stiffness method. Curv ed members.	
Contribution to the professional component	90% Engineering Science 10% Engineering Design	
Prepared by:	Victor Saouma, 10/31/2016	

Course number, name	CVEN4161 Mechanics of Materials II
Credits and contact hours	3-credits, three 50-min lectures per week
Instructor(s)	Prof.Yunping Xi, PhD, Full Professor
Textbook, Other materials	Boresi, A.P., and Schmidt, R.J. (2003) "Advanced Mechanics of Materials", the sixth edition, John Wiley & Sons, New York. Roy R. Craig, Jr. (2011) "Mechanics of Materials", John Wiley & Sons, New York
Course description	Addresses concepts of elastic and inelastic material properties, buckling of columns, torsion analysis of members of noncircular cross sections, nonsymmetric bending, shear center, 3D analysis of stress and strain; anisotropic Hooke's law, and failure theories. Includes selected experimental and computational laboratories.
Prerequisite(s)	CVEN 3161 Mechanics of Materials I
Required or elective	Required for all students in degree program
Course learning objectives	1. The ability to find analytical solution of a single structural member under different loading conditions, such as compression, torsion on noncircular cross sections, and bending on nonsymmetric cross sections. The material behaviors include isotropic and anisotropic, elastic and inelastic behaviors. 2. The ability to analyze stress and strain states and find the principal stresses and strains in 3D loading configurations. The analytical solution includes selection of cross section and examination of safety of a structural member using various 3D failure theories. 3. The ability to determine buckling load of columns, shear center of nonsymmetric cross sections, and elastic parameters of anisotropic materials based on hands-on experience of lab testing on different construction materials. 4. The ability to analyze test data and write laboratory reports.

Relationship of course to program outcomes

Program Outcome	Emphasis
1. an ability to apply knowledge of mathematics, science, and engineering	**Large**
2. an ability to design and conduct experiments	Medium
3. an ability to analyze and interpret data	**Large**
4. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	Small
5. an ability to function on multi-disciplinary teams	None
6. an ability to identify, formulate, and solve engineering problems	Medium
7. an understanding of professional and ethical responsibility	Small
8. an ability to communicate effectively through writing and drawings	**Large**

	9. an ability to communicate effectively through oral presentations	None
	10. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	Small
	11. a recognition of the need for, and an ability to engage in life-long learning	Medium
	12. a knowledge of contemporary issues	Small
	13. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	**Large**
	14. an ability to explain basic concepts in management, business, public policy, and leadership	Small
List of topics covered	1. Buckling of Columns Euler load and differential equation of beam-column Critical loads of perfect columns with various end conditions Imperfect columns and Southwell plot Code specifications 2. Torsion Thin wall members; Noncircular members; Plastic torsion 3. Bending Nonsymmetric bending; Thin wall and built-up beams Shear center; Inelastic bending 4. 3D Stress and Strain Analysis 3D state of stress Stress transformation: principal directions and principal stresses 3D state of strain Strain transformation: principal directions and principal strains 5. Anisotropic elastic materials (wood and fiber reinforced polymers) Hooke's law for anisotropic elastic materials Applications to fiber reinforced polymers (thin FRP sheets and FRP bars) Applications to fiber reinforced concrete (effective properties of composites) 6. Theories of Strength Failure Maximum principal stress criterion and maximum principal strain criterion Van Mises and Tresca criteria Mohr-Coulomb failure criterion Factor of safety Failure theories for anisotropic materials	
Contribution to the professional component	80% Engineering Science 20% Engineering Design	
Prepared by:	Yunping Xi, 02/19/2017	

Course number, name	**CVEN 4545 Steel Design**
Credits and contact hours	3 credits, 2 – 75min lectures per week
Instructor(s)	George Hearn
Textbook, Other materials	AISC Steel Construction Manual, 14th ed. Course notes and design project writeup posted at course website
Course description	Applies basic principles of structural engineering and mechanics to design of steel structures; design of tension members, columns, beams, open-web joists, steel decks, bolts, bolted connections, welding processes, and welded connections.
Prerequisite(s)	CVEN 3525
Required or elective	Elective – CVEN proficiency course
Course learning objectives	Ability to design steel decks, beams, columns and braces for low rise buildings

Relationship of course to program outcomes

Program Outcome	Emphasis
1. an ability to apply knowledge of mathematics, science, and engineering	Small
2. an ability to design and conduct experiments	None
3. an ability to analyze and interpret data	None
4. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	**Large**
5. an ability to function on multi-disciplinary teams	None
6. an ability to identify, formulate, and solve engineering problems	None
7. an understanding of professional and ethical responsibility	**Small**
8. an ability to communicate effectively through writing and drawings	None
9. an ability to communicate effectively through oral presentations	None
10. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	None
11. a recognition of the need for, and an ability to engage in life-long learning	Small
12. a knowledge of contemporary issues	None

	13. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	None
	14. an ability to explain basic concepts in management, business, public policy, and leadership	None
List of topics covered	Steel material, properties Rolled shapes Steel deck, Concrete slabs in steel deck Steel bar joists Steel beams, moment strength, shear strength Steel columns Bolted steel connections Welded steel connections	
Contribution to the professional component	10% Engineering Science 90% Engineering Design	
Prepared by:	George Hearn 10/31/2016	

Course number, name	CVEN 4555 Reinforced Concrete Design
Credits and contact hours	3 credits, 2 – 75min lectures per week
Instructor(s)	George hearn
Textbook, Other materials	ACI318-14 Building Code Requirements for Structural Concrete Course notes and design project writeup posted at course website
Course description	Applies basic principles of structural engineering and mechanics to the design of reinforced concrete structures, including design of beams, columns, slabs, and footings; continuous beams and frames; cast-in-place buildings.
Prerequisite(s)	CVEN 3525
Required or elective	Elective – CVEN proficiency course
Course learning objectives	Ability to design non-prestressed, reinforced concrete slabs, joists, beams and columns for low-rise buildings.

Relationship of course to program outcomes

Program Outcome	Emphasis
1. an ability to apply knowledge of mathematics, science, and engineering	Small
2. an ability to design and conduct experiments	None
3. an ability to analyze and interpret data	None
4. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	**Large**
5. an ability to function on multi-disciplinary teams	None
6. an ability to identify, formulate, and solve engineering problems	None
7. an understanding of professional and ethical responsibility	Small
8. an ability to communicate effectively through writing and drawings	None
9. an ability to communicate effectively through oral presentations	None
10. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	None
11. a recognition of the need for, and an ability to engage in life-long learning	Small

	12. a knowledge of contemporary issues	None
	13. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	None
	14. an ability to explain basic concepts in management, business, public policy, and leadership	None
List of topics covered	Concrete materials, concrete reinforcing steel One-way slabs: moment strength, shear strength, reinforcement limits, reinforcement detailing. Beams, Tee beams: moment strength, shear strength, reinforcement limits, reinforcement detailing. Short columns: Axial load strength, moment strength, interaction of compression and bending, reinforcement limits, reinforcement detailing Slender columns: moment magnification, interaction of compression and bending	
Contribution to the professional component	10% Engineering Science 90% Engineering Design	
Prepared by:	George Hearn 10/31/2016	

ECEN 3030 – Electrical/Electronics Circuits for Non-Majors

Course Syllabus

1. **Course number and name**
   ECEN 3030 – Electrical/Electronics Circuits for Non-Majors
2. **Credits and contact hours**
   3 credit hours/3 contact hours
3. **Instructor's or course coordinator's name**
   Mohammed Hadi.
4. **Textbook, title, author, and year**
   Essentials of Electrical and Computer Engineering, Kerns, Irwin, Pearson - Prentice Hall.
    a. **other supplemental materials**

5. **Specific course information**
    a. **brief description of the content of the course (catalog description)**
       For students not majoring in electrical engineering. Covers analysis of electric circuits by use of Ohm's law; network reduction; super position; node and loop analysis; Thevenin's and Norton's theorems; sinusoidal signals; phasors; power in ac circuits; transient response of simple circuits; operational amplifiers; logic circuits; and flip-flops. Restricted to nonmajors. (Same as GEEN 3854.)
    b. **prerequisites or co-requisites**
       APPM 2360.
    c. **indicate whether a required, elective, or selected elective (as per Table 5-1) course in the program.**

6. **Specific goals for the course**
    a. **specific outcomes of instruction, ex. The student will be able to explain the significance of current research about a particular topic.**

    b. **explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course.**
7. **Brief list of topics to be covered**
   - Concepts of charge, forces between charges, electrical power and energy, conductors and insulators.
   - Circuit analysis using Kirchhoff's laws, node /loop analysis, superposition, Thevenin/Norton Theorems.
   - 1st and 2nd order transient analysis of dynamic circuits using resistors, capacitors and inductors.
   - Complex numbers.
   - AC steady state analysis using phasors.
   - Steady State Power Analysis, complex power, average power, apparent power, power factor correction.
   - Magnetic Coupled circuits, mutual inductance, transformers.
   - Electrical network frequency characteristics, filters, resonant circuits.

- Ideal Op-Amps, analog computation.
- Terminal characteristics of diodes, rectification circuits.
- Electrical motors: DC, AC Poly-phase Induction and Synchronous machines.

ENVD 3114: History & Theories of Environmental Design: Buildings

Course Syllabus

1. **Course number and name**
   ENVD 3114: History & Theories of Environmental Design: Buildings

2. **Credits and contact hours**
   3 Credit Hours

3. **Instructor's or course coordinator's name**
   Georgia Lindsay, PhD

4. **Text book, title, author, and year**
   World Architecture: A Cross-Cultural History, by Richard Ingersoll and Spiro Kostof (Oxford University Press, 2013)

   a. **other supplemental materials**
      iClicker+

5. **Specific course information**
   a. **brief description of the content of the course (catalog description)**
      Focusing on buildings, this class surveys the built environment from the beginning ot time through the present day. Emphasizing developments in the western world, it develops student's recognition of major styles, influential people, and drivers of building form.

   b. **prerequisites or co-requisites**
      none.

   c. **indicate whether a required, elective, or selected elective (as per Table 5-1) course in the program.**

6. **Specific goals for the course**
   a. **Specific outcomes of instruction. ex: the student will be able to explain the significance of current research about a particular topic.**
      At the end of the course, "A" students will have a working knowledge of and familiarity with the major buildings from the architectural canon, an understanding of the way context (climate, culture, and economy) influences buildings, and an in-depth understanding of a topic in environmental design of their choice. Students will also have competency in visual literacy, library research, and argumentative writing skills.

   b. **explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course.**

7. **Brief list of topics to be covered**

- Prehistory
- Pyramids

- Buddhist Architecture
- Greek Architecture
- Early Architecture
- Roman Architecture
- Islamic Architecture
- Eastern palaces
- Christian architecture: Byzantine, Gothic, Renaissance
- Baroque; villas
- Monuments
- Neoclassical architecture
- Secular architecture: train stations and homes in the Gilded Age
- How to write a successful outline
- House styles: the house as consumption
- The Chair
- Museums and Prisons
- Writing your final paper
- Kathy Corbett: Purgatory River
- Using History as Inspiration
- Early Modernism
- Modernism and post-modernism
- Shawhin Roudbari: Activism and Architecture

ENVD 3134. History and Theory of Environmental Design: Landscape

Course Syllabus

1. **Course number and name**
   ENVD 3134. History and Theory of Environmental Design: Landscape

2. **Credits and contact hours**
   3 credits; 3 hours/week

3. **Instructor's or course coordinator's name**
   Victoria Derr, Ph.D. Senior Instructor

4. **Text book, title, author, and year**
   Landscape Design: A Cultural and Architectural History. E.B.Rogers. New York: Abrams Press 2001
   1. **other supplemental materials**
      Illustrated History of Landscape Design. Chip Sullivan and Elizabeth Boults. New York: John Wiley & Sons. 2010

5. **Specific course information**
   a. **brief description of the content of the course (catalog description)** Focuses on design projects not in a building envelope, including landscapes, public and private urban spaces, complexes and similarly scaled design projects. Aspects of architectural and planning thinking are interwoven in a landscape concentration.

   b. **prerequisites or co-requisites**
   None.

   c. **indicate whether a required, elective, or selected elective (as per Table 5-1) course in the program.**

6. **Specific goals for the course**
   a. **Specific outcomes of instruction. ex: the student will be able to explain the significance of current research about a particular topic.**
   Students should be able to identify major historical and theoretical movements in landscape architecture and relate each to its cultural, environmental, intellectual, economic and political contexts; describe the main concepts of a number of design landscapes - explaining the processes by which human creativity and agency invest capital resources and artistic expression into recognizable, meaningful landscapes; diagram a clear framework of processes, ideas, elements, periods, and geographic regions in which the rich diversity of landscape and hits history can be organized and understood across time; analyze the underlying principles of landscape design and investigate their larger cultural contexts.

   b. **explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course.**

6. **Brief list of topics to be covered**
   - Biophilic Design
   - Magic, Myth, and Nature
   - Middles Ages: European Medieval, Moorish & Islamic, Chinese & Japanese Gardens
   - Renaissance & Baroque Landscape Architecture
   - Court and City in European Grand Manner
   - Intellectual History: The Picturesque and Cross-Cultural Appropriations
   - Social History": 19th Century Parks & Botanic Gardens
   - Monuments and Cemeteries
   - Social History: The City Beautiful Movement
   - Cultural History: National Park Ideal
   - Economics: From the Country Place Era to the new Deal
   - Modernism and City Planning
   - Modernist Gardens and Landscapes of Consumerism
   - Cultural Geography: The everyday and the designed landscape
   - Environmental Art
   - Landscape Urbanism and its Discontents
   - Sustainable Design, Resilience, and Advocacy: Restored and Restorative Landscapes.
   - Sustainable Design, Resilience, and Advocacy: Sustainable Campus Design and Learning Landscapes
   - Sustainable Design, Resilience, and Advocacy: Food Systems and Guerilla Gardens

GEEN 1400. First-Year Engineering Projects

Course Syllabus

1. **Course number and name**
   GEEN 1400. First-Year Engineering Projects

2. **Credits and contact hours**
   3 Credit Hours. 15 hours lecture; 60 hours lab.

3. **Instructor's or course coordinator's name**
   Derek Reamon, course coordinator.

4. **Text book, title, author, and year**
   Introductory Engineering Design: A Projects-Based Approach. Third Edition. (Optional)
   https://itll.colorado.edu/courses_workshops/geen_1400/resources/textbook/

   a. **other supplemental materials**

5. **Specific course information**
   a. **brief description of the content of the course (catalog description)**
   First-year students solve real engineering design problems in interdisciplinary teams. Design projects vary by section. Curriculum focuses on iterative design process, teamwork and team dynamics, supporting design with testing and analysis, and technical writing. Completed projects are exhibited at an end-of-semester design expo. Students responsible for contributing towards their design project budget and poster costs, and purchasing safety glasses (approximately $75).

   a. **prerequisites or co-requisites**
   None.

   b. **indicate whether a required, elective, or selected elective (as per Table 5-1) course in the program.**
   This is a required course for Mechanical Engineering, Environmental Engineering and Aerospace Engineering majors. It is optional for all other engineering majors.

6. **Specific goals for the course**
   a. **Specific outcomes of instruction. ex: the student will be able to explain the significance of current research about a particular topic.**
   - Introduction to engineering as a career. Conceptually understands engineering as a field, and its difference from, and interaction with, science and math; appreciates how engineering pervades society and drives societal change; gains insight into the various engineering disciplines; considers engineering as a possible career.
   - Introduction to engineering methodology. Understand the role of analysis in design.;familiar with appropriate computer software; solves engineering problems; effectively uses hand tools; effectively uses manufacturing processes.
   - Open-ended hands-on design experiences. Familiar with iterative design process; able to define functional requirements and client specifications, if appropriate;

generates alternative design concepts; applies structured decision analysis; works within constraints (e.g., budgets); makes environmental and universal design considerations, as appropriate.

- Development of communication skills (oral, written, team, client/adviser). Develops a relationship with an engineering faculty member; develops technical writing, oral presentation and client communication skills as appropriate for project.
- Teamwork skills. Learns and practices effective teamwork skills (e.g., multi-tasking, group leadership, brainstorming, information gathering, team-based decision-making); learns to rely on other team members to give and receive help; demonstrates dedication and commitment to team objectives; and increased understanding of diversity; practices realistic self-evaluation as a team member; learns and practices conflict resolution; develops relationships with other engineering students that extend beyond FYEP.

b. **explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course.**

7. **Brief list of topics to be covered**

a. Social Styles – introduction to basic working social styles, emphasizing that diverse styles lead to higher functioning teams. Distinct from personality type.
b. Team Dynamics Exercises - fun, moderately physical activities and problem-solving games in which students work together to solve a variety of interesting challenges.
c. Intro Project – one or two short (1-2 week) projects to introduce students to iterative design process in fun, hands-on way
d. Main Project – Most of the course is spent working on the main design project. Students have weekly meetings and regular deliverables, including prototype demonstration, preliminary design review, critical design review and demonstration of final hardware. Main projects vary by instructor and may include: Rube Goldberg Contraptions, Interactive Learning Exhibits, Appropriate Technological Systems for the Developing World, Assistive Technology, Fun with Fluids and Lego® Robots.
e. Workshops - throughout the semester will introduce students to some of the hands-on skills students will need to work on their projects, such as shop safety, computer-aided design, circuit design and soldering, and programming microcontrollers.
f. Ethics – an interactive introduction to the importance of ethics in engineering, focusing on the unique training and skills held by practicing engineers.
g. Guest Lectures - throughout the course will be presented by an engineer or faculty member from a sampling of engineering disciplines. They will describe a research and/or design project they are working on to give students a flavor of the various engineering disciplines.
h. Design Expo – students demonstrate final projects and display summary of design process. Engineers from local industry serve as judges. Public event with up to 2000 attendees.

PHYS 1110. General Physics I

Course Syllabus

1. **Course number and name**

PHYS 1110. General Physics I

2. **Credits and contact hours**
   4 credit hrs, 3 lecture hrs + 1 recitation hr per week contact

3. **Instructor's or course coordinator's name**
   Two or three faculty members are assigned to this course and the faculty change every semester. In Spring 1, the instructors were Dr. Daniel Bolton, and Professor Ed Kinney .

4. **Text book, title, author, and year**
   Essential University Physics, Volume 1, 3rd Edition. Richard Wolfson, Addison-Wesley.
   Tutorials in Introductory Physics, McDermott et al., Custom CU edition.

   a. **other supplemental materials**
      Access to the online homework system MasteringPhysics
      Access to the online prelecture videos on FlipItPhysics
      An iClicker that is registered on D2L

5. **Specific course information**
   a. **brief description of the content of the course (catalog description)**
      Three lect., one rec. per week, plus three evening exams in the fall and spring semesters. First semester of three-semester sequence for science and engineering students. Covers kinematics, dynamics, momentum of particles and rigid bodies, work and energy, gravitation, simple harmonic motion and introduction to thermodynamics. Approved for GT-SC2. Approved for arts and sciences core curriculum: natural science.

   b. **prerequisites or co-requisites**
      Prereq or Coreq: APPM 1345 or APPM 1350 or MATH 1300 or MATH 1310

   c. **indicate whether a required, elective, or selected elective (as per Table 5-1) course in the program.** *(leave blank if you are unsure)*

6. **Specific goals for the course**
   a. **Specific outcomes of instruction. ex: the student will be able to explain the significance of current research about a particular topic.**
      Students should understand that learning does not mean memorizing answers to specific questions; instead, learning means understanding general strategies, and developing robust internal models which permit one to recognize which strategy is appropriate and how to apply it. In this course, there are two broad strategies that students should master.

      - Newton's Laws. Given appropriate initial conditions of a classical mechanical system, the student should be able to compute the subsequent motion by applying Newton's Laws. This requires mastery of concepts in kinematics and dynamics, and knowing how to apply Newton's Laws in for both translational and rotational motions.

- Conservation Laws. By comparing a known initial state of a system and a partly-known final state, the student should be able to apply one of the conservation laws (energy, momentum, or angular momentum) to determine the final state of the system.

b. **explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course.**

7. **Brief list of topics to be covered**

Vector Math and Kinematics: velocity and acceleration in 1D and 2D.

Newtonian mechanics

b. Newton's Laws
c. Work and Energy
d. Gravitation
e. Linear Momentum and collisions
f. Rotational motion and angular momentum
g. Simple Harmonic Motion

Fluids.

Introduction to thermodynamics: Calorimetry, changes of phase; heat transport; 1st Law of Thermodynamics, 2nd Law of Thermodynamics.

PHYS 1120 General Physics 2

Course Syllabus

7. **Course number and name**
   PHYS 1120

8. **Credits and contact hours**
   Credits and contact hours: 4 credit hrs; 3 lecture hrs + 1 recitation hr per week contact

9. **Instructor's or course coordinator's name**
   Dr. Michael Dubson

10. **Text book, title, author, and year**
    Tutorials in Introductory Physics, McDermott et al., Prentice-Hall 2013, (Custom CU edition)
    a. **other supplemental materials**
       FlipItPhysics subscription
       MasteringPhysics subscription
       iClicker

11. **Specific course information**
    a. **brief description of the content of the course (catalog description)**
       Three lect., one rec. per week, plus three evening exams in the fall and spring semesters. Second semester of three-semester introductory sequence for science and engineering students. Covers electricity and magnetism, wave motion, and optics. Normally is taken concurrently with PHYS 1140. Approved for GT-SC2. Approved for arts and sciences core curriculum: natural science.

    b. **prerequisites or co-requisites**
       Prereq: PHYS 1110 and prereq or coreq of APPM 1360 or MATH 2300

    c. **indicate whether a required, elective, or selected elective (as per Table 5-1) course in the program.** *(leave blank if you are unsure)*

12. **Specific goals for the course**
    a. **Specific outcomes of instruction. ex: the student will be able to explain the significance of current research about a particular topic.**
       Students should understand that learning does not mean memorizing answers to specific questions; instead, learning means understanding general strategies, and developing robust internal models which permit one to recognize which strategy is appropriate and how to apply it. In this course, the general strategy is application of Maxwell's equations. There are two broad categories for applications of Maxwell's equations:
       - Charges, currents, and fields. Given a known distribution of charges and/or currents, students should be able to compute the electric and magnetic fields. Similarly, given the fields, students should be able to compute the forces on and motion of charges.

- Circuit analysis. Students should be able to understand and analyze simple DC and AC circuits containing batteries, resistors, capacitors, and inductors.

b. **explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course.**

7. **Brief list of topics to be covered**
   Static Electric fields, Gauss's Law, Voltage and capacitance, DC Circuits, Magnetic , Fields: Biot-Savart Law and Ampere's Law , Faraday's Law, inductance, Electromagnetic waves and Maxwell's equations, Ray Optics, Wave optics and diffraction (time permitting)

Course Syllabus

1. **Course number and name**
   WRTG 3030: Writing on Science and Society

2. **Credits and contact hours**
   3 credit hours. 2.5 lecture hours per week contact

3. **Instructor's or course coordinator's name**
   Multiple, inlcuding: Rolf Norgaard, Steve Lamos, Don Wilkerson, Lonni Pearce, Petger Schaberg

4. **Text book, title, author, and year**
   Readings and course materials available D2L.
   The Purdue University OWL (on-line writing lab);

   a. **other supplemental materials (depending on section)**
      - *They Say, I Say: The Moves that Matter in Academic Writing*, Graff and Birkenstein, WW Norton & Co.
      - *Writing Science: How to Write Papers hat Get Cited and Proposals that Get Funded.* Schimel, Oxford UP 2012
      - The Colorado State University Writing Center, which offers an array of writing & teaching resources: http://writing.colostate.edu/
      - College-level writing handbook
      - The Colorado State University "WAC Clearinghouse," which supports scholarly exchange about communication across the curriculum: http://wac.colostate.edu/

5. **Specific course information**
   a. **brief description of the content of the course (catalog description)**
   Through selected reading and writing assignments, students consider ethical and social ramifications of science policy and practice. Focuses on critical thinking, analytical writing, and oral presentation. Taught as a writing workshop, the course addresses communication with professional and non-technical audiences. May be repeated up to 6 total credit hours. Approved for GT-C03. Approved for arts and sciences core curriculum: written communication.

      a. **prerequisites or co-requisites**
      none

      b. **indicate whether a required, elective, or selected elective (as per Table 5-1) course in the program.** *(leave blank if you are unsure)*

6. **Specific goals for the course**
      a. **Specific outcomes of instruction. ex: the student will be able to explain the significance of current research about a particular topic.**

      Critical Thinking and Its Written Application; The Writing Process; Rhetorical Situation; Mechanics and Style. Fulfills the course criteria given to all state institutions by the Colorado Commission on Higher Education. In other words, this writing class is not just about what your writing teacher here at CU thinks is important. It's about deepening your skills in rhetorical knowledge, writing processes, and language conventions so that you can write effectively for a variety of audiences in a variety of situations—both inside and outside the classroom.

b. **explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course.**

7. **Brief list of topics to be covered**

Summary/Response; Resume/Cover Letter; Editorial Argument; Rhetorical Analysis; Research Issues and Approach; Final Project. A substantive inquiry into an issue or topic of the student's choice. The project will go through multiples stages of revision, and will reflect the conventions of an appropriate science, technical communication, or professional writing genre.

Evaluating Disciplinary Scientific Argument; Evaluating Popular Scientific Argument; Research in a Disciplinary Genre; Research "accommodation" in a Popular Genre.

Social & Professional Context; Rhetorical Knowledge; Best Practices for Revision; The Writing Process; The Concept of Genre and Science Writing for a Specialized Audience; Compiling Annotated Bibliography; Deliberative Discourse; Adopting the Ethos of Education not Debater; Defining Terms and Illustrating Claims; Developing Evidence; Making Clear Transitions; Revising for Brevity & Clarity; Anticipating & Answering Objections; Emphasizing Best Ideas; The Essay Form; Writing Introductions for Lay & Scientific Audiences; Paraphrase and Citation; How to Write Developmental, Results, Discussion, and Conclusion, Sections; Voice and Style.

Rhetorical essays including techniques of thesis-building, evidential support, organization, and rhetorical awareness; Research Proposals for funding agencies; Academic Articles including annotated bibliography & disciplinary Analysis.

Rhetorical Framework; Resumes and Professional Writing; Communicating Science; White Papers; Project Development & Science in the Public Sphere; Project Proposals and Ethics; White Paper Presentations;

Appendix B – Faculty Vitae

Listed below in alphabetical order are two page CVs organized by program starting with architectural engineering followed by civil faculty members as many contribute to the AREN program. Last are environmental and water resources faculty, as they generally have much lower contributions to the architectural engineering program.

Bernard Amadei **Professor**

EDUCATION	PhD (Civil Eng.), University of California, Berkeley, U.S.A., 1982 MaSc (Civil Eng.), University of Toronto, Canada, 1979 Dipl. Eng./BS (Geol. Eng.), School of Applied Geology & Mining Eng., Nancy, France, 1977
ACADEMIC EXPERIENCE	University of Colorado Boulder, Dept. Civil, Environmental, and Architectural Engineering: Professor (1994-Present); Assoc. Prof (1989-1994), Assistant Prof. (1982-1989) University of Colorado Boulder, Mortenson Center in Engineering for Developing Communities, Director (2009-2012), co-Director (2015-Present) Visiting Professor, Technion University, Israel (2010-2014)
NON-ACADEMIC EXPERIENCE	U.S. Science Envoy to Pakistan and Nepal, U.S. Department of State (2013-14) Founding President, Engineers Without Borders – USA and co-Founder of Engineers Without Borders – International (2002-Present) Independent Consultant in International Development and Geological Engineering (1982-Present) Senior Engineer, J. F. T. Agapito and Associates, Inc., Grand Junction, Colorado (Jan-June, 1982)
PROFESSIONAL REGISTRATIONS	Registered in EU countries but not in US
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	US National Academy of Engineering National Academy of Construction American Society of Civil Engineers International Society for Rock Mechanics American Society of Mechanical Engineers American Rock Mechanics Association Institute of Electrical and Electronics Engineers American Society of Engineering Education
HONORS AND AWARDS	Five honorary doctoral degrees (UMass Lowell; Carroll College; Clarkson, Drexel, and Worcester Polytechnic Institute). 1984 Manuel Rocha Award, International Society for Rock Mechanics. 1992 Schlumberger Lecture Award, Int. Society for Rock Mechanics. 2002 Bank One Colorado Faculty Community Service Award 2005 Am. Association of Engineering Societies Norm Augustine Award 2005 Service Award for Professional Excellence from Rotary International 2006 General Palmer Award from ACEC, Colorado 2006 Ralph Coats Roe Medal, Am. Society of Mechanical Engineers 2007 Hoover Medal from ASCE, ASME, IEEE, AIME, and AIChE 2007 Heinz Foundation Award for the Environment (co-recipient) 2008 Drexel University College of Engineering's Engineer of the Year 2008 Golden Vector Award, Pan American Fed. of Eng. Assoc. (UPADI) 2008 Member of the US National Academy of Engineering 2008 Engineering News Record Award of Excellence 2009 Distinguished Member of the American Society of Civil Engineers 2013 Member of the National Academy of Construction 2015 Washington Award, The Western Society of Engineers 2015 American Society of Civil Engineers, (OPAL) (education) 2016 C. H. Dunn Award of the Construction Industry Institute

INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	**University of Colorado Service** Dept. of Civil, Environmental, & Architectural Engineering (CEAE) Personnel Committee Curriculum Committee (2013-2015) EWB-USA CU Boulder Chapter Advisor Mortenson Center in Engineering for Developing Communities Director. 2009 – 2012; co-Director: 2015-Present **University (non-CU) Service** Consultant to PeaceEng program at Drexel University Summer course development, Technion University **Non-University Service** • Member NAE Award Committee (2017-2018) • U.S. Science Envoy to Pakistan and Nepal, U.S. Dept. of State (2013-14) • Member, NAE/USIP Roundtable on Technology, Science, and Peace building (2011-present) • Member (and co-chair), Board of the PeaceTech laboratory (2014-present) • Member, NRC Committee on USAID Grand Challenges in International Development (2011-2013) • Member, NRC Committee on Increasing National Resilience to Hazards and Disasters (2010-2012) • Founding-President, Engineers Without Borders - USA (2001-present)
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	• *A Systems Approach to Modeling Community Development Projects*. Amadei, B., ISBN-13: 978-1-60650-518-2, Momentum Press, 2015. • *Engineering for Sustainable Human Development*, Amadei, B., ISBN 978-0-7844-1353-1, ASCE Press, Reston, VA, 2014. • “Disaster Resilience: A National Imperative”, contributing committee member, The National Academies Press, 2012. • “A Retrospective Approach to Assessing the Sustainability of the Grand Canal of China”, N. Tsung, R. Corotis, P. Chinowsky, and B. Amadei, *ASCE Journal of Structure and Infrastructure Engineering*, 9(4), pp. 297-316, 2013. • "Integrating sustainable development into a service learning engineering course”, Mintz et al., *ASCE Journal of Professional Issues in Engineering Education and Practice*, doi: 10.1061/ (ASCE) EI. 1943-5541.0000169, 2013. • “Engineering for developing communities at the University of Colorado Boulder: A ten-year retrospective,” R. Sandekian, P. Chinowsky, B. Amadei, *Int. J. Service Learning in Eng*., pp. 62-77, 2015.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	Attended multiple conferences, workshops, and meetings during the past five years dealing with various aspects of system dynamic modeling, GIS, and science diplomacy.

Rajagopalan Balaji Professor

EDUCATION	B Tech, Civil Engineering, National Institute of Technology, Kurukshetra, India, 1989 M Tech, Quality Reliability and Operations Research, Indian Statistical Institute, Calcutta, India, 1991 Ph.D., Civil and Environmental Engineering, Utah State University, 1995
ACADEMIC EXPERIENCE	University of Colorado – Boulder, Professor, 2010-present; Associate Professor, 2007-2010; Assistant Professor, 2000-2007; Fellow of Cooperative Institute for Research in Environmental Sciences (CIRES), 2001-present Utah State University, Logan, UT, Research Assistant Professor, 1997-2003; Graduate Research Assistant, 1991-1995 Columbia University, New York, NY, Adjunct Associate Research Scientist, 200-present; Associate Research Scientist, 1997-2000; Post-Doctoral Research Scientist, 1995-1997
NON-ACADEMIC EXPERIENCE	Alembic Chemicals Ltd., Baroda, India, Intern, summer 1991 Hindustan Cables Ltd., Hyderabad, India, Intern, summer 1990 Engineers India Ltd., Cochin, India, Intern, summer 1988
PROFESSIONAL REGISTRATIONS	
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Geophysical Union American Society of Civil Engineers – Environment and Water Research Institute
HONORS AND AWARDS	Norbert Gerbier - MUMM International Award, World Meteorological Organization, 2009. Partners in Conservation Award, Department of Interior, 2009. Research Development Award, CEAE Department, University of Colorado – Boulder, 2006. College Research Award, College of Engineering and Applied Sciences, University of Colorado, Boulder, CO, 2014 Young Researcher Award, CEAE Department, University of Colorado – Boulder, 2003.
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	Climate Research, Associate Editor (2008 to present) Advances in Water Resources, Associate Editor (2014 to present) Water Resources Research. Associate Editor (2009 to 2015) Geophysical Research Letters. Associate Editor (2004 to 2012) Journal of Hydrologic Engineering (ASCE). Associate Editor (2004 to 2010) State of Colorado. Member of Technical Advisory Committee, Colorado Water Availability Study (2009 to 2011) U.S. Climate Variability and Predictability Research (CLIVAR). Member of Prediction, Predictability and Applications Panel (2007 - 2012)

	American Water Works Association Research Foundation. Member of Project Advisory Committee (March 2006 – October 2009). **University Service** Dept. of Civil, Environmental, & Architectural Engineering (CEAE) Chair, July 2014 - Associate Chair Fall 2010 - 12 Curriculum Committee - Fall 2001 – Spring 2006, Fall 2009 to 2010; Executive Committee - 2012-2014 Faculty Search Committee. 2003-2004, 2006-2007, 2011-12 Co-operative Institute for Research in Environmental Sciences (CIRES) Executive Committee, Member. Spring 2006 – Spring 2008. Promotion Committee of Dr. Xinzhao Chu, Member. Fall 2006 to present. Graduate Student Fellowship Committee. Member, Fall 2004 – Spring 2006, Fall 2009 – Spring 2010; Chair, Fall 2005 – Spring 2006. Visiting Fellows Committee, Member. Fall 2002 – 2004, 2010-2011
PRINCIPAL PUBLICATIONS OF LAST FIVE YEARS	Samson, C., B. Rajagopalan and S. Summers, Modeling Source Water TOC Using Hydroclimate Variables and Local Polynomial Regression, *Environmental Science & Technology,* 50 (8), 4413–4421, 2016 Weirich, S., J. Silverstein and B. Rajagopalan, Resilience of Secondary Wastewater Treatment Plants: Prior Performance Is Predictive of Future Process Failure and Recovery Time, Environmental Engineering Science, 32(3), 222-231, 2015 Pavlak, G., A. Florita, G. Henze and B. Rajagopalan, Probabilistic identification of inverse building model parameters, Journal of Architectural Engineering, 20(2), 04013011, 2014 Verdin, A., B. Rajagopalan, W. Kleiber and R. Katz, Coupled Stochastic Weather Generation Using Spatial and Generalized Linear Models, Stochastic Environmental Research and Risk Assessment (SERRA), special issue, 29(2), 347-356, 2015 Bracken, C., B. Rajagopalan, M. Alexander and S. Gangopadhyay, Spatial variability of seasonal extreme precipitation in the Western United States, Journal of Geophysical Research – Atmospheres, 12(10), 4522-4533, 2015 Rajagopalan, B. and P. Molnar, Signatures of Tibetan Plateau Heating on Indian Summer Monsoon Rainfall Variability, Journal of Geophysical Research - Atmospheres, 118(3), 1170-1178, 2013
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	Summer Institute 2009 for New Media Pedagogy, Scholarship, and Learning Technologies using Web 2.0 Tools, Organized by Faculty Teaching Excellence Program at the University of Colorado at Boulder, May 11-15, 2009 Chairs Workshop, University of Colorado, Boulder, August 2014-2016

C. Walter Beamer IV Sr. Instructor

EDUCATION	BS, Architectural Engineering, University of Colorado, 1998 MS, Civil Engineering, University of Colorado, 2003 Ph.D., Civil Engineering, University of Colorado, 2005
ACADEMIC EXPERIENCE	University of Colorado Boulder: Sr. Instructor, 2015 – present; Instructor 2012-2015; AREN Faculty Director, 2016-present; Co-Director Rocky Mountain Lighting Academy, 2012-present
NON-ACADEMIC EXPERIENCE	Senior Associate (Acoustics and Lighting), January 2008 to January 2011, Shen Milsom Wilke, LLC. – Denver, Colorado Senior Associate (Acoustics), May –August 2008, Shen Milsom Wilke, LLC-FZ – Dubai, United Arab Emirates Acoustics Consultant, 2005 to 2007, Kirkegaard Associates – Boulder, Colorado Research Assistant, 2000 to 2005, Dept. of Civil, Environmental and Architectural Engineering, University of Colorado – Boulder, Colorado Independent Contractor (Lighting Consultant), 1999 to 2008, Light'n Up – Washington, DC Consultant (Lighting Design), 1998 to 1999, Robert Singer & Associates – Aspen, Colorado Lighting Intern, May - August 1998, Moran Coventry Lighting Associates – Washington, DC
PROFESSIONAL REGISTRATIONS	None
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	Illuminating Engineering Society (IES) Acoustical Society of America (ASA)
HONORS AND AWARDS	Department Teaching Award, CEAE, 2016
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	**Illuminating Engineering Society Service** Technical Committee on Daylighting, IES, 2014 – Present High Dynamic Range Imaging Subcommittee, IES, 2015-Present Illuminating Engineering Society Education Think Tank, 2014-Present **University Service** Dept. of Civil, Environmental, & Architectural Engineering (CEAE) AREN Faculty Director, AY 2016-2017 Co-Director, Rocky Mountain Lighting Academy, 2012 - Present Operations Committee (AREN), 2014 – 2016 Computing Committee, 2015 – Present Chair, Computing Committee, Aug 2013 – Aug 2015

	Curriculum Committee, 2012 – 2013 Computing Committee, 2012 – 2013
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	N/A
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	None

Angela R. Bielefeldt Professor

EDUCATION	BS, Civil Engineering, Iowa State University, 1992 MS, Civil Engineering, University of Washington, 1994 Ph.D., Civil Engineering, University of Washington, 1996
ACADEMIC EXPERIENCE	University of Colorado Boulder: Professor, 2012 – present; Associate Professor, 2003-2012; Assistant Professor, 1996-2003; Faculty Director Sustainable By Design Residential Academic Program, 2014-present; CEAE ABET Assessment Coordinator, 2008-present; Associate Chair CEAE 2012-13, 2014-15; Director EVEN program, 2006-2010; University of Canterbury, Christchurch, NZ (sabbatical), 2013 University of Minnesota, Braun Intertec Professor (sabbatical), 2005-06 University of Washington, Research Assistant, 1992-1996, part time Iowa State University, Research Assistant, 1987-1992, part time
NON-ACADEMIC EXPERIENCE	Remediation Technologies, Seattle, WA, Asst. Engineer, summer 1994 Montgomery Watson, Des Moines, IA, Assistant Engineer, summer 1992 Sandia National Laboratories, Albuquerque, NM, Intern, summer 1991 CH2M Hill, Reston, VA, Intern, summer 1990
PROFESSIONAL REGISTRATIONS	P.E., Colorado, 2003 to present.
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Society for Engineering Education (ASEE) American Society of Civil Engineers (ASCE) Association of Environmental Engineering & Science Professors (AEESP) Water Environment Federation (WEF)
HONORS AND AWARDS	Best Paper Award from PIC IV, ASEE Annual Conference, 2016 Overall Best Paper Award from ASEE Annual Conference, 2015 Distinguished Service Award, AEESP, 2013 Outstanding Reviewer Award, ASCE Journal of Professional Issues in Engineering Education & Practice, 2012 Advisor for winning teams in the national AECOM Student Design Competition, 2012 and 2011 Advisor for the winning teams in the National WEF Student design Competition, 2012 and 2009 Outstanding Service Award, Boulder Faculty Assembly, CU, 2012
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	American Society for Engineering Education (ASEE). Environmental Division director (2010-13); Community Engagement Division chair-elect (2011-13) & secretary (2015-16), best paper committee PIC III (2013, 2015) American Society of Civil Engineers (ASCE). Corresponding member of the Civil Engineering Program Criteria Task Committee, 2013. Association of Environmental Engineering and Science Professors (AEESP). Co-organized 2013 conference. Reviews in Environmental Science and Biotechnology, publisher Springer Netherlands; Editorial Board, 2009 – present. International Journal for Service Learning in Engineering (IJSLE), Editorial Board 2011-present.

	University Service Dept. of Civil, Environmental, & Architectural Engineering (CEAE) Executive Committee. 2015-present. Curriculum Committee. Chair. 2011-13, 2014-2015 Assessment Coordinator. Spring 2008 to present. Environmental Engineering (EVEN) cross-disciplinary degree program Associate Director. 2014 - present. College of Engineering at the University of Colorado - Boulder Undergraduate Education Council. 2012-2013, 2014-2015. Assessment Committee. Spring 2008 to present.
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	Canney, N., A.R. Bielefeldt. 2016. Validity and Reliability Evidence of the Engineering Professional Responsibility Assessment Tool. *Journal of Engineering Education*. 105 (3), 452-477. Bielefeldt, A.R., N.E. Canney. 2016. Humanitarian Aspirations of Engineering Students: Differences Between Disciplines and Institutions. *Journal of Humanitarian Engineering*. 4 (1), 8-17. Bielefeldt, A.R., N. Canney. 2015. Changes in the Social Responsibility Attitudes of Engineering Students Over Time. *Science and Engineering Ethics*. DOI 10.1007/s11948-015-9706-5. Canney, N., A. Bielefeldt. 2015. Differences in Engineering Students' Views of Social Responsibility Between Disciplines. *Journal of Professional Issues in Engineering Education and Practice*. 141 (4), 04015004. http://dx.doi.org/10.1061/(ASCE)EI.1943-5541.0000248 McCormick, M., A.R. Bielefeldt, C. Swan, K. Paterson. 2015. Assessing Students' Motivation to Engage in Sustainable Engineering. *International Journal of Sustainability in Higher Education*. 16 (2), 136-154. DOI 10.1108/IJSHE-06-2013-0054 Bielefeldt, A.R. 2014. Global Interests Among First-Year Civil and Environmental Engineering Students. *Journal of Professional Issues in Engineering Education and Practice.* 140 (2), 04013016-1-9. Bielefeldt, A.R., M. W. Stewart, E. Mansfield, R.S. Summers, J.N. Ryan. 2013. Effects of chlorine and other water quality parameters on the release of silver nanoparticles from a ceramic surface. *Water Research*. 47, 4032-4039.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	ASCE Body of Knowledge 3 Workshop, Aug. 5-6, 2016. ABET Symposium. April 14-15, 2016. IEEE/ASEE Frontiers in Education Conference. Oct. 21-24, 2015. Integrating Design and Community Engagement within the Curriculum Workshop. Sponsored by EPICS, EWB-USA, and EFELTS. West Lafayette, Indiana. June 19-20, 2014. Engineering Education Research Leader Networkshops: Mentoring, Communicating, and Power Brokering for the Next Generation (NSF EEC-1314725, 1314868). Online collaborative. 2013 – 2016.

Paul S. Chinowsky Professor

EDUCATION	BArch, Architecture, Cal Poly San Luis Obispo, 1987 MArch, Architecture, Cal Poly San Luis Obispo, 1988 Ph.D., Civil Engineering, Stanford University, 1991
ACADEMIC EXPERIENCE	University of Colorado Boulder: Professor, 2010–present; Associate Professor, 2002-2010; Associate Vice Provost 2015 – Present; Director, Mortenson Center and Mortenson Professor for Sustainable Development, 2012-2015 Georgia Institute of Technology: Associate Professor, 2000-2002; Assistant Professor, 1994-2002. Loughborough University: Visiting Professor (2005)
NON-ACADEMIC EXPERIENCE	Stone & Webster Engineering: 1991-1994, Principal Analyst
PROFESSIONAL REGISTRATIONS	
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Society of Civil Engineers (ASCE) Academy of Management (AOM) Engineering Project Organization Society (EPOS)
HONORS AND AWARDS	Best Paper Award, Transportation Research Board Conference, 2015. Best Paper Award, Humanitarian Technology Conference, 2014. ASCE, Journal of Management in Engineering, Best Peer Reviewed Paper Award, 2012 Distinguished Service Award, Engineering Project Organization Society, 2011 Best Paper Award, EPOC Conference, 2010
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	Conference Co-Chair, Engineering Project Organization Conference, Winter Park, CO, July 2014. Conference Co-Chair, Engineering Project Organization Conference, Winter Park, CO, July 2013. Conference Co-Chair, Engineering Project Organization Conference, Rheden, The Netherlands, August 2012. **Engineering Project Organization Society,** Co-Founder and Chairman 2010 - Present Contributing Author, IPCC Report 5 Editor, Journal of Engineering Project Organizations, Taylor & Francis, January 2011- Present. Member, Boulder Faculty Assembly, Executive Committee (2010 – 2012), Vice-Chair (2012-2013), Chair (2013-2015) Co-Developer and Co-Coordinator, College Undergraduate Certificate in Global Engineering (2012-2013) Member, Mortenson Center Executive Committee (2010 – 2012) Co-Coordinator, Civil Systems Graduate Program, Department of Civil, Env. And Arch. Engineering, Current

PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	• Walters, J. P., & Chinowsky, P. S. (2016). Planning rural water services in Nicaragua: A systems-based analysis of impact factors using graphical modeling. *Environmental Science & Policy*, *57*, 93-100. • Melvin, A.M., Larsen, P., Boehlert, B., Neumann, J.E., Chinowsky, P., Espinet, X., Martinich, J., Baumann, M.S., Rennels, L., Bothner, A. and Nicolsky, D.J., (2016). Climate change damages to Alaska public infrastructure and the economics of proactive adaptation. *Proceedings of the National Academy of Sciences*, p.201611056. • Espinet, X., Schweikert, A., van den Heever, N., & Chinowsky, P. (2016). Planning resilient roads for the future environment and climate change: Quantifying the vulnerability of the primary transport infrastructure system in Mexico. *Transport Policy*, *50*, 78-86. • Twerefou, D.K.; Chinowsky, P.; Adjei-Mantey, K.; Strzepek, N.L. (2015) "The Economic Impact of Climate Change on Road Infrastructure in Ghana," ***Sustainability***, ***7(9)***, 11949-11966. • Sandekian, R., Chinowsky, P., & Amadei, B. (2014). "Engineering for Developing Communities at the University of Colorado Boulder: A Ten Year Retrospective," *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, 62-77. • Chinowsky, Paul S. and Hoffman, Rod (2014). "Long-Term Viability of Mid-Size Engineering Firms," ASCE Journal of Management in Engineering, 10.1061/(ASCE)ME.1943-5479.0000328. • Neumann, James E., Price, Jason, Chinowsky, Paul, Wright, Leonard, Ludwig, Lindsay, Streeter, Richard, Jones, Russell, Smith, Joel B., Perkins, William, Jantarasami, Lesley, and Jeremy Martinich (2014). "Climate Change Risks to US Infrastructure: Impacts on coastal development, roads, bridges, and urban drainage," Climatic Change. • Chinowsky, Paul S., Price, Jason C. and Neumann, James (2013). "Assessment of Climate Change Adaptation Costs for the U.S. Road Network," Global Environment Change, 23(4): 764-773.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	First-Year Experience Annual Conference, Feb 10-14, 2017 Climate Change Impacts Symposium, EPOC 2016 Conference, August 2016. "Resiliency versus Risk: An Adaptation Challenge," Colorado Municipal League, October 2015

Ross B. Corotis **Professor**

EDUCATION	BS, Civil Engineering, MIT, 1967 MS, Civil Engineering, MIT, 1968 Ph.D., Civil Engineering (Structural Mechanics), MIT, 1971
ACADEMIC EXPERIENCE	University of Colorado Boulder: Professor, 1994 – present; Dean of the College of Engineering and Applied Science, 1994-2001 The Johns Hopkins University: Professor 1981-1994; Founding Chair of the Department of Civil Engineering, 1983-1990; Associate Dean, 1990-1994 Northwestern University: Professor 1979-1981; Associate Professor, 1975-1979; Assistant Professor 1971-1974
NON-ACADEMIC EXPERIENCE	Jefferson Science Fellow, U.S. Department of State, full-time 2007-2008
PROFESSIONAL REGISTRATIONS	P.E., Colorado, 1995 – present; P.E. Maryland, 1981 – present; P.E. Illinois, 1974 – present; S.E. Illinois, 1976 – present
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Society of Civil Engineers (ASCE) Civil Engineering Risk and Reliability Association (CERRA) International Association for Structural Safety and Reliability (IASSAR) International Forum for Engineering Decision (IFED)
HONORS AND AWARDS	National Academy of Engineering, Elected Member, 2002 University of Colorado Discovery Learning Center, Dedicated in my name, 2002 International Association for Structural Safety & Reliability, Senior Research Prize, 2005 U of Colorado Boulder Faculty Assembly Award for Teaching, 2006 Marquis Who's Who in the World, 2006 ASCE Distinguished Member, elected 2011 Charter Fellow, Engineering Mechanics Institute of ASCE, elected 2013
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	International Journal of Structural Safety Editorial Board, 1989- International Journal of Risk Assessment and Management Editorial Board, 2004- International Association for Bridge Maintenance and Safety Scientific Committee, 2002, 2004, 2006, 2010, 2012 Conferences International Association for Structural Safety and Reliability International Advisory Committee: 2012-2013 National Academy of Engineering Chair, Civil Engineering Section, 2009-2011 International Forum on Engineering Decision Making Member, Advisory Council, 2005-2010 Consortium Member, 2010- International Standards Organization U.S. Delegate to ISO 2394, 2011- American Society of Civil Engineers

	Editor, Journal of Engineering Mechanics, 2004-2010 Comm. on Disaster Resilience of Structures, Infrastructure & Communities, 2012- Risk and Resilience Measurements Committee, 2015- National Research Council (The National Academies) Committee on NIST Technical Programs, 1999-2014 (chair 2009-2014) Study Committee on Resilience of Communities behind Dams and Levees, 2011-2012 Laboratory Assessment Board, 2009- Board on Infrastructure and the Constructed Environment, 2012- Colorado Department of Economic Development and International Trade, proposal panel, 2014 Review of School of Civil & Environmental Engineering, Georgia Institute of Technology, 2016
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	Hurley, M. and Corotis, R. 2014. "Perception of Risk of Natural Hazards: A Hazard Mitigation Plan Framework," International Journal of Risk Assessment and Management, 17(3), 188-211. Bonstrom, H. and Corotis, R. 2015. "Optimizing Portfolio Loss Reduction using a First-Order Reliability Method Sensitivity Analysis," Structure and Infrastructure Engineering, 11(9), 1190-1198. Bonstrom, H. and Corotis, R. 2015. "Building Portfolio Seismic Loss Assessment using the First-Order Reliability Method," Structural Safety, 52, 113-120. Bonstrom, H. and Corotis, R. 2016. "First-Order Reliability Approach to Quantify and Improve Building Portfolio Resilience," ASCE Journal of Structural Engineering, 142(8), C4014001. Lin, Y., Corotis, R. and Liel, A. 2015 "A Framework Methodology for Risk-Based Decision Making: Applications to Transportation Agencies," ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems Part A Civil Engineering, September, 1(3), 04015006-1 - 04015006-13 Corotis, R. 2015. "An Overview of Uncertainty Concepts Related to Mechanical and Civil Engineering," ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part B Mechanical Engineering, December, 1(4), 040801-1 - 040801-12. Elwood, E. and Corotis, R. 2015. "Application of Fuzzy Pattern Recognition of Seismic Damage to Concrete Structures," ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part A Civil Engineering, December, 1(4), 04015011-1 - 04015011-12.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	ASCE Colorado Section, monthly meetings (4/year), 2001 – present NSF Workshop on Teaching Ethics in Foreign Extensions, 2011, 2012 Webinar on seismic base isolation, 2016 NSF Education Workshop on Teaching Structural Art, 2016 NSF Workshop on Social and Cultural Implications of Climate Change, 2016

Shideh Dashti **Assistant Professor**

EDUCATION	BS, Civil and Environmental Engineering, Cornell University, 2004 MS, Civil Engineering, University of California at Berkeley, 2005 Ph.D., Civil Engineering, University of California at Berkeley, 2009
ACADEMIC EXPERIENCE	University of Colorado Boulder: Assistant Professor, 2011 – present; Geotechnical Centrifuge Faculty Director 2015-present; University of California at Berkeley, Doctoral Student and Post-doctoral Associate, 2016-2010
NON-ACADEMIC EXPERIENCE	Bechtel National, Geotechnical Engineering, 2005-2016
PROFESSIONAL REGISTRATIONS	None
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Society of Civil Engineers (ASCE) International Society of Soil Mechanics and Geotechnical Engineering (ISSMGE TC 104 committee member) Earthquake Engineering and Soil Dynamics Committee of ASCE Earthquake Engineering Research Institute (EERI) GeoEngineering Extreme Event Reconnaissance (GEER)
HONORS AND AWARDS	American Society of Civil Engineers (ASCE) Outstanding Reviewer Award (2016) Departmental Young Researcher Award, Civil, Architectural, and Env. Engineering, CU Boulder (2015) Dean's Faculty Fellowship, College of Engineering and Applied Sciences, CU Boulder (2015) Departmental Teaching Award, Civil, Architectural, and Env. Engineering, CU Boulder (2014) National Science Foundation (NSF) Fellow for ENHANCE (since December 2012) Outstanding Graduate Student Instructor Award from the Department of Civil and Environmental Engineering, UC Berkeley (2009) Distinguished Leadership Award, Cornell University (April 2004)
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	Journal editorial board: Soils and Foundation Elected as the board member of the United States Universities Council on Geotechnical Education and Research (USUCGER), http://www.usucger.org/. Committee member of the International Society of Soil Mechanics and Geotechnical Engineering (ISSMGE TC 104), ASCE Geo-Institute. Peer-reviewer for: ASCE Journal of Geotechnical and GeoEnvironmental Engineering, Geotechnique, EERI Journal of Earthquake Spectra, Canadian Geotechnical Journal, Journal of Earthquake Engineering, Geotechnical Testing Journal, Soils and Foundations, Soil Dynamics and Earthquake Engineering, Journal of Geotechnical and Geological Engineering

	University Service Dept. of Civil, Environmental, & Architectural Engineering (CEAE) Graduate Committee. 2013-present. Awards Committee. 2012 Faculty Search Committee for Environmental Engineering. 2014 Faculty Search Committee for Geotechnical Engineering. 2015, 2016
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	Dashti, S., and Karimi, Z. (in press), "Ground Motion Intensity Measures to Evaluate I: the Liquefaction Hazard in the Vicinity of Shallow Founded Structures," Earthquake Spectra. Deniz, D., Arneson, E.E., Liel, A.B., Dashti, S., Javernick-Will, A. (2016). "Flood Loss Models for Residential Buildings Based on the 2013 Colorado Floods," Natural Hazards Journal, doi:10.1007/s11069-016-2615-3. Arneson, E., Deniz, D., Javernick-Will, A., Liel, A., and Dashti, S. (2016). "Information Deficits and Post-Disaster Recovery," Natural Hazards Review (accepted and in press). Hushmand, A., Dashti, S., Davis, C., McCartney, J.S. Hushmand, B. (2016). "A Centrifuge Study of the Influence of Site Response, Relative Stiffness, and Kinematic Constraints on the Seismic Performance of Buried Reservoir Structures," Soil Dynamics and Earthquake Engineering Journal, 88, 427-438. Hushmand, A., Dashti, S., Davis, C., Hushmand, B., McCartney, J., Hu, J., Lee, Y. (2016). "Seismic Performance of Underground Reservoir Structures: Insight from Centrifuge Modeling on the Influence of Backfill Soil Type and Geometry," Journal of Geotechnical and Geoenvironmental Engineering, ASCE 10.1061/(ASCE)GT.1943-5606.0001544 , 04016058. Dashti, S., Hashash, Y., Gillis, K., Musgrove, M., and Walker, M. (2016). "Development of Dynamic Centrifuge Models of Underground Structures near Tall Buildings," Soil Dynamics and Earthquake Engineering Journal, 86, 89-105. Y.H. Deng, S. Dashti, A. Hushmand, C. Davis, B. Hushmand (2016). "Seismic Response of Underground Reservoir Structures in Sand: Evaluation of Numerical Simulations using Centrifuge Experiments," Soil Dynamics and Earthquake Engineering Journal, 85, 202-216. Karimi, Z., and Dashti, S. (2016). "Seismic Performance of Structures on Liquefiable Soils: Insight from Numerical Simulations and Centrifuge Experiments," Journal of Geotechnical and Geoenvironmental Engineering, ASCE, 10.1061/(ASCE)GT.1943-5606.0001479.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	Elected as the board member of the United States Universities Council on Geotechnical Education and Research (USUCGER). Committee member of the International Society of Soil Mechanics and Geotechnical Engineering (ISSMGE TC 104), ASCE Geo-Institute. GeoEngineering Extreme Event Reconnaissance (GEER), including leading 1 reconnaissance team and participating in 3 others since 2011

Paul M. Goodrum Professor

EDUCATION	BS, Civil Engineering, University of Washington 1993 MS, Civil Engineering, University of Texas at Austin, 1994 Ph.D., Civil Engineering, University of Texas at Austin, 2001
ACADEMIC EXPERIENCE	University of Colorado Boulder: Professor, 2012 – present; Nicholas R. Petry Professor in Construction Engineering and Management, 2012 – present. University of Kentucky: Professor 2011-2012; Terrill McDowell Chair of Construction Engineering and Management 2011-2012; Associate Professor 2006-2011; Assistant Professor, 2001-2006; University of Texas at Austin: Research Assistant 1998-2001; Research Assistant 1993-1994
NON-ACADEMIC EXPERIENCE	Design Civil Engineering (EIT), DDS Engineering 1996-1998; Project Engineer and Project Safety Engineering, W. L. Hailey and Company, Inc 1994-1996
PROFESSIONAL REGISTRATIONS	P.E., Kentucky (License Number 20220), 1998 to present.
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Society of Civil Engineers (ASCE) Construction Research Council (CRC)
HONORS AND AWARDS	Blue Ribbon Committee Award AFH-10 Construction Management, National Academies Transportation Research Board, 2016 Outstanding Researcher Award, Construction Industry Institute, 2014 Distinguished Professor Award, Construction Industry Institute, 2014 Outstanding Faculty Award in Civil Engineering, University of Kentucky, 2012.
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	ASCE J. of Construction Engineering and Management – Specialty Editors of Labor and Personnel Issues – 2006 -2016 Practice Periodical of Structural Design and Construction, American Society of Civil Engineering, Editor of Special Issue dedicated to the Construction Engineering Conference in Seattle, Washington in April 2014 Construction Economics Research Network (CERN), Core Member, 2005-2012 National Academies, Transportation Research Board, Construction Management Committee Member, 2005 - Present Committee Research Coordinator, 2012 – Present Chair, 2015 - Present National Academies, Transportation Research Board, Information Technology in Construction Subcommittee, Co-Chair, 2010 - 2013 Construction Industry Institute, Breakthrough Strategy Committee, 1999 – 2016

	Construction Industry Institute, Academic Committee (elected Secretary 2005 to 2008, appointed Co-Chair 2011-2012, and appointed Chair 2012-2013), 2005-2016 Construction Industry Institute, Strategic Communications Committee, Academic Liason, 2013-2014. **University Service** Dept. of Civil, Environmental, & Architectural Engineering (CEAE) Executive Committee. 2012-2016 Graduate Committee. 2012-2013 Curriculum Committee. 2013-2014 CEAE Faculty Search Committee. 2012-2013, 2015-2016, 2016-Present (Chair)
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST YEAR	Bannier, P., Jin, H., and Goodrum, P. (2016). "Work Envelope Requirements among Piping Trades and the Influence of Global Anthromorphic Characterstics." Journal of Information Technology in Construction. Vol. 21, pg. 292-314 Karimi, H., Taylor, T., Goodrum, P., and Srinivasan, C. (2016). "The Impact of Craft Professional Staffing Difficulty on Construction Project Safety Performance." Emerald Journal of Construction Innovations. 16.3 (2016). Sweeny, J., Goodrum, P., and Miller, J. (2016). "Analysis of Empirical Data on the Effects of the Format of Engineering Deliverables on Craft Performance." Elsevier Journal of Automation in Construction in Summer. 69(2016). pp. 59-67. Goodrum, P., Miller, J., and Sweany, J. (2016). "Influence of the Format of Engineering Information and Spatial-Cognitive Ability on Craft Worker Performance." ASCE Journal of Construction Engineering and Management. DOI 04016043. Sankaran,B., O'Brien, W., Goodrum. P., Khwaja, N., and Leite, F. (2016). "Civil Integrated Management for Highway Infrastructure – Case Studies and Lessons Learned." National Academies Transportation Research Board Journal of the Transportation Research Record. 2573 (2016). pp. 10-17. Zhai, D., Shan, Y., Sturgill, R., Taylor, T., Goodrum, P. (2016). "Estimating Highway Construction Time Using Parametric Modelling." National Academies Transportation Research Board Journal of the Transportation Research Record. 2573(2016). pp. 1-9
PROFESSIONAL DEVELOPMENT ACTIVITIES	Construction Industry Institute Annual Conference, National Harbor, August 2-4, 2016.

Matthew R. Hallowell **Associate Professor**

EDUCATION	BS, Civil Engineering, Bucknell University, 2004 MS, Civil Engineering, Bucknell University, 2005 Ph.D., Civil Engineering, Oregon State University, 2008
ACADEMIC EXPERIENCE	University of Colorado Boulder: Associate Professor, 2014-present; Assistant Professor, 2008-2014; Faculty Director for Civil Engineering, 2016-present, Director of the President's Teaching and Learning Collaborative, 2016-present, Associate Chair CEAE 2014-15,
NON-ACADEMIC EXPERIENCE	Expert Witness in construction injury and forensics cases Professional consultant for construction safety President, Modular Design Solutions Project Engineer, Pine Tree Engineering Project Engineer, Penn Lyon Homes Carpenter, Fenderson-Howe Builders
PROFESSIONAL REGISTRATIONS	
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Society for Engineering Education (ASEE) American Society of Civil Engineers (ASCE) Construction Industry Institute (CII) The Beavers Chi Epsilon
HONORS AND AWARDS	Charles Hutchinson Memorial Teaching Award, U. of Colorado (2015) Outstanding Researcher Award, Construction Industry Institute (2015) Engineering News Record (ENR) Top 20 Under 40 (2014) Faculty Early Career Development (CAREER) Award, National Science Foundation (2013) Best Paper Award, American Society of Engineering Education Annual Conference (2013) Outstanding Advisor Award, College of Engineering and Applied Science (2013) John and Mercedes Peebles Innovation in Education Award, University of Colorado College of Engineering and Applied Science (2012) Best Paper Award, *Journal of Safety, Health, and Environmental Research* (2012) American Society of Civil Engineering New Faculty Excellence in Teaching Award (2011)
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	Member of the CII Academic Committee Member of the NAE Frontiers of Engineering Education (FOEE) Member of the ASCE Safety Committee, Construction Research Council Mentor, ASCE Excellence in Civil Engineering Education (ExCEEd) **University Service** Director of the President's Teaching and Learning Collaborative, Boulder Campus, 2016-present Member, Future Leadership Advancement Group (FLAG) in the College of Engineering and Applied Science

	Member, Graduate Education Council in the College of Engineering and Applied Science <u>Dept. of Civil, Environmental, & Architectural Engineering (CEAE)</u> Executive Committee. 2016-present. Graduate Committee. Chair. 2014-2015 Associate Chair for Graduate Education. 2014-2015 Study Abroad Advisor Honors Program Advisor Habitat for Humanity Campus Chapter Advisor Engineers without Borders Rwanda Advisor
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	Lingard, H., **Hallowell, M.R.**, Salas, R.*, Prizadeh, P.* (2017). "Leading or lagging? Temporal analysis of safety indicators on a large infrastructure construction project. *Safety Science*, 91, 206-220. Tixier, A.J.P.*, **Hallowell, M.R.**, Rajagopalan, B., and Bowman, D. (2016). "Application of machine learning to construction injury prediction." *Automation in Construction*, Elsevier, (69) 102-114. **Hallowell, M.R.**, Hardison, D.*, and Desvignes, M.* (2016). "Information technology and safety: Integrating empirical safety risk data with building information modeling (BIM), sensing, and visualization technologies." *Construction Innovation* (16)3, 323-347. Arroyo, P., Fuenzalida, C., Albert, A.*, and **Hallowell, M.R.** (2016). "Collaborating in decision making: An experimental study comparing CBA and WRC methods." *Journal of Energy and Buildings*, 128, 132-142. Salas, R.* and **Hallowell, M.R.** (2016). "Predictive validity of safety leading indicators: An empirical assessment in the oil and gas industry." *Journal of Construction Engineering and Management*, ASCE, 04016052-1 to 04016052-11. Tixier, A.*, **Hallowell, M.R.**, Rajagopalan, B., and Bowman, D. (2016). "Automated content analysis for safety: A natural language processing system to extract precursors and outcomes from unstructured injury reports." *Automation in Construction*, 62, 45-56. **Hallowell, M.R.** and Hansen, D.* (2016). "Measuring and improving designer hazard recognition skill: Critical competency to enable prevention through design." *Safety Science*, 82, 254-263. **Hallowell, M.R.** and Yugar-Arias, I.* (2016). "Exploring fundamental causes of safety challenges faced by Hispanic construction workers in the US using Photovoice." *Safety Science*, Elsevier, 82, 199-211.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	ASCE Excellence in Civil Engineering Education (ExCEEd) workshop mentor and participant National Academy of Engineering, Frontiers of Engineering Education (FOEE) workshop President's Teaching and Learning Collaborative, University of Colorado Boulder Campus

George Hearn **Associate Professor**

EDUCATION	DES, Columbia Univ., 1989 MS, Columbia Univ., 1982 BE, The Cooper Union, 1979
ACADEMIC EXPERIENCE	University of Colorado Boulder: Assoc. Prof, 1996 - present University of Colorado Boulder, Asst. Prof. 1989-1996
NON-ACADEMIC EXPERIENCE	Consulting engineer 1979-1989
PROFESSIONAL REGISTRATIONS	P.E., Colorado, New York
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	ASCE, AISC, TRB
HONORS AND AWARDS	
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	Chair, TRB AHD30 Structures Maintenance Committee 2015 – 2018 Academic director, AASHTO TSP2 Western Bridge Preservation Partnership, 2012-present Member, FHWA Expert Task Group for Bridge Preservation, 2010-present Member, NAS Expert Task Group for Long Term Bridge Performance 2012-present **University Service** Dept. of Civil, Environmental, & Architectural Engineering (CEAE) Executive Committee. 2010-present. Faculty Search Committees, 2010-present
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	Hearn,G., (2016). *Bridge Preservation Index and Its Relation to National Performance Management Measures*. TRB Annual Mtg., Paper 16-2301, 149. Hearn,G., (2015). *Element-Level Performance Measures for Bridge Preservation*. Trans. Res. Rec. 2481, p10-17. Hearn,G. (2014). *State Bridge Load Posting Processes and Practices*. Natl Acad., NCHRP Synthesis 453. 136p. Hearn,G. (2014). *Status of Posting for Load Among U.S. Bridges and Culverts*. TRB Annual Mtg., Paper 14-3072, 15p.

	Hearn,G, Juntunen,D., Ahmad,A.S., and Johnson,B.V. (2013). *Performance Measures for Bridge Preservation*. TRB Annual Mtg., Paper 13-1551, 15p. Hearn,G., Pan,S-Y, and Casey,W.F. (2013). *Bridge Management Practices in Idaho, Michigan and Virginia*. TRB Annual Mtg., Paper 13-0869, 14p. Hearn,G. (2012) *Deterioration and Cost Information for Bridge Management*. Colorado DOT, CDOT-2012-4, 354p. Hearn,G. (2012). *Bridge Management Practices in Idaho, Michigan and Virginia*. USDOT FHWA, http://www.fhwa.dot.gov/asset/hif12029/hif12029.pdf, 42p. Hearn,G. and Johnson,B.V. (2011). *An Overview of Identification and Tracking of Highway Bridge Maintenance Actions*. NAS-TRB, Transp. Res. Rec. No 2220, p12-20.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	FHWA training for bridge inspection using national bridge elements

Gregor P. Henze **Professor**

EDUCATION	Technical University of Berlin, Mechanical Engineering, B.S. 1989 Oregon State University, Mechanical Engineering, M.S. 1991 Technical University of Berlin, Mechanical Engineering, Dipl.-Ing. 1992 University of Colorado Boulder, Civil Engineering, Ph.D. 1995
ACADEMIC EXPERIENCE	2014-2015, Visiting Professor, Universidad de Sevilla, Spain 2013 to present, Joint Professor, National Renewable Energy Laboratory 2008 to present, Professor, University of Colorado Boulder 1999-2008, Assistant/Assoc. Professor, University of Nebraska-Lincoln
NON-ACADEMIC EXPERIENCE	2005-2006, Visiting Scientist, Fraunhofer Institute for Solar Energy Systems, Freiburg, Germany 2005, Visiting Scientist, Siemens Building Technologies, Zug, CH 1996-1999, Energy Engineering Manager, Johnson Controls, Germany
PROFESSIONAL REGISTRATIONS	HBDP, High-Performance Building Design Professional, 2006 to present. P.E., Mechanical Engineering, Nebraska, 2004 to present.
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) American Society of Civil Engineers (ASCE) International Building Performance Simulation Association (IBPSA)
HONORS AND AWARDS	University of Colorado AREN Appreciation Award 2015; University of Colorado CEAE Department Service Award 2014 Endowed Lewis-Worcester Faculty Fellowship 2014-2018 Architectural Engineering Institute (AEI) 2013 Best Paper Award University of Colorado CEAE Distinguished Achievement Award 2012 Colorado Cleantech Industry Association Research and Commercialization Award 2011 University of Colorado CEAE Research Development Award 2011
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	Chair for Workshop on Intelligent Building Operations, Purdue University, June 2016; U of Colorado 2013; Concordia U. 2011. Editorial Board Member for Journal of Building Performance Simulation since 2015. Associate Editor for Journal of Architectural Engineering since 2015 Associate Editor for Renewable Energy in the topical area of "Low Energy Architecture and Buildings" for 2014-2015. Renewable and Sustainable Energy Institute (RASEI) Fellow and Executive Committee Member since 2010 American Society of Mechanical Engineers (ASME) Solar Energy Division Technical Committee Chair for Conservation and Solar Buildings for 2008-2014. Associate Editor for Journal of Solar Energy Engineering in topical area of "Conservation and Solar Buildings" for 2008-2014. Member of ASHRAE committee charged with developing a certification program on Sustainable Building Design and Operation.

	University Service Dept. of Civil, Environmental, & Architectural Engineering (CEAE) Curriculum Committee, 2015 to present. Executive Committee, 2012-2014. AREN Faculty Director, 2012-2014. Associate Chair, 2010-2012. College of Engineering at the University of Colorado - Boulder Dean Search Committee, 2015-2016. Energy Engineering Minor Committee, 2013 to present.
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	Giuliani, M., G.P. Henze, and A.R. Florita (2016) „Modeling and Calibration of a High-Mass Historic Building for Energy and Comfort Assessment.“ Energy and Buildings, 116, 434-448. Patteeuw, D., G.P. Henze, and L. Helsen (2016), "Comparison of load shifting incentives for low-energy buildings with heat pumps to attain grid flexibility benefits.“ Applied Energy, 167, 80-92. Henze, G.P., Pless, S., Petersen, A., Long, N., and Scambos, A. T. (2015). Control limits for building energy end use based on frequency analysis and quantile regression. Energy Efficiency, 8(6), 1077-1092 Pavlak, G.S., Henze, G.P., and Cushing, V. J. (2015). Evaluating synergistic effect of optimally controlling commercial building thermal mass portfolios. Energy, 84, 161-176. Harmer, L.C. and Henze, G.P. (2015). Building Commissioning Using Calibrated Energy Models. Energy and Buildings, 92, 2014-2015. Henze, G.P., Pavlak, G.S., Florita, A.R., Dodier, R.H., and Hirsch, A.I. (2015). An energy signal tool for decision support in building energy systems. Applied Energy, 138, 51-70. Zhao, P., Henze, G.P., Brandemuehl, M.J., Cushing, V.J., and Plamp, S. (2015). Dynamic frequency regulation resources of commercial buildings through combined building system resources using a supervisory control methodology. Energy and Buildings, 86, 137-150. Pavlak, G.S., Henze, G.P., and Cushing, V.J. (2014). Optimizing commercial building participation in energy and ancillary service markets. Energy and Buildings, 81, 115-126. Pavlak, G.S., Florita, A.R., Henze, G.P., and Rajagopalan, B. (2013). Comparison of Traditional and Bayesian Calibration Techniques for Gray-Box Modeling. Journal of Architectural Engineering, 20(2). Tanner, R.A., and Henze, G.P. (2014). Stochastic control optimization for a mixed mode building considering occupant window opening behaviour. Journal of Building Performance Simulation, 7(6), 427-44.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	Co-Chair for Workshop on Intelligent Building Operations, West Lafayette, IN, Purdue University, June 2016. Co-Chair for Workshop on Building-to-Grid Integration, Universidad de Sevilla, Spain, June 2015. Chair for Workshop on Intelligent Building Operations, University of Colorado Boulder, June 2013. Chair for Workshop on Model Predictive Control in Buildings, Concordia University, Montreal, June 2011.

Mija H. Hubler **Assistant Professor**

EDUCATION	BS, Civil Engineering, University of Illinois, 2006 MS, Civil Engineering, Cornell University, 2009 Ph.D., Civil Engineering, Northwestern University, 2013
ACADEMIC EXPERIENCE	University of Colorado Boulder, Assistant Professor, 2015 – present Massachusetts Institute of Technology, Postdoctoral Researcher, 2013-2015 Northwestern University, Research Assistant, 2009-2013, part time Cornell University, Research Assistant, 2006-2009, part time
NON-ACADEMIC EXPERIENCE	F.H. Paschen/S.N. Nielsen, Chicago, IL, Engineering Intern, summer 2005 Architectural Alliance Inc., Santa Fe, NM, Intern, summer 2004
PROFESSIONAL REGISTRATIONS	
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Society of Civil Engineers (ASCE) International Association for Life-Cycle Civil Engineering (IALCE) Society of Engineering Sciences (SES) American Concrete Institute (ACI)
HONORS AND AWARDS	
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	RILEM Technical Committee MDC – Multi-decade creep and shrinkage of concrete: material model and structural analysis, 2012-2013 Voting Member for ACI 209 Creep and Shrinkage of Concrete, 2012 – 2013, secretary for subcommittee on rate type modeling, Member of ACI 241, Nanotechnology of Concrete Scientific Committee for International Association of Fracture Mechanics for Concrete and Concrete Structures Conference 9 Reviews in Journal of Engineering Mechanics, Materials and Structures, Construction & Building Materials, Journal of Nanomechanics and Micromechanics, Journal of Materials in Civil Engineering, and Journal of Mechanical Engineering Science, and Mechanics Research Communications, 2015 - present **University Service** <u>Dept. of Civil, Environmental, & Architectural Engineering (CEAE)</u> External Joint Evaluation Committee. Coordinator. 2016
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	M. H. Hubler, and F.-J. Ulm. 2016. "Size-Effect Law for Scratch Tests of Axisymmetric Shape." *Journal of Engineering Mechanics*, 04016094. Q. Yu, J.-L. Le, M. H. Hubler, R. Wendner, G. Cusatis, and Z. P. Bazant. 2016. "Comparison of Main Models for Size Effect on Shear Strength of Reinforced and Prestressed Concrete Beams." *Structural Concrete*. RILEM TC-242-MDC, 2015. "RILEM draft recommendation: TC-242-MDC multi-decade creep and shrinkage of concrete: material model and structural analysis*," *RILEM Mater. and Str*uc., 48(4).

	R. Wendner, M. H. Hubler, and Z. Bažant, 2015. "Optimization method, choice of form and uncertainty quantification of Model B4 using laboratory and multi-decade bridge databases," *RILEM Mater. and Struc.*, 48(4). M. H. Hubler, R. Wendner, and Z. Bažant, 2015. "Statistical justification of Model B4 for drying and autogenous shrinkage of concrete and comparisons to other models," *RILEM Mater. and Struc.*, 48(4). R. Wendner, M. H. Hubler, and Z. Bažant, 2015. "Statistical justification of model B4 for multi-decade concrete creep using laboratory and bridge databases and comparisons to other models," *RILEM Mater. and Struc.,* 48(4). M. H. Hubler, R. Wendner, and Z. Bažant, 2015. "Extensive Concrete Creep and Shrinkage Database – Analysis and Recommendations for Testing and Reporting," *ACI Mat. J.* Z. Bažant and M. H. Hubler, 2013. "Theory of Cyclic Creep of Concrete Based on Paris Law for Fatigue Growth of Subcritical Microcracks," *JMPS,* 63, pg. 187-200. C. Hoover, Z. Bažant, J. Vorel, R. Wendner, and M. H. Hubler, 2013. "Comprehensive Concrete Tests: Description and Results," *ACI Materials J.*, 114, pg. 92-103. Z. Bažant, M. H. Hubler, and M. Jirásek, 2013. "Improved Estimation of Long-Term Relaxation Function from Compliance Function of Aging Concrete," *ASCE J. of Eng. Mechanics*, 139(2), pg. 146-152. Z. Bažant, M. H. Hubler, and Q. Yu, "Pervasiveness of Excessive Segmental Bridge Deflections: Wake-Up Call for Creep," *ACI Structural J.* 2011, 108(6), pg. 766-774.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	NAPP Program for Teaching, Aug. 2015 PCA Education Foundation Professor's Workshop, July 2015

Amy N. Javernick-Will   Associate Professor

EDUCATION	BS, Civil Engineering, University of Colorado Boulder, 1999 MS, Civil Engineering, University of Colorado Boulder, 2001 Ph.D., Civil Engineering, Stanford University, 2009
ACADEMIC EXPERIENCE	University of Colorado Boulder: Associate Professor, 2016 – present; Assistant Professor, 2010-2016-; Associate Director of Graduate Education and Research, Mortenson Center in Engineering for Developing Communities, 2015—present Stanford University: Stanford Graduate Fellow, Research Assistant, Teaching Assistant, 2006-2009
NON-ACADEMIC EXPERIENCE	Opus Northwest, L.L.C., Denver, CO, Project Manager, 2005-2006; Associate Project Manager, 2001-2004 Neenan Company, Fort Collins, CO, Project Engineer, 2000-2001 Turner Construction Company, Denver, CO, Intern, summer 1999
PROFESSIONAL REGISTRATIONS	F.E., Colorado, 1999; LEED Accreditation 2005-Present.
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Society for Engineering Education (ASEE) American Society of Civil Engineers (ASCE) Construction Research Congress (CRC) Construction Industry Institute (CII)
HONORS AND AWARDS	Distinguished Professor Award, Construction Industry Institute, 2016 Best Paper Award, Engineering Project Organizations Conference: 2015 and 2016. Outstanding Undergraduate Research Mentor, University of Colorado-Boulder, 2015 Honorary Commended Paper, International Journal of Disaster Resilience in the Built Environment, 2014 ASCE Excellence in Civil Engineering Education (ExCEEd) New Faculty Excellence in Teaching Award ,2014 Outstanding Advisor, College of Engineering and Applied Science, University of Colorado-Boulder, 2014 Young Researcher Award, Department of CEAE, University of Colorado Boulder, 2014
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	Construction Management and Economics, Editor (2016-current) Journal of Construction Engineering and Management, Assistant Specialty Editor (2011-2016) National Academy of Engineering, member of panel working on research project “Understanding the Engineering Education—Workforce Continuum” (2013-2016) Construction Industry Institute, Academic Committee (2010-2016), Conference Chair, CII-track (2014-2016), Academic Co-chair-Global Community of Practice (2012-2016) **University Service** Dept. of Civil, Environmental, & Architectural Engineering (CEAE)

	Associate Director, Mortenson Center in Engineering for Developing Communities (2015-present) Graduate Committee, Curriculum Committee College of Engineering at the University of Colorado - Boulder Faculty Leadership Affairs Group (FLAG), College of Engineering and Applied Science (2015-present) University Service Boulder Faculty Affairs Leadership Committee (2014-2015)
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	Zerio, A., Opdyke, A., and A. Javernick-Will (2016). "Characterizing Post-Disaster Reconstruction Training Methods and Learning Styles". *Engineering Project Organization Journal*. Opdyke A., Lepropre, F., Javernick-Will, A. and M. Koschmann (2016). "Inter-organizational resource coordination in post-disaster infrastructure recovery." *Construction Management and Economics*. Antillon, E., Molenaar, K., and A. Javernick-Will (2016). "Evaluating the Effect of Contract Timing on Life Cycle Design Innovation in Public-Private Partnerships: A Comparative Case Study of Highway Projects". *Journal of Construction Engineering and Management*. Deniz, D., Arneson, E., Liel, A., Dashti, S., and A. Javernick-Will (2016). "Flood Loss Models for Residential Buildings Based on the 2013 Colorado Floods". *Natural Hazards*. Jordan, E., Javernick-Will, A. and Tierney, K. (2016). "Post-Tsunami Recovery in Tamil Nadu, India: Combined Social and Infrastructural outcomes". *Natural Hazard*: Poleacovschi, C. and A. Javernick-Will. (2016). "Spanning Knowledge Across Subgroups and Its Effects on Individual Performance". *Journal of Management in Engineering*. Litchfield, K., Javernick-Will, A., and A. Maul (2016). "Technical and Professional Skills of Engineers Involved and Not Involved in Engineering Service." *Journal of Engineering Education. 105(1): 70-92.* Litchfield, K. and A. Javernick-Will (2015). "'I am an Engineer AND': A Mixed-Methods Study of Socially Engaged Engineers". *Journal of Engineering Education*. 104(4): 393-4166. Wanberg, J., Javernick-Will, A., Taylor, J. and P. Chinowsky (2015). "The Effects of Organizational Divisions on Knowledge Sharing Networks in Multi-lateral Communities of Practice". *Engineering Project Organizations Journal* Walters, J. and A. Javernick-Will (2015). "Management of Rural Water Services in Nicaragua: A Systemic Network Approach to Evaluating Stakeholder Alignment". *International Journal of Sustainable Development and World Ecology*. 22(4): 358-367.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	Penn State PACE, Innovation Research Road mapping Workshop, June 2015. NSF IDEAS Lab, Virginia, March 2014 NAE, Engineering Education to Workforce Continuum, 2013-201

Moncef Krarti **Professor**

EDUCATION	BS, Diplôme d'Ingénieur, Ecole des Ponts et Chaussées, Paris, 1984 MS, Civil Engineering, University of Colorado, 1985 Ph.D., Civil Engineering, University of Colorado, 1987
ACADEMIC EXPERIENCE	University of Colorado Boulder: Professor, 2004 – present; Associate Professor, 1998-2004; Assistant Professor, 1991-1998; Associate Chair CEAE 2006-08; Director JCEM program, 1997-1998; Nanyang Technological University, Singapore (sabbatical), 2012-2013 Ecole des Mines de Paris, Adjoint Professor, 1998-Present Texas A&M University, Post-doctoral Fellow, 1986-1988
NON-ACADEMIC EXPERIENCE	Associate, Steven Winter Associates, Norwalk, CT, 1988-1991.
PROFESSIONAL REGISTRATIONS	P.E., Colorado, 1998 to present. LEED-AP, Green Building Certification Institute, 2009 to present.
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Society for Mechanical Engineers (ASME), Fellow. American Society of Heating, Refrigerating, and Air Conditioning (ASHRAE) American Solar Energy Society (ASES)
HONORS AND AWARDS	Distinguished Achievement Award, CEAE Department, 2016. Elected ASME Fellow, 2015. New Inventor Award, University of Colorado at Boulder, 2013. Eckel Award for Excellence, University of Colorado at Boulder, 2012. Service Award, Solar Energy Division Chair, ASME, New York, NY, 2011.
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	American Society for Mechanical Engineers (ASME). Co-director of Integrated and Sustainable Building Equipment and Systems (ISBES). Environmental Division director (2011-13); Editor of ASME Handbook on ISBES, Editor of Monographs. Chair and co-chair of several ASME Energy sustainability conferences, 1992-present. American Society of Heating, Refrigerating, and Air Conditioning (ASHRAE), Voting member of several technical committees on Thermal Energy Storage, Intelligent Buildings, and Building Thermal Load Calculations, 1992-present. of the Civil Engineering Program Criteria Task Committee, 2013. American Solar Energy Society (ASES), Technical Chair of two annual ASES conferences, 2006-present. Editorial Member of Journal of Solar Energy Engineering (JSEE), published by ASME, Chair of Energy Fundamentals Section, 2006-2012. Editorial board of Francis and Taylor publishing on Building Energy Efficient Systems. 2012-present. **University Service** Dept. of Civil, Environmental, & Architectural Engineering (CEAE) Executive Committee. 2010-2013 and 2015-present. Graduate Committee. 1998-2002, 2006-2015

	Chair of CEAE Faculty Search Committees, 2002-2003, 2006-2007, 2008-2009, 2013-2014. Coordinator of High School Honor Institute: to attract high school honor students to enroll in engineering, 2002-2005. College of Engineering at the University of Colorado - Boulder First Level Review Committee, Chair, Engineering College, 2007-2008. First Level Review Committee, Member, Engineering College, 2004-2008. CU-Campus Carbon Neutral Committee, Member, Campus wide Committee, since 2008.
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	A. Alaidroos and M. Krarti, "Numerical Modeling of Ventilated Wall Cavities with Spray Evaporative Cooling Systems" Energy and Buildings, accepted and available online 24 August (2016) B. Park and M. Krarti, "Energy performance analysis of variable reflectivity envelope systems for commercial buildings" Energy and Buildings, 116, 249-262 (2016). B. Ameer and M. Krarti, "Impact of Subsidization on High Energy Performance Designs for Kuwaiti Residential Buildings, Energy and Buildings, 124, (2016). J. Mun, and M. Krarti, "Optimal Insulation for Ice Rink Floors", Energy and Buildings, In Press, Available online 25 September, (2015). M. Krarti "Evaluation of large scale building energy efficiency retrofit program in Kuwait", Renewable and Sustainable Energy Reviews, 50, 1069-1080, (2015). B. Park, W.V. Srubar, and M. Krarti, "Energy performance analysis of variable thermal resistance envelopes in residential buildings", Energy and Buildings, 103, 317-325, (2015). M. Krarti, Analysis Methods for Building Energy Auditing, Chapter in Energy Efficiency and Renewable Energy Handbook, Second Edition, Y. Goswami and F. Kreith, CRC Press, Taylor and Francis Publishing, (2015). C. Kaltreider, M. Krarti, and J.S. McCartney, "Heat Transfer Analysis of Thermo-Active Foundations". Energy and Buildings, 86, 492-501, (2015). M. Krarti, Thermo-active Foundations for Sustainable Buildings, Editor, monograph, 150 pages, ASME Press, 2015. M. Krarti, Energy Efficient Building Electrical Systems, textbook, 520 pages, Taylor and Francis, 2016.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	DOE Conference on Collaboration between Universities and DOE Research Laboratories, Washington DC, April 1-2, 2015. ASES Workshop, on Energy Efficient Residential Buildings, Phoenix, Aug. 5-6, 2014.

Abbie B. Liel **Associate Professor**

EDUCATION	BSE, Civil and Environmental Engineering, Princeton University, 2002 MS, Civil and Environmental Engineering, University College London, 2003 MS, Building and Urban Design and Development, University College London, 2004 Ph.D., Civil and Environmental Engineering, Stanford, 2008
ACADEMIC EXPERIENCE	University of Colorado at Boulder, Assistant Professor, 2008-2015; Associate Professor 2016 – present Stanford University, Stanford, CA, Research Assistant, 2004-2008 University of Tokyo, Japan, Visiting Researcher, 2006 University College London, England, Research Assistant, 2004 Princeton University, Princeton, NJ, Research Assistant, 2002-2002
NON-ACADEMIC EXPERIENCE	Applied Technology Council, Consultant, 2005-present URS Corporation, Portland, OR, Structural Engineering Intern, 2001
PROFESSIONAL REGISTRATIONS	Professional Engineer, State of California
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Society of Civil Engineers (ASCE). Earthquake Engineering Research Institute (EERI). American Society of Engineering Education (ASEE) Consortium of Universities for Research in Earthquake Engineering (CUREE)
HONORS AND AWARDS	Civil Engineering Honorary Visiting Research Award, University of Auckland, 2015 Shah Family Innovation Prize, Awarded by the Earthquake Engineering Research Institute, 2015 Outstanding Faculty Advisor Award, College of Engineering, 2015 Outstanding Paper *Earthquake Spectra*, 2013 Outstanding Paper of 2012 (Runner-up) in *Journal of Performance of Constructed Facilities*, 2013 Dean's Award for Outstanding Junior Faculty Member, College of Engineering, 2013 (Awarded 2014) Faculty Teaching Award, Dept. of Civil, Environmental and Architectural Engineering, 2013 National Science Foundation CAREER Award, 2012 Selected as Next-Generation Hazards and Disaster Researcher, 2009 Research Fellowship, Japan Society for the Promotion of Science, 2006 Winner, Student Paper Competition, Earthquake Engineering Research Institute, 2006 Recipient, Graduate Research Fellowship, National Science Foundation, 2004 – 2008 Marshall Scholar, 2002 – 2004
INSTITUTIONAL AND PROFESSIONAL	Research Consultant, Applied Technology Council Project Management Committee for ATC-78, Identification and Mitigation of Non-ductile Concrete Buildings, 2010 – present

SERVICE IN LAST FIVE YEARS	Working group for ATC-63, Quantification of Building System Performance and Response Parameters, and ATC-63-1, Development of Structural Component Equivalency Methodologies, 2005 – 2010 Research Consultant, Building Seismic Safety Council, National Institute of Building Sciences Working group for Development of Simplified Seismic Design Procedures, 2010 – 2012 Co-chair, 2017 ASCE Structures Congress, Local Planning Committee EERI Annual Meeting Working Group, 2016 – present Committee on Reform of Structural Engineering Education, Structural Engineering Institute, ASCE, 2015 - present Affiliate Member, Structural Engineers Association of Colorado, 2013 – Present & Member of Sub-Committee on Snow Loads, 2012 – Present Founding Member, Young Professionals Committee, Structural Engineering Institute, American Society of Civil Engineers, 2011- 2016
PRINCIPAL PUBLICATIONS OF LAST FIVE YEARS	Liel, Abbie B., D. Jared DeBock, James R. Harris, Jeannette Torrents, Bruce Ellingwood, "Reliability-Based Design Snow Loads: II Reliability Assessment and Mapping Procedures," ASCE Journal of Structural Engineering, in Press. Deniz, Derya, Erin E. Arneson, Abbie B. Liel, Shideh Dashti and Amy N. Javernick-Will, "Flood Loss Models for Residential Buildings Based on the 2013 Colorado Floods", Natural Hazards, In Press. Harrington, Cody C. and Abbie B. Liel, "Collapse Assessment of Moment Frame Buildings, Considering Vertical Ground Shaking", Earthquake Engineering and Structural Dynamics, In Press. Welsh-Huggins, Sarah J and Abbie B. Liel, "A Life-Cycle Framework for Integrating Green Building and Hazard-Resistant Design: Examining the Seismic Impacts of Buildings with Green Roof Systems", Structure and Infrastructure Engineering, 13(1), 2017. Sattar, Siamak and Abbie B. Liel. "Seismic Performance of Non-Ductile Reinforced Concrete Frames with Masonry Infill Walls: II. Collapse Assessment", Earthquake Spectra, 32(2), pp. 819 – 842, 2016. Raghunandan, Meera, Abbie B. Liel, and Nicolas Luco. "Aftershock Collapse Vulnerability Assessment of Reinforced Concrete Frame Structures", Earthquake Engineering and Structural Dynamics, 44(3), pp. 419-439, 2015.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	TRESTLE Scholar. Transforming Education, Supporting Teaching and Learning Excellence (TRESTLE), University of Colorado Boulder Center for STEM Learning, Fall, 2016. Participant in *Creative Art of Structural and Civil Engineering Workshop*, Hosted by UMass Amherst, June, 2016.

Keith R. Molenaar Professor

EDUCATION	BS, Architectural Engineering, University of Colorado, 1990 MS, Civil Engineering, University of Colorado, 1995 Ph.D., Civil Engineering, University of Colorado, 1996
ACADEMIC EXPERIENCE	University of Colorado Boulder: Professor, 2011 – present; Associate Dean for Graduate Programs, 2015-present; Associate Professor, 2006-11; Assistant Professor, 1999-06; CEAE Department Chair, 2010-15; Polytechnic University of Valencia, Valencia Spain (sabbatical), 2014-15 Catholic University of Chile, Santiago, Chile (sabbatical), 2006-07 Georgia Institute of Technology: Assistant Professor, 1997-99 University of Colorado, Instructor/Research Assistant, 1994-97
NON-ACADEMIC EXPERIENCE	Pre-Construction Services Consultant, 1991-97, Architectural Resource Consultants, Inc., Boulder, Colorado; Assistant Site Superintendent, 1988-91, Spectrum Builders, Inc., Boulder, Colorado
PROFESSIONAL REGISTRATIONS	DBIA Professional, 2002-present
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Society of Civil Engineers Association for the Advancement of Cost Engineering International Construction Management Association of America Design-Build Institute of America
HONORS AND AWARDS	Pan-American Academy of Engineering, 2012 Excellence in Leadership Fellow, University of Colorado, 2010 Fulbright Scholar, Fulbright Commission of Chile, 2006 Provost Faculty Achievement Award, University of Colorado, 2006 Top 50 "Trendsetter," Public Works Magazine, 2004
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	**National Service** American Society of Civil Engineers Department Heads Executive Committee, 2011-2015. International Activities Committee, ASCE Lead Representative to the Union of Pan-American Engineering Associations, 2008-2014. Design-Build Institute of America Chair, Registration Board, 2016; Member, 2009-2016. Faculty Advisor, Design-Build of America Student Competition Team, 2015 and 16. National Research Committee, 2008-2014. TRB Transportation Research Board Construction Management Committee 2014-present **University Service** College of Engineering and Applied Science Associate Dean for Graduate Programs, 2015-present Dept. of Civil, Environmental, & Architectural Engineering (CEAE) Department Chair, 2010-14 Graduate Committee, 2015-present

PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	Tran, D., Molenaar, K.R., and Gransberg, D.D. (2016). "Implementing Best-Value Procurement for Design-Bid-Build Highway Projects," *Transportation Research Record: Journal of the Transportation Research Board, National Academies*. *2573, 26-33.* Stanford, M.S. Molenaar, K.R. and Sheeran, K.M. (2016). "Application of Indefinite Delivery-Indefinite Quantity Construction Strategies at the Federal Level," *ASCE Journal of Management in Engineering,* 32(5), *04016011.* Pellicer, E., Sanz, M., Esmaeili, B. and Molenaar, K., (2016), "Exploration of Team Integration in Spanish Multi-Family Residential Construction," *ASCE Journal of Management in Engineering,* 32(5), *05016012.* Harper, C.M., Molenaar, K.R., and Cannon, J.P. (2016). "Measuring Constructs of Relational Contracting in Construction Projects," *ASCE Journal of Construction Engineering and Management,* 142(10), *04016053.* Mesa, H., Molenaar, K.R., and Alarcón, L.F. (2016). "Exploring Performance of the Integrated Project Delivery Process on Complex Building Projects," *International Journal of Project Management,* 34(7), 1089–1101. Tran, D., Molenaar, K., and Alarcón, L.F. (2016). "A Hybrid Cross-Impact Approach to Predicting Cost Variance of Project Delivery Decisions for Highways," *ASCE Journal of Infrastructure Systems,* 22(1), 04015017.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	Design-Build Institute of America's Design-Build Conference and Exposition, Denver, CO, November, 2015. American Association of Port Authorities Annual Conference, San Diego, CA, October, 2015. Construction Industry Institute Annual Conference, Boston, MA, August, 2015. Transportation Research Board Annual Conference, Washington, DC, January 2015. Advanced Methodologies for Construction Management, Catholic University of Chile and Chilean Association of Construction, Santiago, Chile, September 2014. 18th International Congress on Project Management and Engineering, Alcañiz, Spain, July 2014. New York State Department of Transportation Design-Build Peer Exchange, Rochester, NY, April 2014. American Society of Civil Engineers, Department Heads Committee Meeting, Oklahoma City, OK, April 2014. Federal Highway Administration, Risk Management Peer Exchange, Atlanta, GA, March 2014. American Society of Civil Engineering, Texas Section Centennial Conference, Dallas, TX, September 2013.

Matthew Morris **Senior Instructor**

EDUCATION	BS, Civil Engineering, University of Colorado Boulder, 1999 MS, Civil Engineering, University of Colorado Boulder, 2002
ACADEMIC EXPERIENCE	University of Colorado Boulder: Senior Instructor, 2016 – present; Instructor, 2012-2016 United States Military Academy, West Point: Associate Professor, 2005-2006; Instructor, 2003-2005
NON-ACADEMIC EXPERIENCE	Mortenson Construction, Denver, CO, Project Manager, 2006-2012 U.S. Air Force, Civil Engineer Officer, 1999-2006
PROFESSIONAL REGISTRATIONS	P.E., Colorado, 2005 to present. LEED AP, 2007 to present
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	Design Build Institute of America (DBIA)
HONORS AND AWARDS	University of Colorado Civil Engineering Faculty Excellence Award, 2016 Dan Ivanoff Construction Engineering & Management Fellowship, 2014-present University of Colorado Architectural Engineering Faculty Excellence Award, 2014 University of Colorado Marinus Smith Award – Teaching Excellence, 2013 Meritorious Service Medal Air Force Commendation Medal National Defense Service Medal Global War on Terrorism Service Medal Korean Defense Service Medal Air Force Overseas Ribbon Air Force Longevity Service Small Arms Expert Marksmanship Company Grade Officer of the Quarter, 2003 Company Grade Officer of the Quarter, 2001
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	**University Service** Dept. of Civil, Environmental, & Architectural Engineering (CEAE) Curriculum Committee, 2015-present Construction Engineering & Management Industry Advisory Board Executive Committee, 2012-present Associated General Contractors (AGC) Student Chapter Faculty Advisor, 2012-present College of Engineering at the University of Colorado - Boulder Scholarship Committee, 2012-present College internship committee, 2014

	College of Engineering Renovation Design/Construction Committee, 2015-2016 Larson Lab Mechanical Upgrade Construction Project liaison, 2015-2016
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	Not Applicable
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	Town of Superior Open Space Advisory Committee, 2014-present Design Build Institute of America Owner's Forum, 2015

Ronald Y.S. Pak Professor

EDUCATION	BE, Civil Engineering, McMaster University, 1979 MS, Civil Engineering, Caltech, 1980 Ph.D., Civil Engineering, Caltech, 1985
ACADEMIC EXPERIENCE	Professor, University of Colorado Boulder (1995-present) Associate Professor, University of Colorado Boulder (1991-95) Assistant Professor, University of Colorado Boulder (1985-91) Research Fellow, California Institute of Technology (1985)
NON-ACADEMIC EXPERIENCE	Associate Engineer, C.F. Braun & Co, California (1981-82)
PROFESSIONAL REGISTRATIONS	None
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	Engineering Mechanics Institute (EMI) American Society of Civil Engineers (ASCE) Consortium of University of Earthquake Engineering (CUREE)
HONORS AND AWARDS	Distinguished Visiting Professor, Northwest University NSF Presidential Young Investigator Award Association of Professional Engineers Gold Medal, Ontario, Canada
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	**Professional Service** Board of Directors and Executive Committee, Consortium of Universities for Earthquake Engineering (CUREE) American Society of Civil Engineers (ASCE) Engineering Mechanics Institute (Vice-Chair) American Society of Civil Engineers (ASCE) Geo-Institute Soil Dynamics Committee **University of Colorado Boulder** <u>Dept. of Civil, Environmental, & Architectural Engineering (CEAE)</u> Executive Committee, Personnel Committee, Faculty Search Committees Civil Engineering and Applied Math Double-Degree Program Director Junior Faculty Mentoring Committee (Chair) Facilities Committee (Chair) <u>College of Engineering at the University of Colorado - Boulder</u> First Level Review Committee for Promotion and Tenure
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	1. Shahmohamadi, M.; Khojasteh, A.; Rahimian, M., Pak, R.Y.S., “Rigid cylinder in a transversely isotropic half-space under lateral loads,” International J. for Numerical and Analytical Methods in Geomechanics, Volume 36, Issue 10, 2012, 1368-1386. 2. Eskandari-Ghadi, Morteza; Pak, Ronald Y. S.; Ardeshir-Behrestaghi, Azizollah, “Vertical Action of a Concentric Multi-Annular Punch on a Transversely Isotropic Elastic Half-Space,” J. Applied Mechanics, ASME, 79, Issue 4, July 2012.

	3. Soudkhah, M. and Pak, R.Y.S. "Performance of Wave-Absorbing Boundary Method for Seismic Vertical Free-Field Soil Motion in Centrifuge Simulations," Computers and Geotechnics, Volume: 43, June 2012, 155-164. 4. Pak, R.Y.S. and Soudkhah, M and Jeramy C. Ashlock, "Dynamic Behavior of a Square Foundation in Planar Motion on a Sand Stratum," Soil Dynamics and Earthquake Engineering, Vol. 42, 2012, 151-160. 5. Morteza Eskandari-Ghadi, Azizollah Ardeshir-Behrestaghi, Ronald Y.S. Pak , Mostafa Karimi and Masoud Momeni-Badeleh," Forced vertical and horizontal movements of a rectangular rigid foundation on a transversely isotropic half-space, Int. J. Analytical and Numerical methods in Geomechanics, Vol 37 , 14, 2013, 2301-2315. 6. Shahmohamadi, M.; Khojasteh, A.; Rahimian, M.; et al., " Dynamics of a Cylindrical Pile in a Transversely Isotropic Half-Space under Axial Excitations, J. Engrg. Mech., ASCE, Vol. 139, Issue 5, 568-579, 2013. 7. Naeeni, MR , Eskandari-Ghadi, M.)[, Ardalan, Alireza A and Pak, R. Y. S. "Asymmetric motion of a transversely isotropic thermoelastic half-space under time-harmonic buried source," ZAMP Zeitschrift für Angewandte Mathematik und Physik, Vol.65, 5, 2014, 1031-51. 8. Zhang ZC, Liu HL and Pak RYS "Computational Modeling of Buried Blast-induced Ground Subsidence and Ground Motion," Geomechanics and Engineering, Vol. 7, No. 6, Dec 2014, 613-631. 9. M. R. Naeeni, M. Eskandari-Ghadi, A. A. Ardalan, R. Y. S. Pak, M. Rahimian, Y. Hayati, "Coupled thermoviscoelastodynamic Green's functions for biomaterial half-space, Journal of Applied Mathematics and Mechanics/ Zeitschrift für Angewandte Mathematik und Mechanik (ZAMM), Vol. 95 Issue: 3, 260-282, 2015. 10. Kalantari, M, Khojasteh, A., Mohammadnezhad, H., Rahimian, M., Pak, R. Y. S., "An inextensible membrane at the interface of a transversely isotropic bi-material full-space," Int. J. Engrg. Science, Vol. 91, 34-48, 2015 (DOI: 10.1016/j.ijengsci.2015.02.004) 11. Farzanian M., Arbabi F. and Pak R. "PML Solution of Longitudinal Wave Propagation in Heterogeneous Media." Journal of Earthquake Engineering and Engineering Vibration, 2016,15 (2), 357-368. 13. Hansen, C. and Pak, R.Y.S. "Centrifuge Characterization of Buried, Explosive-Induced Soil Ejecta Kinematics and Crater Morphology," J. Dynamic Behavior of Materials, 2(3), 2016, 306–325
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	Invited lecture, Hohai University, China Invited lecture, Northwest University, China Civil Engineering and Applied Mathematics Dual Degree Program development Civil Engineering–Engineering Science Program Development

W. Tad Pfeffer **Professor**

EDUCATION	BS, Geology, University of Vermont, 1976 MS, Geology, University of Maine, 1981 Ph.D., Geophysics, University of Washington, 1987
ACADEMIC EXPERIENCE	University of Colorado Boulder: Professor, CEAE, 2006 – present; Associate Professor, CEAE, 1999-2006; Fellow, Institute of Arctic and Alpine Research (INSTAAR), 1997-present; Assistant Research Professor, Geological Sciences, 1995-1999; Research Associate, INSTAAR, 1988-1997; Post-Doctoral Researcher, INSTAAR, 1987-1988.
NON-ACADEMIC EXPERIENCE	President, **W.T. Pfeffer Geophysical Consultants LLC**, Nederland Colorado, USA.
PROFESSIONAL REGISTRATIONS	N/A
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Geophysical Union International Glaciological Society
HONORS AND AWARDS	Jefferson Science Fellow (National Academy of Sciences), 2015-2016 Nye Lecture, American Geophysical Union, December 2011. University of Colorado Council on Research and Creative Work, Sabbatical year support for 2007-2008. Graham Foundation for Advanced Studies in the Fine Arts, Chicago, Illinois. Grant support for research and photography for *The Hand of the Small Town Builder* (published by David R. Godine, 2014), 2003
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	Editor in Chief, Oxford University Press Oxford Research Review/Natural Hazard Science, 2013-Present Lead Author, IPCC AR5 WGI, Chapter 13 (Sea Level Change); 2010 – 2013. Invited participant, Climate Change Impacts and Integrated Assessment Workshop/Snowmass Energy Modeling Forum, Snowmass, Colorado, August 2013. Committee Member, National Academy of Sciences, National Committee for the International Union of Geodesy and Geophysics, 2012 – 2015. Sigma Xi Distinguished Lecturer (2011-2012) <u>University Service</u> Academic Affairs Committee, Boulder Faculty assembly (2007-2012) Secretary, Boulder Faculty Assembly (2006 – 2007) Search Committee member, CU Graduate School Dean/Vice Chancellor for Research (2007) CEAE Committee Work: Facilities Committee (2000-2006) CEAE Curriculum Committee (2011)

PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	Bahr, D. B., W. T. Pfeffer, and G. Kaser (2015), A Review of Volume-Area Scaling of Glaciers, Reviews of Geophysics, 52, doi:10.1002/2014RG000470. Bahr, D.B., W.T. Pfeffer, and G. Kaser. (2014) Glacier volume estimation as an ill-posed inversion. Journal of Glaciology, 60(223), 2014 doi: 10.3189/2014JoG14J062 Pfeffer, W.T., A.A. Arendt; A. Bliss; T. Bolch; J.G. Cogley; A.S. Gardner; J-O Hagen; R. Hock; G. Kaser; C. Kleinholz; E.S.Miles; G. Moholdt; N.Mölg; F.Paul; V. Radić; P. Rastner; B.H. Raup; J. Rich; M.J. Sharp; and the Randolph Consortium. (2014) The Randolph Glacier Inventory: A globally complete inventory of glaciers. Journal of Glaciology. Gregory, J.M., J.A. Church, P.U. Clark, A.J. Payne, M.A. Merrifield, R.S. Nerem, P.D. Nunn, W.T. Pfeffer, D. Stammer, (2014). Comment on "Expert assessment of sea-level rise by AD 2100 and AD 2300", by Horton et al. (2014), Quat. Sci. Rev., 97 pp. 193-194, 10.1016/j.quascirev.2014.05.24 Gardner, A. S., G. Moholdt, J. G. Cogley, B. Wouters, A. A. Arendt, J. Wahr, E. Berthier, R. Hock, W. T. Pfeffer, G. Kaser, S. R. M. Ligtenberg, T. Bolch, M. J. Sharp, J. O. Hagen, M. R. van den Broeke & F. Paul, A Reconciled Estimate of Glacier Contributions to Sea Level Rise: 2003 to 2009. Science, 340, 852-857, 2013 Church, J.A., P.U. Clark, A. Cazenave, J.M. Gregory, S. Jevrejeva, A. Levermann, M.A. Merrifield, G.A. Milne, R.S. Nerem, P.D. Nunn, A.J. Payne, W. T. Pfeffer, D. Stammer, A.S. Unnikrishnan, (2013). Sea Level Rise by 2100. Science, 342(6165), p. 1445-1445. National Research Council, Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future, The National Academies Press, Washington, D.C., 2012 Pfeffer, W.T., Adaptation to a Non-steady Coastal Environment: Designing Infrastructure in a Non-Steady World, The International Journal of the Constructed Environment, V 2, No. 3, pp. 81-92, 2012 Pfeffer, W.T., Land Ice and Sea Level Rise: A Thirty-Year Perspective, Oceanography 24(2): 94–111, http://dx.doi.org/10.5670/oceanog.2011.30, 2011
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	None

Fatemeh Pourahmadian **Assistant Professor**

EDUCATION	BSc, Mechanical Engineering, University of Tabriz, Iran, 2007 MSc, Mechanical Engineering, Iran University of Science and Technology, Iran, 2010 MSc, Geo Engineering, University of Minnesota, Iran, 2015 PhD, Civil Engineering, University of Minnesota, 2016
ACADEMIC EXPERIENCE	University of Minnesota, Twin Cities, MN, Postdoctoral Fellow in Waves & Imaging Laboratory, 2016; Graduate Research Assistant, 2011-2016 Iran University of Science and Technology, Tehran, Iran, Research Associate in Experimental Modal Analysis Laboratory, 2010-2011; Graduate Research Assistant, 2008-2010
NON-ACADEMIC EXPERIENCE	HEPCO, Arak, Iran, Intern, summer 2004 Wagon Pars CO, Arak, Iran, Intern, summer 2007
PROFESSIONAL REGISTRATIONS	
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	Society of Engineering Science (SES) Engineering Mechanics Institute (EMI) American Society of Mechanical Engineers (ASME) American Rock Mechanics Association (ARMA)
HONORS AND AWARDS	Sommerfeld Fellowship, University of Minnesota, 2011-2012 Daneshy Fellowship, University of Minnesota, 2014-2015 Exceptional student award, Iran University of Science and Technology, 2009
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	Reviewer for Journal of Mechanical Systems and Signal Processing International Journal of Rock Mechanics and Mining Sciences Journal of Inverse Problems in Science and Engineering
PRINCIPAL PUBLICATIONS OF LAST FIVE YEARS	Pourahmadian, F., B.B. Guzina and H. Haddar, Generalized linear sampling method for elastic-wave sensing of heterogeneous fractures, *Inverse Problems,* In press, 2016 Pourahmadian, F., B.B. Guzina, On the elastic-wave imaging and characterization of fractures with specific stiffness, *International Journal of Solids and Structures,* In press, 71, 126-140, 2015 Guzina B.B., F. Pourahmadian, Why the high-frequency inverse scattering by topological sensitivity may work. *Proceedings of the Royal Society A* 471, 20150187, 2015 Pourahmadian F., S. G. Mogilevskaya, Complex variables-based approach for analytical evaluation of boundary integral representations of three-dimensional acoustic scattering. *Engineering Analysis with Boundary Elements* 53, 9-17, 2015 Pourahmadian F, Ahmadian H, Jalali H. Modeling and identification of

	frictional forces at a contact interface experiencing vibro- impacts. *Journal of Sound and Vibration* 331, 2874-2886, 2012 Jalali H, H Ahmadian, F Pourahmadian, Identification of micro- vibro-impacts at the boundary condition of a nonlinear beam, *Journal of Mechanical Systems and Signal Processing* 25, 1073-1085, 2011 Pourahmadian F, B. B. Guzina, Elastic anatomy of fracture in rock, *Geophysical Research Letters*, under review, 2016
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	

Richard A. Regueiro Associate Professor

EDUCATION	BSE, Civil Engineering Systems, University of Pennsylvania, 1991 SM, Aeronautics & Astronautics, Massachusetts Institute of Technology, 1993 Ph.D., Civil & Environmental Engineering, Stanford University, 1998
ACADEMIC EXPERIENCE	University of Colorado Boulder: Associate Professor, 2012-present; Assistant Professor, 2005-2012 Oxford University, United Kingdom (sabbatical), Fall 2014 Stanford University (sabbatical), Winter-Spring 2014
NON-ACADEMIC EXPERIENCE	Sandia National Laboratories, Livermore, CA, Principal Member of Technical Staff (2004-2005), Senior Member of Technical Staff (1998-2004)
PROFESSIONAL REGISTRATIONS	none
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	Engineering Mechanics Institute (EMI), American Society of Civil Engineers (ASCE)
HONORS AND AWARDS	Research Development Award (2012). Department of Civil, Environmental, and Architectural Engineering, University of Colorado Boulder.
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	**Associate Editor/ Editorial Board Member:** ASCE Journal of Engineering Mechanics (01/12-present), Acta Geotechnica (10/12-present), International Journal for Numerical and Analytical Methods in Geomechanics (09/13-present) **University Service** <u>Dept. of Civil, Environmental, & Architectural Engineering (CEAE)</u> Computer Committee Member, Chair (08/15-present) Curriculum Committee Member (8/15-present) <u>University of Colorado Boulder</u> Boulder Campus Cyberinfrastructure Board (BCCB) (1/15-present).
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	Regueiro, R.A., Duan, Z., Wang, W., Sweetser, J.D., Jensen, E.W. (2016) General formulation of a poromechanical cohesive surface element with elastoplasticity for modeling interfaces in fluid-saturated geomaterials, Int. J. Multi. Comp. Eng., accepted. Regueiro, R.A., Duan, Z., Yan, B. (2016) Overlapped-coupling between spherical discrete elements and micropolar finite elements in one dimension using a bridging-scale decomposition for statics, Eng. Comput. 33(1):28-63. Bennett, K., Regueiro, R.A., Borja, R.I. (2016) Finite strain elastoplasticity considering the Eshelby stress for materials undergoing plastic volume change, Int. J. Plast. 77:214-245. Zhang, B., Regueiro, R.A. (2015) On large deformation granular strain measures for generating stress-strain relations based upon three-

	dimensional discrete element simulations, Int. J. Solids Struct 66:151-170. Burd, H.J., Regueiro, R.A. (2015) Finite element implementation of a multiscale model of the human lens capsule, Biomech. Model. Mechanobiology 14(6):1363-1378. Wang, W., Regueiro, R.A., McCartney, J.S. (2015) Coupled axisymmetric thermo-poro-mechanical finite element analysis of energy foundation centrifuge experiments in partially saturated silt, Geotechnical and Geological Engineering 33(2):373-388.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	Multi-scale mechanics of particulate media, with K. Kamrin, J. Andrade, D. Hennan (lead), SES2016, University of Maryland, College Park, October 2016. Computational Geomechanics, with J. Andrade, R. Borja, Q. Chen, M. Manzari, S. Sun (lead), J. White, EMI2016, Vanderbilt University, May 2016. Multi-scale mechanics of particulate media, with K. Kamrin, J. Andrade, D. Hennan (lead), SES2015, Texas A&M University, October 2015. Computational Geomechanics (as lead organizer), with J. Andrade, R. Borja, M. Manzari, J. White, EMI2015, Stanford University, June 2015.

Victor E. Saouma Professor

EDUCATION	Baccalaureat Serie Scientifique, Lycee Chateaubriand, Rome, 1971 B.E. Civil Engineering, American University of Beirut, 1975 M.E., Civil Engineering, Cornell University, 1977 Ph.D., Civil Engineering, Cornell University, 1980
ACADEMIC EXPERIENCE	Visiting Professor: Politecnico of Milan, Visiting Professor, Department of Structural Engineering (2003-2004); Swiss Federal Institute of Technology, Lausanne (1997-1998); Politecnico de Catalunya (Barcelona), Ecole Normale Superieure de Cachan, and Universite de Toulouse (each one month) University of Colorado – Boulder, Professor, 1995-present; Associate Professor, 1988-1995, Assistant Professor, 1984-1988 University of Pittsburg, Pittsburgh, PA, Assistant Professor, 1981-1983 Princeton University, Princeton, NJ, Research Associate, 1980-1981
NON-ACADEMIC EXPERIENCE	University of Colorado – Boulder, Director and Principal investigator of the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES), on Fast Hybrid Test (2006-2009)
PROFESSIONAL REGISTRATIONS	None
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Concrete Institute (ACI) International union of laboratories and experts in construction materials systems and structures (RILEM)
HONORS AND AWARDS	Fellow and Past President of the International Association of Fracture Mechanics for Concrete and Concrete Structures (IA-FraMCOs)
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	**Professional Service** ACI-ASCE Committee 447, Finite Element Analysis of Reinforce Concrete Structures RILEM QFS Committee on Size Effect and Scaling of Quasibrittle Fracture Organized the 9th International conference on fracture mechanics of concrete (IA-FraMCoS). Chair of a RILEM committee on Alkali Silica Reaction Member of the *Expanded Proactive Materials Degradation Analysis Expert Panel*(PMDA) for concrete in nuclear reactors; Nuclear Regulatory Commission, 2010- 2014 Member of the *Materials Aging and Degradation* (MAaD) External Review Committee (ORNL, Light Water Reactor Sustainability R&D Program). Member of the Scientific Committee of MACENA (France) ,*Managing confinement structures in the event of an accident*. **University Service** Chair of Search Committee

PRINCIPAL PUBLICATIONS OF LAST FIVE YEARS	Saouma, V. and Hariri-Ardebili, M. and Le Pape Y. and Balaji, R. (2016) E*ffect of Alkali-Silica Reaction on the Shear Strength of Reinforced Concrete Structural Members*. A Numerical and Statistical Study, Nuclear Engineering and Design Hariri-Ardebili, M. and Saouma, V. (2016) *Seismic Fragility Analysis of Concrete Dams; A State-of-the-Art Review*, Engineering Structures, Vol. 128, pp. 374-399 Hariri-Ardebili, M. and Saouma, V. (2016) *Probabilistic Seismic Demand Model and Intensity Measure for Concrete Dam*s, Journal of Structural Safety, Vol. 59, pp. 67-85 Hariri-Ardebili, M. and Furgani, L. and Maghella, M., and Saouma, V. (2016) *A new class of seismic damage and performance indices for arch dams via ETA method*, Engineering Structures, V. 110 pp. 145-160, Hariri-Ardebili, M. and Saouma, V. and Porter, K. (2015) *Quantification of Seismic Potential Failure Modes in Concrete Dams*, Earthquake Engineering and Structural Dynamic, Hariri-Ardebili, M. and Saouma, V. (2016) C*ollapse Fragility Curves for Concrete Dams; A Comprehensive Study,* ASCE J. of Structural Engineering, Saouma, V.E. (2015) *Applications of Fracture Mechanics to Cementitious Materials; A Personal Perspective,* in ACI SP-300 Fracture Mechanics Applications in Concrete, G.L. Cusatis Editor Saouma, V.E. and Martin, R. and Hariri-Ardebili, M. and Katayama, T.(2015) *A Mathematical Model for the Kinetics of the Alkali Silica Chemical Reaction,* Cement and Concrete Research, Vol. 68, pp. 184-195 Saouma, V. and Hariri-Ardebili, M. (2014) *A Proposed Aging Management Program for Alkali Silica Reactions in a Nuclear Power Plant* Nuclear Engineering and Structural Design, Vol 277, pp. 248-264. Saouma, V., Kang, D., Haussman, G. (2012), *A Computational Finite-Element Program for Hybrid Simulation*, Earthquake Engineering and Structural Dynamic Journal, Vol. 41, pp. 375-389.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	

Petros Sideris **Assistant Professor**

EDUCATION	Diploma, Civil Engineering, National Tech. U. of Athens, Greece, 2005. M.S., Civil Engineering, University at Buffalo – SUNY, 2008 Ph.D., Civil Engineering, University at Buffalo – SUNY, 2012 Post-doctoral Research Fellow, University at Buffalo – SUNY, 2012-13
ACADEMIC EXPERIENCE	University of Colorado at Boulder, Assistant Professor (2013 – Present) University at Buffalo – SUNY, Adjunct Lecturer (2012-13) University at Buffalo – SUNY, Graduate Research Assistant (2008-12) University at Buffalo – SUNY, SEESL Fellow (2007-08) University at Buffalo – SUNY, Graduate Teaching Assistant (2005-07)
NON-ACADEMIC EXPERIENCE	None
PROFESSIONAL REGISTRATIONS	Engineer in Training (E.I.T), Michigan, 2013 to present
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Society of Civil Engineers (ASCE) Earthquake Engineering Research Institute (EERI) Transportation Research Board of the National Academies American Concrete Institute (ACI)
HONORS AND AWARDS	*2014 Outstanding Reviewer*, Journal of Structural Engineering, American Society of Civil Engineers (ASCE), U.S.A. *2013 Chair's Recognition Award*, Department of Civil, Structural and Environmental Engineering (CSEE), University at Buffalo, The State University of New York *2010 Liu Huixian Earthquake Engineering Scholarship Award*, US-China Earthquake Engineering Foundation, USA *2010 Paul J. Koessler Memorial Scholarship Award*, Peace Bridge Authority and ASCE Buffalo Section *Fellowship* (2007-08), Structural Engineering and Earthquake Simulation Laboratory (SEESL), University at Buffalo, The State University of New York (SUNY)
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	Professional Committees: TRB Committee on Seismic Design and Performance of Bridges – AFF50 (since 2015) ASCE/SEI Seismic Effects Committee (since 2013) ASCE/SEI Performance-based Design of Structures Committee (since 2016) Reviewer for 9 peer-reviewed journals: ASCE Natural Hazards Review, Earthquake Engineering and Engineering Vibration (Springer), ASCE Journal of Bridge Engineering, ASCE Journal of Engineering Mechanics, Engineering Structures Journal, ASCE Journal of Structural Engineering, Journal of Building Engineering (Elsevier), Transportation Research Record (TRR), Journal of the Transportation Research Board, Journal of Earthquake Engineering (Taylor & Francis) University Service:

	Director, *Structures and Materials Testing Laboratory* (SMTL), University of Colorado – Boulder (since 2013, 4 years) Department Committee Work: (a) Facilities Committee, since 2014 (3 years); (b) Graduate Committee (2013-14); and (c) SESM Faculty Search Committee (2013-16)
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	Nikoukalam M.T. and **Sideris, P.** (2016), "Experimental Performance Assessment of Nearly Full-Scale Reinforced Concrete Columns with Partially Debonded Longitudinal Reinforcement", *ASCE Journal of Structural Engineering* (Accepted). Nikoukalam M.T. and **Sideris, P.** (2016), "Low-Damage Post-Tensioned Segmental Bridge Columns with Flexible End Joints for Seismic Accelerated Bridge Construction", *TRR - Journal of the Transportation Research Board* (In press, DOI:10.3141/2592-17). **Sideris, P.** and Salehi, M. (2016), "A Gradient Inelastic Flexibility-Based Frame Element Formulation", *ASCE Journal of Engineering Mechanics*, 142(7), 04016039. **Sideris, P.** (2015), "Nonlinear Quasi-static Analysis of Hybrid Sliding-Rocking Bridge Columns Subjected to Lateral Loading", *Engineering Structures Journal*, 101, 125-137. **Sideris, P.**, Aref, A. and Filiatrault, A. (2015), "Experimental Seismic Performance of a Hybrid Sliding-Rocking Bridge for Various Specimen Configurations and Seismic Loading Conditions", *ASCE Journal of Bridge Engineering*, 20(11), 04015009. **Sideris, P.**, Aref, A. and Filiatrault, A. (2014), "Effects of Anchorage Hardware on the Cyclic Tensile Response of Unbonded Monostrands", *PCI Journal*, 59(6), 60-77. **Sideris, P.**, Aref, A. and Filiatrault, A. (2014), "Quasi-Static Cyclic Testing of a Large-Scale Hybrid Sliding-Rocking Segmental Column with Slip-Dominant Joints", *ASCE Journal of Bridge Engineering*, 19(10), 04014036. **Sideris, P.**, Aref, A. and Filiatrault, A. (2014), "Large-scale Seismic Testing of a Hybrid Sliding-Rocking Post-Tensioned Segmental Bridge System", *ASCE Journal of Structural Engineering*, 140(6), 04014025. **Sideris, P.** and Filiatrault, A. (2014), "Seismic Response of Squat Rigid Bodies on Inclined Planes with Rigid Boundaries", *ASCE Journal of Engineering Mechanics*, 140(1): 149–158.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	Faculty Teaching Excellence Program, University of Colorado – Boulder, Fall 2015 2012 Future Faculty Workshop, Strategies for Effective Teaching, Office of the Vice Provost for Faculty Affairs & the Teaching & Learning Center, University at Buffalo, The State University of New York

Jeong-Hoon Song Assistant Professor

EDUCATION	BS, Civil Engineering, Yonsei University, 2001 MS, Civil Engineering, Yonsei University, 2003 Ph.D., Theoretical and Applied Mechanics, Northwestern University, 2008
ACADEMIC EXPERIENCE	University of Colorado Boulder: Assistant Professor, 2014-present University of South Carolina: Assistant Professor, 2011-2014 Northwestern University, Post-doctoral Fellow, 2008-201 Northwestern University, Research Assistant, 2004-2008
NON-ACADEMIC EXPERIENCE	Naval Research Laboratory, Faculty Research Fellow, summer 2014-2016
PROFESSIONAL REGISTRATIONS	None
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Society of Civil Engineers (ASCE) American Society of Mechanical Engineers (ASME) US Association for Computational Mechanics (USACM) International Association for Computational Mechanics (IACM)
HONORS AND AWARDS	ONR Faculty Research Fellowship (2014-2016): Office of Naval Research
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	Committee Member (2013-Present): Computational Mechanics Committee; technical committee in Engineering Mechanics Institute (EMI) at American Society of Civil Engineers (ASCE) Corresponding Guest Editor (2015-2016): Special Issue on “Computational modeling of material deterioration at various length scales”, International Journal of Fracture. Guest Editor: Special Issue on “Experimental Testing and Computational Modeling of Dynamic Fracture”, International Journal of Impact Engineering, 87: 1-212 (2016). Member of Editorial Board (2014-Present): International Journal of Modern Mechanics Member of Editorial Board (2012-Present): Journal of Computational Engineering **University Service** <u>Dept. of Civil, Environmental, & Architectural Engineering (CEAE)</u> Graduate Committee. 2014-present.
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	K.C. Hoang, Y. Fu, and J.H. Song, An hp-proper orthogonal decomposition-moving least squares approach for molecular dynamics simulation, Computer Methods in Applied Mechanics and Engineering, 298: 548-575 (2016). J. Lua, T. Zhang, E. Fang and J.H. Song, “Explicit phantom paired shell element approach for crack branching and impact damage prediction of aluminum structures”, International Journal of Impact Engineering, 87:28–43 (2016).

	Y. Fu, J.G. Michopoulos and J.H. Song, "Dynamic response of polyethylene polymer nanocomposites to shock wave loading", Journal of Polymer Science, Part B: Polymer Physics, 53: 1292-1302 (2015). Y. Fu, J.G. Michopolous and J.H. Song, "Coarse-grained molecular dynamics simulations of epoxy resin during the curing process", Computational Materials Science, 107: 24-32 (2015). Y. Fu and J.H. Song, "Heat flux expressions that satisfy the conservation laws in atomistic system involving multibody potentials", Journal of Computational Physics, 294: 191–207 (2015). Y. Fu and J.H. Song, "Large deformation mechanism of glassy polyethyelene polymer nanocomposites: coarse grain molecular dynamics study", Computational Materials Science, 96: 485-494 (2015). A. Tabarraeia, S. Shadaloua and J.H. Song, "Mechanical properties of Graphene nanoribbons with disordered edges", Computational Materials Science, 96: 10-19 (2015). A. Tabarraie, X. Wang, A. Sadeghirad and J.H. Song, "An enhanced bridging domain method for linking atomistic and continuum domains", Finite Elements in Analysis and Design, 92:36-49 (2014). Y. Fu and J.H. Song, "On computing stress in polymer systems involving multi-body potentials from molecular dynamics simulation", Journal of Chemical Physics, 141: 054108 (2014). J.H. Song and Y.C. Yoon, "Multiscale failure analysis with coarse-grained micro cracks and damage", Theoretical and Applied Fracture Mechanics, 72: 100-109 (2014). Y.C. Yoon and J.H. Song, "Extended particle difference method for moving boundary problems", Computational Mechanics, 54:723–743 (2014). Y.C. Yoon and J.H. Song, "Extended particle difference method for weak and strong discontinuity problems: Part II. Formulations and applications for various interfacial singularity problems", Computational Mechanics, 53:1105-1128 (2014). Y.C. Yoon and J.H. Song, "Extended particle difference method for weak and strong discontinuity problems: Part I. Derivation of the extended particle derivative approximation for the representation of weak and strong discontinuities", Computational Mechanics, 53:1087-1103 (2014). A. Tabarraei, J.H. Song and H. Waisman, "Two-scale approach for modeling adiabatic shear band propagation under impact loads", International Journal for Multiscale Computational Engineering, 11: 543-563 (2013).
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	None

Wil V. Srubar III Assistant Professor

EDUCATION	BS, Civil Engineering, Texas A&M University, 2006 MS, Civil Engineering, University of Texas Austin, 2008 Ph.D., Civil and Environmental Engineering, Stanford University, 2013
ACADEMIC EXPERIENCE	University of Colorado Boulder: Assistant Professor, 2014-present University of Colorado Boulder: Adjunct Assistant Professor, 2013-2014 Stanford University, Graduate Research Assistant, 2009-2013 University of Texas at Austin, Graduate Teaching Assistant, 2007-2008
NON-ACADEMIC EXPERIENCE	Project Engineer, Alpha Facilities Solutions, San Antonio TX, 1-8, 2009 Graduate Engineer, Walter P. Moore and Associates, Inc, Austin, TX, 6/08 – 1/09 Engineering Intern, Walter P. Moore and Associates, Inc, Austin, TX, 5/06 – 8/06
PROFESSIONAL REGISTRATIONS	Engineer-In-Training (EIT), Texas
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Concrete Institute American Society of Civil Engineers (ASCE) Architectural Engineering Institute Structural Engineering Institute American Ceramics Society: Cements Division
HONORS AND AWARDS	Faculty Appreciation Award • University of Colorado 2016 Young Researcher Award • University of Colorado 2016 Excellence in Civil Engineering Education (ExCEEd) Fellow • ASCE 2016 Best Presentation Award • NSF/NIST Polymers and Composites Workshop 2013 ASCE Best Paper Competition • San Jose Branch 2012, 2013 Gerald J. Leiberman Fellowship • Stanford University 2012 Graduate Scholar Award • International Conference on Sustainability 2012 Best Paper Award: Green • American Composites Manufacturers' Association 2011 NSF Graduate Research Fellowship • National Science Foundation 2007
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	*Professional Service* Architectural Engineering Institute • Academic Council June 2015 – present 1st International Conference on Biobased Building Materials • Moderator June 2015 American Society of Engineering Education Conference • Moderator June 2015 ASCE Structures Congress • Session Chair April 2015 Journal of Renewable Materials • Guest Co-Editor 2014-2015 External Peer Reviewer for Grants & Journal Paper August 2013 – present *NSF, NDSEG, EPA, 10+ Scientific and Technical Journals*

	Institutional Service oSTEM Faculty Advisor, College of Engineering and Applied Sciences 2016 – present AEI Student Chapter Faculty Advisor, CEAE Department 2015 – present Graduate Committee Member, CEAE Department 2014 – present
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	a. Hinchcliffe, SA*, KM Hess*, **WV Srubar III**. "Experimental and Theoretical Investigation of Prestressed Natural Fiber-Reinforced Polylactic (PLA) Composite Materials." *Composites Part B: Engineering*, 95: 346-354, 2016. b. Hess, KM*, **WV Srubar III**. "Activating Relaxation-Controlled Diffusion Mechanisms for Tailored Moisture Resistance of Gelatin-based Bioadhesives for Engineered Wood Products." *Composites Part A*, 84: 435-441, 2016. c. Frazier, SD*, **WV Srubar III**. "Evaporation-based Method for Preparing Gelatin Foams with Aligned Tubular Pore Structures." *Materials Science and Engineering C*, 62:467-473, 2016. doi:10.1016/j.msec.2016.01.074 d. Barnhouse, PW*, **WV Srubar III.** "Material Characterization and Hydraulic Conductivity Modeling of Macroporous Recycled-Aggregate Pervious Concrete." *Construction and Building Materials*, 110: 89-97, 2016. e. **Srubar III, WV**, SL Billington. "A Micromechanical Model for Moisture-Induced Deterioration in Fully Biorenewable Wood-Plastic Composites." *Composites Part A: Applied Science and Manufacturing*; 50: 81-92, 2013. doi:10.1016/j.compositesa.2013.02.001 f. **Srubar III, WV**, "An Analytical Model for Predicting the Freeze-Thaw Durability of Natural Fiber Composites." *Composites Part B: Engineering*; 69: 435-442. g. Billington, SL, **WV Srubar III**, AT Michel. "Renewable Biobased Composites for Civil Engineering Applications." in *Sustainable Composites: Fibers, Resins, and Applications*. Netravali, A, C Pastore, Eds. DESTech: Lancaster, PA, pp. 313-336, 2014
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	1. American Concrete Institute (ACI) Conference Fall 2014, 2015, 2016 2. Architectural Engineering Institute (AEI) Conference 2015, 2016 3. Structural Engineering Institute (SEI) Conference 2015 4. American Society of Engineering Education Conference 2015 5. American Ceramics Society: Cements Division Conference 2015, 2016 6. Symposium for Sustainable Infrastructure 2016 7. International Concrete Sustainability Conference 2016 8. 3rd International Conference on Urban Disaster Reduction 2014 9. Sustainable Structures Symposium 2014 10. NSF Durability of Polymers and Polymer Composites Workshop 2013 11. BioEnvironmental Polymer Society Annual Meeting 2012

Sandra L. Vásconez Senior Instructor

EDUCATION	BA, Modern Foreign Languages, The King's College, 1993 MS, Lighting, Rensselaer Polytechnic Institute, 2000 MA, Art History and Museum Studies, University of Denver, 2005
ACADEMIC EXPERIENCE	University of Colorado at Boulder: Senior Instructor, 2007-present; Co-Director and Instructor of Rocky Mountain Lighting Academy 2012-present; Co-Administrator and Instructor of ENVD Lighting Design Certificate, 2014-present Rensselaer Polytechnic Institute, Troy, NY, Adjunct Assistant Professor 1998-2002; Outreach Education Instructor, 1998-2002
NON-ACADEMIC EXPERIENCE	Quenroe Associates, Boulder, CO, Project Manager and Assistant Designer, 2004-2007 Denver Art Museum, Denver, CO, Museum Internship, 2004 Victoria H. Myhren Gallery, University of Denver, CO, Senior Gallery Assistant, 2003-2004 Quenroe Associates, Boulder, CO, Exhibition Design Internship, 2003 Lighting Research Center, Rensselaer Polytechnic Institute, Troy, NY, Manager of Program Development, 1998-2002 MCI Customer Delivery Services, Colorado Springs, CO, Systems Security Administrator, 1994-1995 MCI Citicorp Account, New York, NY, Staff Assistant, 1993-1994
PROFESSIONAL REGISTRATIONS	National Council on Qualification for Lighting Professionals (NCQLP), Lighting Certified, 2002-present
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	IESNA (Illuminating Engineering Society of North America), 1998–present IALD (International Association of Lighting Designers), 2015 – present
HONORS AND AWARDS	Marinus Smith Award, 2013, University of Colorado-Boulder Architectural Engineering Faculty Appreciation Award, Civil, Environmental and Architectural Engineering, 2013 Service Award; Civil, Environmental and Architectural Engineering, 2012
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	IES Research Symposium Committee - 2016 **University Service** <u>Dept. of Civil, Environmental & Architectural Engineering (CEAE)</u> Operations Committee, 2015-2016 Chair, David L. DiLaura Faculty Fellowship in Architectural Engineering, 2013-Present Interim Curriculum Committee Chair 2013-2014 Environmental Engineering Search Committee, 2013 Civil, Environmental and Architectural Engineering Cooperative Representative, 2011-2013 Curriculum Committee 2010-12 IES Student Chapter Advisor, 2007-present <u>College of Engineering at the University of Colorado - Boulder</u>

	Undergraduate Education Council, 2013-2014
PRINCIPAL PUBLICATIONS OF LAST FIVE YEARS	Not Applicable
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	Lightfair International Annual Conference – 2012-present International Association of Lighting Designers Annual Conference – 2015, 2016 IES Light + Behavior Symposium – 2014 Rocky Mountain Lighting Academy – 2012-present

Yunping Xi Professor

EDUCATION	BS, Civil Engineering, Beijing Institute of Civil Engineering and Architecture, 1982 MS, Structural Engineering, Central Research Institute of Building and Construction, Beijing, 1985 Ph.D., Structural Engineering, Northwestern University, 1991
ACADEMIC EXPERIENCE	University of Colorado – Boulder, Professor, 2005-present; Associate Professor, 2000-2005; Assistant Professor, 1997-2000 Drexel University, Assistant Professor, 1993-1997 Northwestern University, Research Scientist, 1991-1993; Visiting Scholar, 1987-1988
NON-ACADEMIC EXPERIENCE	Beijing Central Research Institute of Building and Construction, Structural Engineer 1985-1987 Beijing Design Institute of Building and Construction, 1982-1983
PROFESSIONAL REGISTRATIONS	None
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Society of Civil Engineers (ASCE) International Association on Concrete Creep (IA-Concreep) American Concrete Institute (ACI)
HONORS AND AWARDS	2014 *Chang Jiang Chaired Professor*, Department of Education, China. 2010 *Kwang-Hua Chair Professor* at Tongji University, China. A recipient of *2010 Faculty Fellowship* at University of Colorado at Boulder. Research Development Award, Department of Civil, Environmental, and Architectural Engineering (CVEN), University of Colorado – Boulder, 2004. Young Researcher's Award, CVEN, University of Colorado – Boulder, 1998-1999 Faculty Advisor for Drexel Teams in American Concrete Institute (ACI) Beam Competition, First Prize for highest ultimate load and First Prize for best prediction, 1994
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	- The chair of Experimental Analysis and Instrumentation (EA&I) Committee, ASCE Engineering Mechanics Institute (EMI) - University Administrator of Colorado Local Technical Assistance Program - Members of the editorial board of international journals "*Computers in Concrete*", "*Magazine of Concrete Research"*, and "*Journal of Sustainable Cement Based Materials"*. **University Service** - A member of First Level Review Committee of College of Engineering (2012 – 2015).

PRINCIPAL PUBLICATIONS OF LAST FIVE YEARS	1. Musiket, K., Vernerey, F., and Xi, Y. (2016) "Numeral Modeling of Fracture Failure of Recycled Aggregate Concrete Beams under High Loading Rates", *International Journal of Fracture*, doi:10.1007/s10704-016-0145-3. 2. Jiang, Z., Huang, Q.H., Xi, Y., Gu, X.L., Zhang, W.P. (2016) "Experimental Study of Diffusivity of Interfacial Transition Zone between Cement Paste and Aggregate", *J. of Materials for Civil Engineering, ASCE*, 28(10): 04016109; DOI: 10.1061/(ASCE)MT.1943-5533.0001637. 3. Homan, L., Ababneh, A., and Xi, Y. (2016) "The Effect of Moisture Transport on Chloride Penetration in Concrete", *Construction and Building Materials*, 125, 1189-1195. 4. Na, O., and Xi, Y. (2016) "Mechanical and Durability Properties of Portland Cement Insulation Mortar with Rubber Powder from Waste Tires", *Journal of Material Cycles and Waste Management*, DOI 10.1007/s10163-016-0475-2. 5. Na, O., Ou, E., Xi, Y., and Saouma, V. (2016) "The Effects of Alkali-Silica Reaction on Mechanical Properties of Concrete with Three Different Types of Reactive Aggregates", *Structural Concrete*, DOI: 10.1002/suco.201400062. 6. Musiket, K., Rosendahl, M., and Xi, Y. (2016) "Fracture of Recycled Aggregate Concrete under High Loading Rates", *J. of Material in Civil Eng., ASCE*, 10.1061/(ASCE)MT.1943-5533.0001513 , 04016018. 7. Zhang, W.P., Tong, F., Gu, X.L., Xi, Y. (2015) "Study on Moisture Transport in Concrete in Atmospheric Environment", *Computers and Concrete*, 16(5), 775-793. 8. Zhang, W.P., Min, H.G., Gu, X.L., Xi, Y., Xing. Y.S. (2015) "Mesoscale Model for Thermal Conductivity of Concrete", Construction and Building Materials, 98, 8-16. 9. Bai, Y., Harajli, A., Xi, Y. (2015) "Analytical Solutions of Ionic Diffusion and Heat Conduction In Multi-Layered Porous Media", *Journal of Applied Mathematics*, Vol. 2015, Article ID 208914, 11 pages, doi:10.1155/2015/208914. 10. Damrongwiriyanupap, N., Limkatanyu, S., and Xi, Y. (2015) "A Thermo-Hygro coupled Model for Chloride Penetration in Concrete Structures", *Advances in Materials Science and Engineering*, vol. 2015, Article ID 682940, 10 pages, doi:10.1155/2015/682940.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	- Mastering the subsurface through technology innovation and collaboration: carbon storage and oil and Natural gas technologies review meeting, Aug. 16-18, Pittsburgh, PA. - Annual meeting of engineering mechanics institute of ASCE, May 22, Nashville, TN. - MAMNA 2016, March 21, Johns Hopkins.

Zhiqiang (John) Zhai **Professor**

EDUCATION	• BS, Engineering Mechanics, Tsinghua University, 1994 • MS, Fluid Mechanics, Tsinghua University, 1995 • PhD, Fluid Mechanics, Tsinghua University, 1999 • PhD, Building Technology, MIT, 2003
ACADEMIC EXPERIENCE	University of Colorado Boulder: Professor, 2015-present; Associate Professor, 2010-2015; Assistant Professor, 2003-2010; Faculty Director AREN Program, 2014-2016
NON-ACADEMIC EXPERIENCE	Senior Fellow, Rocky Mountain Institute, Boulder, CO (sabbatical), 2010-2011
PROFESSIONAL REGISTRATIONS	
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	• International Society of Indoor Air Quality and Climate (ISIAQ) • International Building Performance Simulation Association (IBPSA) • American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) • China Green Building Council (CGBC)
HONORS AND AWARDS	• Named as Distinguished Lecturer by American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), 2014. • Invited Participant for 2010 US Frontiers of Engineering (US FOE) Symposium and Invited Organizer for 2011 US FOE Symposium by National Academy of Engineering of US • Research Development Award, Department of Civil, Environmental, and Architectural Engineering, University of Colorado at Boulder, May, 2010 • Distinguished Service Award (DSA) of American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE), May, 2010 • William Mong Visiting Research Fellowship in Engineering, The University of Hong Kong, 2009 • 2008 Best Paper Award, International Journal of Building Simulation, 2009 • Sustainability Award of Green Faculty, University of Colorado at Boulder, 2008 • Young Researcher Award, Department of Civil, Environmental, and Architectural Engineering, University of Colorado at Boulder, 2007 • Presidential Fellowship, Massachusetts Institute of Technology, 1999–2003 • Grant-in-Aid Fellowship, American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE), 2001 • Martin Family Society of Fellows for Sustainability, Massachusetts Institute of Technology, 2000
INSTITUTIONAL AND PROFESSIONAL	• Associate Editor for Energy and Buildings Journal

SERVICE IN LAST FIVE YEARS	• Editorial Board Member for Building Simulation: An International Journal ; Journal of Building Physics; Indoor and Built Environment Journal; Journal of Energy; Journal AIMS Energy • Voting member and ASHRAE Learning Institute Coordinator of ASHRAE Technical Committee 4.10 – Indoor Environmental Modeling, 2004-Present • Scientific Committee Member for Urban Transitions Global Summit 2016, Sept 5-9, 2016, Shanghai, China • Vice President for the Healthy Buildings 2015 North America Conference, July 19-22, 2015, Boulder, Colorado • Vice President for the 9th International Symposium on Heating, Ventilation and Air Conditioning and the 3rd International Conference on Building Energy and Environment (ISHVAC-COBEE 2015), July 12-15, 2015, Tianjin, China • International Scientific Committee Member for Indoor Air 2016, July 3-8, 2016, Ghent, Belgium • Scientific Committee Member for International Building Physics Conference 2015 (IBPC 2015), June 14-17, 2015, Torino, Italy
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	• Zhai Z, Yates AP, Duanmu Lin, Wang Z. 2015. An Evaluation and Model of the Chinese Kang System to Improve Domestic Comfort in Northeast Rural China – Part-1: Model Development. Renewable Energy, 84: 3-11. • Zhai Z, Yates AP, Duanmu Lin, Wang Z. 2015. An Evaluation and Model of the Chinese Kang System to Improve Domestic Comfort in Northeast Rural China – Part-2: Result Analysis. Renewable Energy, 84: 12-21. • Zhai Z, Abarr M, AL-Saadi S, and Yate P. 2014. Energy Storage for Residential Buildings. Journal of Architectural Engineering, 20(4). SPECIAL SECTION: Housing and Residential Building Construction, B4014004. • Zhai Z, Xue Yu and Chen Q. 2014. Inverse Design Methods for Indoor Ventilation Systems Using CFD-Based Multi-Objective Genetic Algorithm. Building Simulation: An International Journal, 7(6): 661-669. • Zhai Z and Osborne A. 2013. Simulation-Based Feasibility Study of Improved Air Conditioning Systems for Hospital Operating Room. Frontiers of Architectural Research, 2(4): 468-475. • Zhai Z, Hermansen KA and Al-Saadi S. 2012. The Development of Simplified Rack Boundary Conditions for Numerical Data Center Models. ASHRAE Transactions, 118(2): 436-449.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	NSF STEM Mentor Workshop, every Feb, Washington, DC.

Yida Zhang **Assistant Professor**

EDUCATION	BS, Civil Engineering, Zhejiang University, 2010 MS, Civil Engineering, Louisiana State University, 2012 Ph.D., Civil Engineering, Northwestern University, 2016
ACADEMIC EXPERIENCE	University of Colorado Boulder: Assistant Professor, 2016 – present;
NON-ACADEMIC EXPERIENCE	N/A
PROFESSIONAL REGISTRATIONS	N/A
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Society of Civil Engineers (ASCE) American Rock Mechanics Association (ARMA)
HONORS AND AWARDS	**Terminal Year Fellowship**, Northwestern University, 2016 **Walter P. Murphy Fellowship**, Northwestern University, 2013 **Outstanding Undergraduate Final Project**, Zhejiang University, 2010 **First Prize of Chinese Physics Olympiad**, China, 2005
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	American Society of Civil Engineers (ASCE). Technical board, Unsaturated Soils (2016-present)
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	Publications Zhang, Y.D. & Buscarnera, G. (2017) Rate-dependent breakage mechanics: a continuum theory accounting for the fracture kinetics of minerals. Accepted, *Géotechnique*. Gao, S., Zhang, Y.D., Sonta, A. & Buscarnera, G. (2016) Evolution of water retention characteristics of granular material subjected to grain crushing. *Journal of Geotechnical and Geoenvironmental Engineering* 142 (9). Zhang, Y.D., Buscarnera, G. & Einav, I. (2015) Grainsize dependence of yielding in granular soils interpreted using fracture mechanics, breakage mechanics, and Weibull statistics. *Géotechnique* 66(2), 149-160. Zhang, Y.D. & Buscarnera, G. (2015) Implicit Integration under Mixed Controls of a Breakage Model for Unsaturated Crushable Soils. *International Journal for Numerical and Analytical Methods in Geomechanics*. Published online, DOI: 10.1002/nag.2431. Zhang, Y.D. & Buscarnera, G. (2015) Prediction of breakage-induced couplings in unsaturated granular soils. *Géotechnique* 65(2), 135-140.

	Zhang, Y.D. & Buscarnera, G. (2014). Grainsize dependence of clastic yielding in unsaturated granular soils. *Granular Matter* 16(4), 469-483. Voyiadjis, G.Z., Faghihi, D. & Zhang, Y.D. (2014) A theory for grain boundaries with strain-gradient plasticity. *International Journal of Solids and Structures* 51, 1872-1889. Presentations EMI 2016 & PMC 2016, "*Grain size effect in the comminution of granular materials*" May, 2016, Nashville, TN. 49th US Rock Mechanics/Geomechanics Symposium, "*Constitutive couplings in unsaturated granular media with crushable grains*" July, 2015, San Francisco, CA. 17th U.S. National Congress on Theoretical & Applied Mechanics, "*Computational aspects of a hydro-mechanical model for crushable granular soils*", June, 2014, East Lansing, MI. 2013 Conference of the ASCE Engineering Mechanics Institute, "*Understanding hydro-mechanical coupling in brittle unsaturated granular matter*", Aug. 2013, Evanston, IL
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	N/A

Dobroslav Znidarcic Professor

EDUCATION	BS, Civil Engineering, University of Zagreb, Croatia, 1972 MS, Civil Engineering, University of Zagreb, Croatia, 1978 Ph.D., Civil Engineering, University of Colorado Boulder, 1982
ACADEMIC EXPERIENCE	University of Colorado Boulder: Professor, 2006 – present; Associate Professor, 1992-2006; Assistant Professor, 1985-1992; University of Zagreb, Croatia, Docent 1983-1984 Purdue University, Visiting Assistant Professor, 1984-1985 University of Zagreb, Fulbright Scholar (sabbatical), 2001-2002 University of Colorado, Boulder, Research Assistant 1980-1982 University of Zagreb, Research and Scientific Assistant, 1972-1979
NON-ACADEMIC EXPERIENCE	ISMES Bergamo, Italy, Visiting Scientist (sabbatical) 1993-1994 Geoexpert Zagreb, Croatia, Head of the field laboratory, 1974-1977
PROFESSIONAL REGISTRATIONS	
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Society of Civil Engineers (ASCE) Croatian Society for Soil Mechanics and Geotechnical Engineering (HGD) International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE) American Society for Testing and Materials (ASTM)
HONORS AND AWARDS	Fulbright Scholar, 2001-2002. Suklje Lecturer, Slovenian Geotechnical Society, Strunjan 2007 Nonveiller Lecturer, Croatian Geotechnical Society, Zagreb, 2012 Ardaman-Wissa Lecturer, University of Florida, Gainesville, 2016
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	Modeling Aspects of Tailings Disposal Facility Design – Prediction of Storage Capacity, Short Course Delivered at the - Tailings and Mine Waste conferences, US and Canada with G. Gjerapic and D. vanZyl, 2012-2016. **University Service** <u>Dept. of Civil, Environmental, & Architectural Engineering (CEAE)</u> Operations Committee Chair, 2011- Transfer Students Evaluator, 2011- <u>University of Colorado – Boulder Campus</u> Graduate School Fellowship Committee, member, 2012-2015 Graduate School Dissertation Completion Fellowship Committee, member, 2012-2015
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	Lee, J. and Znidarcic, D., 2013, Flow Pump System for Unsaturated Soils: Measurement of Suction Response and the Soil–Water Retention Curve, <u>Geotechnical Testing Journal</u>, Vol. 36, No. 5, 12 pp. Estepho, M., van Zyl, D., Znidarcic, D., and Revington, A., 2013, Seepage Induced Consolidation Testing of Mature Fine Tailings, Tailings and Mine Waste '13 conference proceedings, November 3-6, Banff, AB, Canada, ISBN: 978-1-55195-326-7, pp.101-109.

	Brink, N., Kim, H., and Znidarcic, D., 2013, Consolidation Modelling for Geotextile Tubes Filled with Fine-Grained Materials, Proceedings of the GeoAfrica 2013 Conference, Accra, 2013. 18-20 November 2013, Accra, Ghana, CD-ROM.pp.10. Treinen, J.M., Cooke, R., and Znidarcic, D., 2014, A discussion of the critical drivers for tailings beach flows, Proceedings of the 17th International Seminar on Paste and Thickened Tailings, June 9-12, 2014 Vancouver, Canada, Richard Jewell, Andy Fourie, Patrick Sean Wells, and Dirk van Zyl eds., InfoMine Inc., June 2014 ISBN 978-0-9917905-3-1, pp. 19-30. Gjerapic, G., Bronson, B.R., Johnson, J.M. and Znidarcic, D., 2014, Embankment Stability on Soft Soil Foundations, Tailings and Mine Waste '14 conference proceedings, October 6-8, Keystone, CO, Brink, N., Kim, H., and Znidarcic, D., 2015, Numerical Modeling Procedures for Consolidation of Fine-Grained Materials in Geotextile Tubes, Proceedings of the Geosynthetics 2015 Conference, Portland, OR, 15-18 February 2015, pp.10. Znidarcic, D., 2015, If it creeps, does it matter? Tailings and Mine Waste '15 conference proceedings, October 25-28, Vancouver, BC, Canada, pp.229-235. Znidarcic, D., Adkins, D., Utting, L. and Catling, M., 2015, Rheomax® ETD technology, a laboratory study of application performance and associated geotechnical characteristics for polymer assisted tailings deposition of oil sands MFT, Tailings and Mine Waste '15 conference proceedings, October 25-28, Vancouver, BC, Canada, pp.508-520. Fourie, A., and Znidarcic, D., 2016, Optimising the Thin-lift Deposition of Thickened Tailings, Tailings and Mine Waste '16 conference proceedings, October 2-5, Keystone, CO. Gjerapic, G., Malgesini, M., Johnson, J.M., and Znidarcic, D., 2016, Use of Pore Water Pressure Measurements to Evaluate Risk to Tailings Stability, Tailings and Mine Waste '16 conference proceedings, October 2-5, Keystone, CO. Znidarcic, D., Van Zyl, D., Mario Ramirez, M., Mittal K., and Kaminsky, H., 2016, Consolidation Characteristics of Flocculated MFT – Experimental Column and SICT data, International Oil Sands Tailings conference proceedings, December 4-7, Lake Louise, AB, Canada, pp. Al-Yaqoub, T.H. Parol, J. and Znidarcic, D., 2017, Experimental investigation of volume change behavior of swelling soil, <u>Applied Clay Science</u>, Vol. 137, pp. 22-29
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	Tailings and Mine Waste conferences 2011, 2012, 2013, 2014, 2015 and 2016. International Oil Sands Tailings Conference, 2016.

Environmental and Water Resources Faculty Resumes follow, in alphabetical order

(These faculty typically devote about 5% of their time to architectural engineering; see Table 6-2)

Sherri M. Cook **Assistant Professor**

EDUCATION	BS, Civil Engineering, Virginia Tech (VPI&SU), 2008 MS, Environmental Engineering, University of Michigan, 2009 Ph.D., Environmental Engineering, University of Michigan, 2014
ACADEMIC EXPERIENCE	University of Colorado Boulder: Assistant Professor, 2014 – present University of Michigan, Research Assistant, 2008-2014, part time Clarkson University, Research Assistant, summer 2007 Virginia Tech, Research Assistant, 2005-2006, part time
NON-ACADEMIC EXPERIENCE	Froehling & Robertson, Sterling, VA, Intern, summer 2005
PROFESSIONAL REGISTRATIONS	E.I.T., Virginia, 2008 to present.
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	Association of Environmental Engineering & Science Professors (AEESP) Water Environment Federation (WEF) International Water Association (IWA) Society of Women Engineers (SWE)
HONORS AND AWARDS	Rackham Predoctoral Fellow, 2013-2014 Graham Sustainability Institute Doctoral Fellow, 2010-2013 National Science Foundation Graduate Research Fellow, 2009-2012 Phi Kappa Phi Honor Society National Fellow, 2008-2009 Virginia Tech College of Engineering Outstanding Senior, 2008 Morris K. Udall Scholar, 2007 and 2006
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	International Water Association Wastewater Treatment Modeling Conference. Scientific Committee (2014, 2016); Chair of Young Water Professional Scientific Committee and Workshop (2016) IWA/Water Environment Federation (WEF) Nutrient Removal and Recovery Conference. Scientific Committee (2016) Rocky Mountain Water Environment Association (RMWEA) Internship Committee (2016) Peer Review: Funding Agencies (WERF, NSF) and Journals (6) **University Service** Dept. of Civil, Environmental, & Architectural Engineering (CEAE) Curriculum Committee. 2014 to present. Graduate Committee. 2014-2015 Classroom Renovation Committee. 2015. University of Colorado - Boulder Udall Scholarship Selection Committee. 2016 Faculty Student Mentor Program. 2014
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF	Thompson, K.; Shimabuku, K.K.; Kearns, J.P.; Knappe, D.R.U.; Summers, R.S.; Cook, S.M. Environmental comparison between biochar and activated carbon for tertiary wastewater treatment. Accepted for publication at *Environmental Science & Technology*. Thompson, K.A.; Shimabuku, K.T.; Kearns, J.P., Knappe, D.R.U.; Summers, R.S; Cook, S.M. An environmental comparison between

LAST FIVE YEARS	powdered activated carbon and biochar for tertiary wastewater treatment. *Biochar 2016,* Corvallis, OR, August 2016. Cornejo, P.K.; Hogrewe, B.; Jones, C.H.; Cook, S.M. Improving Decision Support for Small Drinking Water Systems: An Innovative Approach to Alternatives Assessment. *American Water Works Association 16th Annual Conference & Exposition*, Chicago, IL, June 2016. Jones, C.H.; Shilling, E.; Cook, S.M. Sustainability Comparison of Innovative and Conventional Treatment Technologies for Small Systems. *Rocky Mountain Student Region AWWA and WEA 13th Annual Student Conference*, Laramie, WY, May 2016. Shilling, E.; Linden, K.; Cook, S.M. A Comparison of Life Cycle Environmental Emissions from Disinfection Technologies for Small Drinking Water Systems. *Association of Environmental Engineering and Science Professors (AEESP) Education and Research Conference*, New Haven, CT, June 2015. Cook, S.M.; Skerlos, S.J.; Love, N.G. Resource recovery from waste: A design-oriented analysis of anaerobic co-digestion stability. Oral presentation at the *Borchardt Conference*. Ann Arbor, MI, February 25, 2014. Cook, S.M.; Delgado Vela, J.; Stadler, L.G. Modeling advancing the success of engineering service projects from the classroom to the field. (failure and success analysis of water and sanitation projects in developing communities) Poster Presentation at the *AEESP Education and Research Conference*, Golden, CO, July 14-16, 2013. Cook, S.M.; VanDuinen, B.J.; Love, N.G.; Skerlos, S.J. Life cycle comparison of environmental emissions from three disposal options for unused pharmaceuticals. *Environmental Science & Technology*, *46* (10), 5535-5541, 2012.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	Development Effectiveness Workshop at UIUC, Sept 29- Oct 1, 2016 CU-Boulder LEAP (Leadership Education for Advancement and Promotion) Introductory Leadership Workshop, May 12-13, 2016 AEESP-NSF Grand (Environmental Engineering) Challenges Workshop, May 19-20, 2016 CU-Boulder FTEP (Faculty Teaching Excellence Program) Learning Goals Workshop, Aug. 10, 2015. CU-Boulder FTEP Writing (Well written? Well argued!) Workshop, October 2014 (4 sessions)

Christopher J Corwin **Instructor**

EDUCATION	BS, Civil Engineering, University of Kentucky, 1996 MS, Civil Engineering, University of Colorado, 2007 Ph.D., Civil Engineering, University of Colorado, 2010
ACADEMIC EXPERIENCE	University of Colorado Boulder: Instructor, 2014 – present; Postdoctoral Research Associate, 2010-2011; Graduate Research Assistant, 2006-2010
NON-ACADEMIC EXPERIENCE	Jacobs Engineering, Denver, CO, Water Process Engineer, 2011-2013 Landmark Consultants, Steamboat Springs, CO, Project Manager, 2002-2006 JF Sato & Assoc., Littleton, CO, Project Manager, 2001 - 2002 Carroll & Lange, Inc, Lakewood, CO, Engineer, 1999 – 2001 Environmental Engineering Service, Lebanon, OH, Engineer, 1998-1999 STEELOX Building Systems, Mason, OH, Engineer, 1997-1998
PROFESSIONAL REGISTRATIONS	P.E., Colorado, 2002 to present.
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	Association of Environmental Engineering & Science Professors (AEESP) American Water Works Association (AWWA)
HONORS AND AWARDS	John and Mercedes Peebles Innovation in Education Award, 2016 College of Engineering Outstanding Faculty Advisor, 2016 Environmental Engineering Faculty Appreciation Award, 2016 Environmental Engineering Faculty Appreciation Award, 2015 Environmental Engineering Faculty Appreciation Award, 2014 Best Paper Award – Water Quality and Technology Division, American Water Works Association, 2013 Advisor for winning teams in the national FAA Student Design Competition, 2016 and 2014
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	**University Service** Dept. of Civil, Environmental, & Architectural Engineering (CEAE) Faculty Advisor for Student Chapter of RMSAWWA/WEF 2014 to present Environmental Engineering (EVEN) cross-disciplinary degree program Curriculum Committee. 2014 to present Awards Committee. Chair 2015 to present Faculty Advisor for Student Environmental Engineers (SEVEN) 2014 to present
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF	Chowdhury, Z.K., Summers, R. S., Westerhoff, G.P., Leto, B., Nowack, K., Corwin, C. J.; Passantino, L., technical editor. (2012). "Activated Carbon: Solutions for Improving Water Quality," American Water Works Association, Denver, CO.

LAST FIVE YEARS	Seidel, C. J., and Corwin, C. J. (2013) "Total Chromium and Hexavalent Chromium Occurrence Analysis," Journal of American Water Works Association, 105(6) 37-38. Seidel, C. J., Najm, I., Blute, N.K., Corwin, C. J., and Wu, Y. (2013) "National and California Implications of Potential Hexavalent Chromium MCLs," Journal of American Water Works Association, 105(6) 39-40. Summers, R.S., Kim, S.M., Shimabuku, K., Chae, S. and Corwin, C.J. (2013) "Granular activated carbon adsorption of MIB in the presence of dissolved organic matter," Water Research, 47 (10) 3507-3513. Corwin, C. J., and Summers, R. S. (2012) "Controlling Trace Organic Contaminants with Granular Activated Carbon Adsorption," Journal of American Water Works Association, 104(1) E36-E47. Corwin, C. J. and Summers, R. S. (2011) "Adsorption and Desorption of Trace Organic Contaminants from Granular Activated Carbon Adsorbers after Intermittent Loading and Throughout Backwash Cycles," Water Research, 45 (2) 417-426.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	National Effective Teaching Institute (NETI1) Workshop, June 23-25, 2016.

John P. Crimaldi **Professor**

EDUCATION	BSE, Mechanical and Aerospace Engineering, Princeton University, 1987 MS, Civil and Environmental Engineering, Stanford University, 1992 Ph.D., Civil and Environmental Engineering, Stanford University, 1998
ACADEMIC EXPERIENCE	University of Colorado Boulder: Professor, 2015 – present; Associate Professor, 2007-2015; Assistant Professor, 2000-2007; CEAE Associate Chair for Graduate Education, 2013-present; Affiliated Faculty, Dept. of Applied Mathematics, University of Colorado Boulder, 2010-present
NON-ACADEMIC EXPERIENCE	Northrop Aircraft Company, Engineer, 1987-1991
PROFESSIONAL REGISTRATIONS	
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Society for Limnology and Oceanography American Geophysical Union
HONORS AND AWARDS	*Research Development Award, CEAE 2016* *Faculty Research Fellow,* University of Colorado, 2008-2009 *CAREER Award:* National Science Foundation, Biological Oceanography Program, 2004-2009 *Young Researcher Award:* CEAE, 2004 *Charles Hutchinson Teaching Award:* College of Engineering, University of Colorado, 2003 *Department Teaching Award:* CEAE, 2002 *Junior Faculty Development Award:* University of Colorado, 2001 *Graduate Fellowship:* Achievement Rewards for College Scientists Foundation, 1995-1996 *Graduate Fellowship:* Office of Naval Research, 1991-1994 *Donald J. Dyke Award for Excellence in Undergraduate Research:* Princeton University, 1987
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	Limnology and Oceanography: Methods, Associate Editor, 2008 - present Session Organizer and Chair, "Consequences of fluid stirring and mixing: from organisms to ecosystems," American Society for Limnology and Oceanography, Ocean Sciences meeting, Honolulu, Hawaii, February 24-28, 2014. **University Service** Dept. of Civil, Environmental, & Architectural Engineering (CEAE) Associate Chair for Graduate Education, 2013-present Facilitator for selection of Department Chair, 2013 Chair of Graduate Committee, 2013-present College Outstanding Dissertation Award Committee, 2010

	Chair of Awards Committee, 2009-2013 <u>College of Engineering at the University of Colorado - Boulder</u> Campus Ethics Committee, CEAS Representative 2011-2014 Engineering Excellence Fund, Faculty Advisor, 2010-2014 Dean's Blue Ribbon Committee on Graduate Programs, 2012 Steering Committee, Integrated Teaching and Learning Graduate STEM Program, 2011-2012
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	Pratt, K.R., Meiss, J.D. and **J.P. Crimaldi**. Reaction Enhancement of Initially Distant Scalars by Lagrangian Coherent Structures. *Physics of Fluids* **27**, no. 3, 035106, 2015. Soltys, M A, and **J.P. Crimaldi**. Joint Probabilities and Mixing of Isolated Scalars Emitted From Parallel Jets. *Journal of Fluid Mechanics* **769,** 130-153, 2015. **Crimaldi, J.P.** and T.R. Kawakami. Reaction enhancement in an unsteady obstacle wake: Implications for broadcast spawning and other mixing-limited processes in marine environments. *Journal of Marine Systems* **114**,130-137, 2015. **Crimaldi, J.P.** and R.A. Zimmer. The physics of broadcast spawning in benthic invertebrates. *Annual Review of Marine Science* **6**, 141-165, 2014. (Invited review article) **Crimaldi, J.P.** and *T.R. Kawakami. Reaction of initially distant scalars in a cylinder wake. *Physics of Fluids* **25**, 053604, 1-16, 2013. Koehl, M.A.R., **Crimaldi, J.P.**, and *D.E. Dombroski. Wind chop and ship wakes determine hydrodynamic stresses on larvae settling on different microhabitats in fouling communities. *Marine Ecology Progress Series* **479**, 47-62, 2013. Cullis, J. D. S., **Crimaldi, J. P.** and D. M. McKnight. Hydrodynamic shear removal of the nuisance stalk-forming diatom *Didymosphenia geminata*. *Limnology & Oceanography: Fluids & Environments* **3**, 256-26, 2013. **Crimaldi, J.P.** The role of structured stirring and mixing on gamete dispersal and aggregation in broadcast spawning. *The Journal of Experimental Biology* **215**, 1031-1039, 2012. (Invited review, Cover article) Soltys, M.A. and **J.P. Crimaldi**. Scalar interactions between parallel jets measured using a two-channel PLIF technique. *Experiments in Fluids* **50**, 1625-1632, 2011.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	

**Michael N. Gooseff		Associate Professor**

EDUCATION	BCE, Civil Engineering, Georgia Institute of Technology, 1996 MS, Civil Engineering, University of Colorado, 1998 Ph.D., Civil Engineering, University of Colorado, 2001
ACADEMIC EXPERIENCE	University of Colorado Boulder: Associate Professor, 2015-present; Director of the McMurdo Dry Valleys LTER program, 2015-present; Co-Director of the Graduate Hydrologic Sciences Program, 2015-present; Colorado State University, Associate Professor, 2013-2015; Penn State University, Assistant Professor, 2007-2012; Associate Professor, 2012-2013 Colorado School of Mines, Assistant Professor, 2004-2007 Utah State University, Assistant Professor, 2002-2004 Oregon State University Postdoctoral Fellow, 2002 University of Colorado, Research Assistant, 1998-2001, part time
NON-ACADEMIC EXPERIENCE	Hydrosphere Resource Consultants, geospatial technician, 1996-1998; GEDCO, process safety management technician, 1995
PROFESSIONAL REGISTRATIONS	E.I.T., Georgia, 1996 to present.
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Geophysical Union (AGU) Association for the Science of Limnology & Oceanography (ASLO) Geological Society of America (GSA) Society of Freshwater Science (SFS) Ecological Society of America (ESA)
HONORS AND AWARDS	Lead Principal Investigator of the McMurdo Dry Valleys Long-Term Ecological Research Project, 2015 – present. Outstanding Teaching Award, 2011, Penn State Engineering Alumni Society Harry West Teaching Award, 2011-2012, Department of Civil & Environmental Engineering, Penn State University Universities Council On Water Resources (UCOWR) Award for Education and Public Service to the MOCHA team, 2011 Hartz Family Development Professorship at Penn State University, 2007-2010 Outstanding Faculty Mentor, 2004, Utah State University
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	American Geophysical Union, Water Quality Technical Committee, Chair, 2014 – present; Chair elect, 2012-2014; Hydrologic Sciences Award Committee, Member, 2012-2015. Consortium of Universities for the Advancement of Hydrologic Sciences, Inc., Board of Directors, Member, 2014 – present. Environmental Protection Agency, Scientific Advisory Board on Connectivity of Waters, 2013 – 2014. Eos, Transactions of the American Geophysical Union, Editorial Board, 2009 - present Hydrology and Earth System Sciences, Associate Editor, 2009-2015

	Water Resources Research, Associate Editor, 2011-2015 WIRES Water, Associate Editor, 2012 – present. **University Service** Dept. of Civil, Environmental, & Architectural Engineering (CEAE) Curriculum Committee. 2016 - present Awards Committee. 2015 - present. Center for Water, Earth Science, and Technology (CWEST) Education Committee. Chair. 2016 - present.
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	Gooseff, MN, MA Briggs, KE Bencala, BL McGlynn, and DT Scott. 2013. Do transient storage parameters directly scale in longer, combined stream reaches? Reach length dependence of transient storage interpretations, *Journal of Hydrology*, 483: 16-25. Wohl, E, BP Bledsoe, KD Fausch, N Kramer, KR Bestgen and MN Gooseff. 2016. Management of large wood in Streams: An overview and proposed framework for hazard evaluation. *Journal of the American Water Resources Association*, 52(2): 315–335. Harvey, J, and M Gooseff, 2015. River corridor science: Hydrologic exchange and ecological consequences from bedforms to basins. *Water Resources Research*, 51(9): 6893-6922. Kelleher, C, T Wagener, B McGlynn, AS Ward, MN Gooseff and R Payn. 2013. Identifiability of transient storage model parameters along a mountain stream. *Water Resources Research*, 49(9): 5290-5306. Wollheim, WM, TK Harms, BJ Peterson, K Morkeski, CS Copkinson, RJ Stewart, MN Gooseff, and MA Briggs. 2014. Nitrate uptake dynamics of surface transient storage in stream channels and fluvial wetland. *Biogeochemistry*, 120: 239-257. Ward, AS, MN Gooseff, M Fitzgerald, TJ Voltz, and K Singha. 2014. Spatially distributed characterization of hyporheic solute transport during baseflow recession in a headwater mountain stream using electrical geophysical imaging. *Journal of Hydrology*, 517: 362-377. Ward, AS, MN Gooseff, TJ Voltz, M Fitzgerald, K Singha, and JP Zarnetske. 2013. How does rapidly changing discharge during storm events affect transient storage and channel water balance in a headwater mountain stream? *Water Resources Research*, 49(9): 5473-5486. Ward, AS, RA Payn, MN Gooseff, BL McGlynn, KE Bencala, CA Kelleher, SM Wondzell, and T Wagener. 2013. Variations in surface water-ground water interactions along a headwater mountain stream: Comparisons between transient storage and water balance analyses. *Water Resources Research*, 49(6): 3359-3374.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	National Academy of Engineering Frontiers in Engineering Education Symposium, 2011 (1 of 65 selected participants from Engineering programs across the US)

Mark Hernandez Professor

EDUCATION	BS, Civil Engineering, University of California at Berkeley, 1986 MS, Civil Engineering, University of California at Berkeley, 1988 Ph.D., Civil Engineering, University of California at Berkeley, 1992 PstDoc, Applied Microbiology, University of California at Berkeley, 1995
ACADEMIC EXPERIENCE	University of Colorado Boulder: Professor, 2009 – present; Associate Professor, 2002-2008; Assistant Professor, 1996-2002; Faculty Director Colorado Diversity Initiative, 2002-2014 University of California , Research Assistant, 1987-1992, part time
NON-ACADEMIC EXPERIENCE	Civil Engineer, *City and County of San Francisco*, Responsible to the Engineering Bureau for in-house process engineering and research projects for the City's main wastewater treatment facilities. *Oro Loma Sanitary District (OLSD)/CH2M Hill Inc.,* Oakland, CA. Served as liaison and staff engineer to CH2M Hill, Inc. for the District's master plan and expansion.
PROFESSIONAL REGISTRATIONS	P.E., Civil Engineering, California, 1996 to present.
SCIENTIFIC AND PROFESSIONAL SOCIETIES	American Association for Aerosol Research (AAAR) American Society for Microbiology (ASM) Association of Environmental Engineering & Science Professors (AEESP) Water Environment Federation (WEF)
HONORS AND AWARDS	Great Minds in STEM Foundation, Hispanic Educator of the Year, 2012 Sigma Xi, Distinguished Lectureship, 2012 President's Commendation for Advancing Diversity, University of Colorado System Award, 2008 University of Colorado at Boulder, Diversity and Equity Award, 2008 University of Colorado, Dept. of Civil Engineering, Teaching Award, 2003 Association of Environmental Engineering and Science Professors Advisor to Outstanding Doctoral Dissertation, 2001 University of Colorado, Dept. of Civil Engineering, Young Researcher Award, 2000
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	Executive Committee, The Leadership Alliance, one of a five-member executive board overseeing the policy, operations and financing of this premier NGO promoting diversity in higher education. The National Academy of Science, Engineering and Medicine: committee (2016/2017): Standards for the Microbiology of the Built Environment; (2011/2012): Review of Environmental Risk Assessment for Expansion of Facilities for Experimentations with Airborne Agricultural Pathogens American Association for Aerosol Research: Editor, Journal of Aerosol Science and Technology, 2008-2013, Bioaerosol Committee Working Group Chairman, 2015-2016 University Service Director, The Colorado Diversity Initiative Principal Investigator of an AGEP grant (of 22 awarded nationwide). I conceived, designed and led a joint

	NIH-NSF funded program to recruit and integrate graduate students from socioeconomic groups that have been traditionally underrepresented in STEM PhD programs. Dept. of Civil, Environmental, & Architectural Engineering (CEAE) Joint Program Coordinator for new Civil Engineering Program at Mesa State University, 2016 - Present Environmental Engineering (EVEN) cross-disciplinary degree program Graduate Admissions Committee. 2015-present.
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	Mehsah-Attipoe, J., Taubel, M., **Hernandez, M.**, Pitkaranta, M., Reponen, T., (2016) Toward a better understanding of the potential benefits and adversity of microbe exposures in the indoor environment, Indoor Air, *In Press*. Caicedo Ramirez, A., Ling, L., **Hernandez, M.,** (2016), Diffusion susceptibility demonstrates relative inhibition potential of sorbent-immobilized heavy metals against sulfur oxidizing acidophiles, *Journal of Microbiological Methods, 131:42-44.* **Hernandez, M.**, Perring, A.E., McCabe, K., Kok, G., Granger, G., Baumgardner, D., (2016) Chamber catalogues of optical and fluorescent signatures distinguish bioaerosol classes, *Atmospheric Measurement Techniques*, 9, 3283-3292, doi:10.5194/amt-9-3283-2016 Handorean A. M., Robertson, C., Harris, J.K, Frank, D.N, Kotter, C., Stevens M.J., Pace, N.R., **Hernandez, M.** (2105) Microbial aerosol liberation from soiled textiles isolated during routine residuals handling in modern health care setting. *Microbiome*, 3:72, DOI 10.1186/s40168-015-0132-3 Levin, H., Taubel, M., **Hernandez, M**. (2015) Microbiology of the Built Environment, Healthy Buildings Europe *Microbiome*, 3:68, 10.1186/s40168-015-0115-4 Turner, J, **Hernandez, M**, Snowder, J, Handorean, A, and McCabe, K., (2015) An optimized analytical suite for comparing toxicity effects of diesel exhaust particles and their extracts on human lung cells, *Aerosol Science and Technology* 49(**8**):599 Ling, A., Robertson, C., Harris, J.K, Frank, D.N, Kotter, C., Stevens M.J., Pace, N.R., and **Hernandez M**. (2014) High-resolution microbial community succession of microbially induced concrete corrosion in working sanitary manholes. *PLoSOne*, DOI: 10.1371/journal.pone.0116400 Ling, A., Robertson, C., Harris, J., Frank, D., Kotter, C., Stevens M., Pace, N.R., **Hernandez M**. (2014) Carbon Dioxide and Hydrogen Sulfide Associations with Regional Bacterial Diversity Patterns in Microbially Induced Concrete Corrosion, *Environmental Science & Technology,48* (13): 7357 Abu Dalo, M, Nevostrueva, S, **Hernandez, M,** (2014) Enhanced Copper (II) Removal from Acidic Water By Granular Activated Carbon Impregnated with Carboxybenzotriazole, *APCBEE Procedia*, 5: 64-6 Ling, A.L., Pace, N.R., Hernandez, M., and LaPara, T. (2013) Tetracycline Resistance and Class 1 Integron Genes Associated with Indoor and Outdoor Aerosols, *Environmental Sci & Tech 47* (9): 4046
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	Conference Chairman: The Microbiology of the Built Environment, University of Colorado at Boulder. 2012-2016 Indoor Air Workshop: Healthy Buildings Europe Annex 2015

Joseph Kasprzyk Assistant Professor

EDUCATION	BS, Civil Engineering, Penn State University, 2007 MS, Civil Engineering, Penn State University, 2009 Ph.D., Civil Engineering, Penn State University, 2013
ACADEMIC EXPERIENCE	University of Colorado Boulder: Assistant Professor, 2013 – present, full time Penn State University, Research Assistant, 2006-2013, part time
NON-ACADEMIC EXPERIENCE	AECOM, Intern, 2009-2013, performed engineering analysis on project assessing climate change effects on flood insurance, part time S and G Gas and Oil, Intern, 2005-2007, performed stormwater management calculations and created land development plans, part time
PROFESSIONAL REGISTRATIONS	E.I.T., Pennsylvania, 2007
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Geophysical Union (AGU) American Society of Civil Engineers (ASCE) Association of Environmental Engineering & Science Professors (AEESP)
HONORS AND AWARDS	Early Career Research Excellence Award of the International Environmental Modelling and Software Society (iEMSs). Awarded at iEMSs meeting in Toulouse, France, July 2016. University Council on Water Resources (UCOWR) Ph.D. Dissertation Award in Natural Science and Engineering, Awarded at UCOWR Conference, June 2014. Quentin Martin Best Practice-Oriented Paper, ASCE Journal of Water Resources Planning and Management, for Fu et al. (2013) "Optimal Design of Water Distribution Systems Using Many-Objective Visual Analytics" Awarded at EWRI 2014 in Portland, OR. Reviewing awards: Environmental Modelling and Software (2014); Journal of Water Resources Planning and Management (Best Reviewer, 2014; Outstanding Reviewer; 2011); Water Resources Research (2014) Student Presentation Award, International Environmental Modelling and Software Society Meeting, July 2012 US Environmental Protection Agency Science to Achieve Results (STAR) Graduate Fellowship, 2010-2013 NSF Graduate Research Fellowship Program Honorable Mention, 2009 First Place Technical Paper/Presentation Competition, ASCE Mid-Atlantic regional student competition, 2007
INSTITUTIONAL AND PROFESSIONAL SERVICE IN	Member of AGU technical committees on hydrologic uncertainty and water and society Member of control group of Environmental Water Resource Systems (EWRS) committee of ASCE Environmental Water Resources Institute, 2016-2020 (a four year term that includes serving as Secretary, Vice Chair, Chair, and Past Chair).

LAST FIVE YEARS	Vice Chair of a task committee sponsored by EWRS within EWRI: ECSTATIC: Excellence in Systems Analysis Teaching and Innovative Communication. Guest editor of Thematic Issue on evolutionary algorithms in water resources for Environmental Modelling and Software Associate Editor, Journal of Water Resources Planning and Management, 2016-Present **University Service** <u>Dept. of Civil, Environmental, & Architectural Engineering (CEAE)</u> Graduate Committee. 2013-2015; 2016-2017 Curriculum Committee. 2014-2015
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	Piscopo, A, R Neupauer, JR Kasprzyk. 2016. "Optimal design of active spreading systems to remediate sorbing groundwater contaminants in situ" *Contaminant Hydrology*. vol 190: 29-43. Smith, R, JR Kasprzyk, E Zagona. 2016. "Many Objective Analysis to Optimize Pumping and Releases in a Multi-Reservoir Water Supply Network" Journal of Water Resources Planning and Management. vol. 142, no. 2 Kasprzyk, JR, PM Reed, D Hadka. 2016. "Battling Arrow's Paradox to Discover Robust Water Management Alternatives" Journal of Water Resources Planning and Management. vol 142, no. 2. Matrosov, E, I Huskova, JR Kasprzyk, JJ Harou, C Lambert, PM Reed. 2015. "Many-Objective Optimization and Visual Analytics Reveal Key Trade-offs for London's Water Supply" Journal of Hydrology, vol 531, part 3: 1040-1053. Piscopo, AN, JR Kasprzyk, RM Neupauer. 2015. "An Iterative Approach to Multi-Objective Engineering Design: Optimization of Engineered Injection and Extraction for Enhanced Groundwater Remediation" Environmental Modelling and Software, vol 69: 253-261. Kasprzyk, JR, JN Ryan, "Tradeoff analysis of setback distance and density for oil and natural gas development" Presented at American Water Resources Association (AWRA) 2015 meeting, Denver, CO, Nov 2015. Maier, HM, Z Kapelan, JR Kasprzyk, JB Kollat, LS Mattot, MC Cunha, GC Dandy, MS Gibbs, E Keedwell, A Marchi, A Ostfeld, D Savic, DP Solomatine, JA Vrugt, AC Zecchin, BS Minsker, EJ Barbour, G Kuczera, F Pasha, A Castelletti, M Giuliani, PM Reed. 2014. "Evolutionary Algorithms and Other Metaheuristics in Water Resources: Current Status, Research Challenges, and Future Directions" Environmental Modelling and Software, vol. 62: 271-299.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	Participated in yearly workshops with water managers at University of California Davis to improve relevance of research results, 2008-present Attended Faculty Teaching Excellence Program workshops on learning objective design and how to get the most out of the first day of class Workshop on NSF CAREER proposals at AEESP conference, 2015

Karl G. Linden Professor

EDUCATION	BS, Agricultural and Biological Engineering, Cornell University, 1989 MS, Civil/Environmental Engineering, Univ. of California Davis, 1993 Ph.D., Civil/Environmental Engineering, Univ. of California Davis, 1997
ACADEMIC EXPERIENCE	University of Colorado Boulder: Mortenson Professor in Sustainable Development, 2015 – present; Helen and Huber Croft Endowed Professor, 2011-15; Professor, 2008-2011 Duke Univ.: Associate Professor, 2005-07; Assistant Prof., 1999-2005 University of North Carolina Charlotte: Assistant Professor 1997-99 University of Colorado at Boulder Visiting Professor 2006 EAWAG, Swiss Federal Institute for Environmental Science and Technology: Visiting Professor, 2003 University of Vienna: Visiting Professor, 2003 University of California Davis, Research Assistant, 1991-1997, part time Cornel University, Research Assistant, 1987-89, part time
NON-ACADEMIC EXPERIENCE	Larry Walker and Associates, Davis CA, Project Engineer 1993 Microgen Corporation, Ithaca NY, Project Engineer 1990 Black & Veatch, Montgomery Watson Harza, US EPA, Cadmus Group, Malcolm Pirnie, Hazen, Carollo Engineers, Colorado Department of Public Health and Environment, Dow Water, Brown and Caldwell, Tetra Tech: Intermittent Engineering Consultant 1998-present
PROFESSIONAL REGISTRATIONS	BCEEM, American Academy of Environmental Engineers and Scientists, 2015-present EIT: License XE095615, California; February 1995
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Society of Civil Engineers (ASCE) Association of Environmental Engineering & Science Professors (AEESP) American Water Works Association (AWWA) International UV Association (IUVA) International Water Association (IWA
HONORS AND AWARDS	WateReuse Person of the Year Award, 2014 Australian Water Recycling Center of Excellence Fellow 2013-2014 Pioneer Award in Disinfection and Public Health, Water Environment Federation, 2013 University Research Award, Boulder Faculty Assembly, CU 2013 Best Research Paper Award, International UV Association, 2013 Best Classic UV Paper Award, International UV Association, 2013 Faculty Research Award, College of Engineering and Applied Sci., 2012 Distinguished Faculty Award, CEAE, CU College of Engineering, 2011 Best Paper of the Year, J. AWWA 2010. *Journal AWWA*, 101(4)90+
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	Board of Directors, Association of Environmental Engineering and Science Professors (AEESP) 2016 – 2019 World Health Organization (WHO) Water Quality Technical Advisory Group member 2015-present Trustee, Vice Chair (2014-2016), Water Science and Research Division, American Water Works Association 2011-17

	Associate Editor, Journal of the American Water Works Association, 2012- 2018 Associate Editor, ASCE: Journal of Environmental Engin., 2005 - 2015 **University Service** <u>Dept. of Civil, Environmental, & Architectural Engineering (CEAE)</u> Executive Committee. 2010-2015. Facilities Committee. Chair. 2013-2016 <u>Mortenson Center (MCEDC) cross-disciplinary degree program</u> Co-Director. 2015 - present. <u>College of Engineering at the University of Colorado - Boulder</u> Vice Chancellors Advisory Committee, 2012-2015.
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	Lester, Y., Thurman, E.M., Ferrer, I., Sitterley, K., Korak, J.A., Aiken, G., *Linden, K.G. (2015) "Characterization of fracturing flowback water in Colorado: Implications for water treatment" *Science of the Total Environment* 521-513: 637-644. Beck, S.E., Wright, H.B., Hargy, T.M., Larason, T.C., *Linden, K.G. (2015) "Action Spectra for Validation of Pathogen Disinfection in Medium-Pressure Ultraviolet (UV) Systems" *Water Res.*, 70:27-37 Barstow, C.K., Dotson, A.D., *Linden, K.G. (2014) "Assessing point of use ultraviolet disinfection for safe water in urban developing communities" *IWA Journal of Water and Health,* 12(4):663-669 Chatterley, C., Javernick-Will, A., Linden, K.G., Kawser, A., Laure, B., Mohini, V. (2014) "A qualitative comparative analysis of well-managed school sanitation in Bangladesh" BMC public health, Vol. 14, No. 6. Pp. 1-14. Keen, O.S. and *Linden, K.G. (2013) Degradation of Antibiotic Activity during UV/H2O2 Advanced Oxidation and Photolysis in Wastewater Effluent *Environmental Sci. & Technol* 2013 *47* (22), 13020-13030 Rodriguez, R.A., Bounty, S., *Linden, K.G. (2013) Long-Range Quantitative PCR for Determining Inactivation of Adenovirus 2 by UV Light. *J. Applied Microbiology.* 114(6) 1854-1865
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	American Water Works Association (AWWA) Water Quality Technol Conference (WQTC); Salt Lake City, UT, November 14-16, 2015 International Ultraviolet Association Research Frontiers Conference, Leeuwarden, The Netherlands. May 20, 2015. Water Sustainability in Oil and Gas Exploration: Treatment Issues, American Chemical Society, Denver CO, March 25, 2015 Association of Environmental Engineering and Science Professors Conference, Yale University New Haven CT. June 14, 2015 ReNUWIt Sunlight Symposium, Stanford University, April 2, 2013.

Ben Livneh **Assistant Professor**

EDUCATION	BS, Civil Engineering, University of Western Ontario, 2004 MS, Civil Engineering, University of Western Ontario, 2006 Ph.D., Civil Engineering, University of Washington, 2012
ACADEMIC EXPERIENCE	University of Colorado Boulder: Assistant Professor, 2015-present; Research Scientist II, 2014-2015; Research Scientist I, 2012-2014 University of Washington, Research Assistant, 2006-2012 Seattle University, Adjunct Professor, 2008, 2010, 2011 University of Western Ontario, Research Assistant, 2004-2006
NON-ACADEMIC EXPERIENCE	Design and CAD Engineer, Lican Developments, Windsor, ON, 2006 Univercycle Recycling Co., Windsor, ON, Jiang Ying, China, 2003-2006 Quality Engineering Company, Southfield, MI, 2002 Event Manager, Canada Summer Games, London, ON, 2001
PROFESSIONAL REGISTRATIONS	
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Geophysical Union (AGU)
HONORS AND AWARDS	Symposium Scholar, DISCCRS VIII: Dissertations Initiative for the Advancement of Climate Change Research, 2013 CIRES Visiting Fellowship Award, 2012
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	American Geophysical Union (AGU) Lead session convener for both oral and poster sessions, 2013-2016 Associate Editor, Journal of the American Water Resources Association, 2016-present **University Service** Dept. of Civil, Environmental, & Architectural Engineering (CEAE) Computing Committee. 2016-present Graduate Committee. 2015-2016. Cooperative Institute for Research in Environmental Sciences (CIRES) Distinguished Lecturer Series Committee: 2015-present.
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	Houle, E.S., **B. Livneh**, and J.R. Kasprzyk, 2016: Exploring Snow Model Parameter Sensitivity Using Sobol' Variance Decomposition, Environmental Model and Software (accepted). Raseman, W., J.R. Kasprzyk, F. L. Rosario-Ortiz, J.R Stewart, and **B. Livneh**, 2016: Decision support systems for water treatment under climate extremes: A critical review, Environmental Science: Water Research & Technology (accepted). Yanto, **B. Livneh**, J.R. Kasprzyk, and B. Rajagopalan, 2016: Hydrologic Model Application Under Data Scarcity on Multiple Watersheds in Java Island, Indonesia, Journal of Hydrology: Regional Studies (accepted).

	Livneh B., and M.P. Hoerling, 2016: The Physics of Drought in the U.S. Central Great Plains. Journal of Climate, 29, 6783-6804. **Livneh B**., R. Kumar, and L. Samaniego, 2015: Influence of Soil Textural Properties on Hydrologic Fluxes in the Mississippi River Basin, Hydrological Processes, 29, 4638–4655. **Livneh B**., T.J. Bohn, D.S. Pierce, F. Munoz-Ariola, B. Nijssen, R. Vose, D. Cayan, and L.D. Brekke, 2015: A spatially comprehensive, hydrometeorological data set for Mexico, the U.S., and southern Canada 1950-2013, Nature Scientific Data, 2, 150042, doi:10.1038/sdata.2015.42. Buma B., and **B. Livneh**, 2015: Potential effects of forest disturbances and management on water resources in a warmer climate, Forest Science, http://dx.doi.org/10.5849/forsci.14-164. **Livneh B**., J.S. Deems, B. Buma, J.J. Barsugli, D. Schneider, N.P. Molotch, K. Wolter, and C.A. Wessman, 2015: Catchment Response to Bark Beetle Outbreak in the Upper Colorado River Basin, Journal of Hydrology 523,196–210. Pal, I., E. Towler, and **B. Livneh**, 2015: How Can We Better Understand Low River Flows as Climate Changes?, Eos Opinion, AGU, 96, doi:10.1029/2015EO033875. **Livneh, B**., J.S. Deems, D. Schneider, J.J. Barsugli, and N.P. Molotch, 2014: Filling in the gaps: Inferring spatially distributed precipitation from gauge observations over complex terrain, Water Resources Research, 50, doi:10.1002/2014WR015442. **Livneh B**., E.A. Rosenberg, C. Lin, B. Nijssen, V. Mishra, K.M. Andreadis, E.P. Maurer, and D.P. Lettenmaier, 2013: A Long-Term Hydrologically Based Dataset of Land Surface Fluxes and States for the Conterminous United States: Update and Extensions, Journal of Climate, 26, 9384–9392. **Livneh B**., and D.P. Lettenmaier, 2013: Regional parameter estimation for the Unified Land Model, Water Resources Research, doi:10.1029/2012WR012220. **Livneh, B**. and D.P. Lettenmaier, 2012: Multi-criteria parameter estimation for the unified land model, Hydrology and Earth System Sciences, 16, 3029-3048, doi:10.5194/hess-16-3029-2012.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	Co-organizer, Reservoir Evaporation Workshop, Oct. 2015, CU Boulder Science-lead, Climate Change and Water Working Group, Aug. 2015 Seattle Mentor, Faculty Mentoring Students Program, CU-Boulder, 2013-2015 Resource Speaker, Water Education Foundation: Lower Colorado River Tour, 2013 Vice President, Chi Epsilon, University of Washington Chapter, 2011-2012

Diane M. McKnight Professor

EDUCATION	BS, Mechanical Engineering, Massachusetts Institute of Technology, 1975 MS, Civil Engineering, Massachusetts Institute of Technology, 1978 Ph.D., Environmental Engineering, Massachusetts Institute of Technology, 1979
ACADEMIC EXPERIENCE	University of Colorado – Boulder, Professor, 1999-present; Associate Professor, 1996-1999 Massachusetts Institute of Technology – INCRA Fellow, 1975-1979
NON-ACADEMIC EXPERIENCE	University of Colorado – Boulder; Fellow of INSTARR, 1996-present; Associate Director, Mountain Research Station, 1996-2002 U.S. Geological Survey – Research Hydrologist, National Research Program, 1979-1996; Research Advisor, Ecology, Water Resources, 1986-1992; National Research Council Fellow, 1979-1980 National Science Foundation- Arctic Sciences, Program Officer, 2015-present
PROFESSIONAL REGISTRATIONS	N/A
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Society of Limnology and Oceanography (ASLO) American Geophysical Union (AGU) American Chemical Society (ACS) International Humic Substances Society (IHSS) Phycological Society of America (PSA) Society of Freshwater Science (SFS) Sigma Xi
HONORS AND AWARDS	Distinguished Research Lecturer, University of Colorado (2015) Faculty Research Award, College of Engineering and Applied Science, University of Colorado (2014) John Dalton Medal, European Geophysical Union (2014) American Geophysical Union, Hydrology Career Award (2014) National Academy of Engineering, member (2012) American Association for the Advancement of Science, Fellow (2009) Honorary Chair, Humic Sciences and Technology Conference XI (2008) American Geophysical Union, Langbein Lecturer (2005) American Geophysical Union Fellow (2003) USGS, Meritorious Service Award (1995) Arthur T. Ippen Award, Ralph M. Parsons Laboratory, Massachusetts Institute of Technology (1978)
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	Chair, Editorial Committee, Schoolyard Children's Book Series, Long-term Ecological Research Network (2006-2015) National Academies, Chair, Committee on the Effects of Diluted Bitumen on the Environment: A Comparative Study, 2014-2016 **University Service** Dept. of Civil, Environmental, & Architectural Engineering (CEAE) Co-Director Hydrologic Sciences Graduate Program, 2004-2015 INSTARR

	Various Promotion and Tenure Committees
PRINCIPAL PUBLICATIONS OF LAST FIVE YEARS	McKnight, D. M., Cozzetto, K., Cullis, J. D. S., Gooseff, M. N., Jaros, C., Koch, J. C., Lyons, W. B., Neupauer, R., Wlostowski, A. 2015. Potential for real-time understanding of coupled hydrologic and biogeochemical processes in stream ecosystems: Future integration of telemetered data with process models for glacial meltwater streams. Water Resources Research 51(8):6725-6738. Cullis, J. D. S., L. F. Stanish, D.M. McKnight. 2014. Diel flow pulses drive particulate organic matter transport from microbial mats in a glacial meltwater stream in the McMurdo Dry Valleys. Water Resources Research, 50: 86-97, DOI: 10.1002/2013WR014061 Gabor, R. S., K. Eilers, D. M. McKnight, N. Fierer, S. P. Anderson. 2014. From the litter layer to the saprolite: Chemical changes in water-soluble soil organic matter and their correlation to microbial community composition. Soil Biology and Biochemistry, 68:166-176. Cozzetto, K. D., K. E. Bencala, M. N. Gooseff, D. M. McKnight. 2013. The influence of stream thermal regimes and preferential flow paths on hyporheic exchange in a glacial meltwater stream. Water Resources Research. 49 (9): 5552–5569. Koch, J. C., R. L. Runkel, R. Striegl, D.M. McKnight. 2013. Hydrologic controls on the transport and cycling of carbon and nitrogen in a boreal catchment underlain by continuous permafrost. Journal of Geophysical Research-Biogeosciences. 118(2): 698-712. Todd, A. S.; Manning, A. H.; Verplanck, P. L. Crouch, C., McKnight, D. M.; Dunham, R., 2012. Climate-Change-Driven Deterioration of Water Quality in a Mineralized Watershed. Environmental Science & Technology, 46: 9324-9332, DOI: 10.1021/es3020056. Cawley, K. M., Butler, K. D., Aiken, G. R., Larsen, L. G., Huntington, T. G., McKnight, D. M., 2012. Identifying fluorescent pulp mill effluent in the Gulf of Maine and its watershed. Marine Pollution Bulletin, 64:1678-1687, DOI:10.1016/j.marpolbul.2012.05.040 SanClements, M. D., Oelsner, G. P., McKnight, D. M., Stoddard, J. L., Nelson. S. J. 2012. New insights into the source of decadal increases of dissolved organic matter in acid-sensitive lakes of the Northeastern United States. Environmental Science & Technology. doi.org/10.1021/es204321x.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	Serving as a Program officer in the Arctic Science program at the National Science Foundation

Lupita D. Montoya Assistant Professor

EDUCATION	BS, Engineering, California State University, 1989 MS, Mechanical Engineering, Stanford University, 1991 PhD, Civil and Environmental Engineering, Stanford University, 1999
ACADEMIC EXPERIENCE	University of Colorado Boulder: Assistant Professor, 2010 – present. Colorado School of Public Health, Environmental and Occupational Health Department, Assistant Professor, 2010-present. Rensselaer Polytechnic Institute, Assistant Professor, 2003–2009. State of New York University at Albany, Postdoctoral Fellow, 1998-2000. Harvard School of Public Health, Postdoctoral Fellow, 2000-2003
NON-ACADEMIC EXPERIENCE	The Aerospace Corporation, Asst. Engineer, El Segundo CA, summers 1988-1991 Hughes Aircraft Corporation, Asst. Engineer, Canoga Park CA, summer 1987
PROFESSIONAL REGISTRATIONS	NA
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Society for Engineering Education American Society of Civil Engineers Association of Environmental Engineering & Science Professors American Association for Aerosol Research (AAAR)
HONORS AND AWARDS	Fulbright Senior Specialist (Environmental Sciences), U.S. Department of State (2011-present). David M. Darrin '40 Counseling Award, for “a faculty member who has made unusual contributions to the personal counseling of students”, awarded by the *Phalanx Honor Society* at Rensselaer Polytechnic Institute (2009). Second place, 2009 International Latino Book Award, Best Biography for “Paths to Discovery: Autobiographies from Chicanas with Careers in Science, Mathematics and Engineering”. First prize, (co-PI) third annual ARCHITECT magazine R+D Awards for “Active Phytoremediation Wall System”, August 2009. Rensselaer NSF-RAMP UP (ADVANCE) Career Campaign Award “in recognition of outstanding scholarship and early career achievement” (March 2007).
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	American Association for Aerosol Research (AAAR): Chair of Health Effects Working Group (2015-2016); Chair of Internet Communications Committee (2015-2016); Chair of Membership Committee (2016-2017); National Secretary (2008-2011). Association of Environmental Engineering and Science Professors (AEESP). Organized "Air Quality Challenges for the Environmental Engineer of 2050" Symposium at 2013 conference.

	Member of the Senior Fulbright Specialists Program in Environmental Science, Council for the International Exchange of Scholars and the U.S. Department of State (2011-present) **University Service** Scholarship Committee, College of Engineering and Applied Science, (2011-present). Awards Committee, Department of Civil, Environmental and Architectural Engineering, (2012-present). Awards Committee, Environmental Engineering Program(2013-present). Faculty Advisor, Society of Hispanic Professional Engineers/Mexican American Engineers and Scientists, CU Chapter (2010- present).
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	Barraza F., Jorquera H., Heyer J., Palma W., Edwards A.M., Muñoz M., Valdivia G., Montoya L.D (2016). "Short-term dynamics of indoor and outdoor endotoxin exposure: Case of Santiago, Chile, 2012", *Environment International*, 92-93:97-105. Ward, B.J., Yacob T.W., Montoya L.D. (2014). "Evaluation of Solid Fuel Char Briquettes from Human Waste", *Environmental Science and Technology*, 48 (16):9852–9858. Barraza F., Jorquera H., Valdivia G., Montoya L.D. (2014). "Indoor PM2.5 in Santiago, Chile, spring 2012: Source apportionment and outdoor contributions", *Atmospheric Environment,* 94:692-700. Escobedo L. E., Champion W., Li N., Montoya L. D. (2014). "Indoor Air Quality in Latino Homes in Boulder, Colorado", *Atmospheric Environment,* 92:69-75. McQuillan B., Hertzberg J. and Montoya L.D. (2014). "Flow Visualization Study of Synthetic Flow Control in the Indoor Environment", *Building and Environment,* 73:239-248. Lennox E., Kreisberg N. and Montoya L.D. (2013). "Design and Characterization of a New Area Aerosol Sampler Based on Microtrap Collection Technology", *Aerosol Science and Technology,* 47(6):626-633. Wei Z., Chen L., Thompson D. and Montoya L.D. (2014). "Effect of Size on In Vitro Cytotoxicity of Titania and Alumina Nanoparticles", *Journal of Experimental Nanoscience,* 9(6):625-638. Aydogan A. and Montoya L.D. (2011)."Formaldehyde Removal by Common Indoor Plant Species and Various Growing Media", *Atmospheric Environment* 45:2675-2682.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	Sustainable Engineering Education Community Workshop, NSF, Arlington VA, August 5-6, 2014. Integrating Sustainability into Engineering: Design principles and tools to expand your educative capacity. National conference of the Society for the Advancement of Chicanos and Native Americans in Science (SACNAS, University of South Florida, October 21, 2010. Summer Leadership Institute, AAAS and SACNAS, Washington DC, July 28 – August 1, 2009.

Roseanna M. Neupauer Professor

EDUCATION	BS, Civil Engineering, Carnegie Mellon University, 1989 MS, Civil Engineering, Massachusetts Institute of Technology, 1991 MS, Mathematics, New Mexico Institute of Mining and Tech., 1999 Ph.D., Hydrology, New Mexico Institute of Mining and Tech., 2000
ACADEMIC EXPERIENCE	University of Colorado Boulder: Professor, 2016 – present; Associate Professor, 2009-2016; Assistant Professor, 2005-2009; Faculty Director for Civil Engineering, 2014-2015; Associate Chair CEAE 2015 - present; Escuela Superior Politécnica del Litoral, Guayaquil, Ecuador, Fulbright scholar, 2015 University of Virginia, Visiting Assistant Professor, 2004-2008, Assistant Professor, 2001-2004 New Mexico Institute of Mining and Tech., Research Assistant, Teaching Assistant, Research Fellow, 1995-2000, part time Massachusetts Institute of Technology, Research Assistant, 1989-1991, part time
NON-ACADEMIC EXPERIENCE	Idaho National Engineering Laboratory, Idaho Falls, ID, Engineer, Senior Engineer, 1991-1995 F&M Associates, Allentown, PA, Intern, summers 1988, 1989 Lehigh County Authority, Wescosville, PA, Intern, summer 1987
PROFESSIONAL REGISTRATIONS	P.E., New Mexico, 1998 to present P.E., Virginia, 2002 to present
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Geophysical Union (AGU) American Society of Civil Engineers (ASCE) American Society for Engineering Education (ASEE) Geological Society of America (GSA) National Groundwater Association (NGWA) Society for Industrial and Applied Math (SIAM)
HONORS AND AWARDS	"Best Should Teach" Faculty Gold Award, Univ. of Colorado, 2016; President's Teaching Scholar, Univ. of Colorado, 2015; Fulbright U.S. Scholar Grant, 2015; Editor's Citation for Excellence in Refereeing, *Water Resources Research*, 2015, *Geophysical Research Letters*, 2013; Fellow, Geological Society of America
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	Associate Editor, *Journal of Hydrology*, 2012 – present American Society of Civil Engineers – Committee on Faculty Development (Member 2009 – 2016, Secretary 2013-14, Chair 2014-15, Past Chair 2015-16); ExCEEd Teaching Workshop (Director 2010, Mentor and presenter 2011, 2012); Groundwater Council (Secretary 2012-14, Vice Chair 2014-present); Excellence in Water Resources Education Task Committee (Vice Chair 2008-14); Groundwater Management Committee (Member 2003-present); Groundwater Symposium Committee (Member 2007-present) American Geophysical Union – Langbein Lecture Committee (Member 2011-2014, Chair 2013-14)

	University Service Dept. of Civil, Environmental, & Architectural Engineering (CEAE) Curriculum Committee. Chair. 2015- present; Member 2013-present Coordinator for establishing a joint Civil Engineering program with Colorado Mesa University, 2015-present Representative to the Boulder Faculty Assembly (BFA), 2014-present College of Engineering at the University of Colorado - Boulder Undergraduate Education Council. 2010-12, 2014, 2015-present. Writing Sub-Committee. Spring 2016 – present. University of Colorado President's Teaching Scholar Program Selection Committee, 2015-16 GPTI Award Selection Committee, 2013-present BFA Intercollegiate Athletics Committee, 2015-present, Chair 2016-present BFA Budget and Planning Committee, 2015-present
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	Okkonen, J. and R.M. Neupauer, Capture zone delineation methodology based on the maximum concentration - Preventative groundwater well protection areas for heat exchange fluid mixtures, *Water Resources Research*, 52, doi:10.1002/2016WR018715, 2016. Piscopo, A.N., R.M. Neupauer, J.R. Kasprzyk, Optimal design of active spreading systems to remediate sorbing groundwater contaminants in situ, *Journal of Contaminant Hydrology*, 190, 29-43, 2016. Wagner, D.E., R.M. Neupauer, and C. Cichowitz, Adjoint-based probabilistic source characterization in water distribution systems with transient flows and imperfect sensors, *Journal of Water Resources Planning and Management*, DOI: 10.1061/(ASCE)WR.1943-5452.0000508, 2015. Neupauer, R.M. and D.C. Mays, Engineered injection and extraction for in situ remediation of sorbing solutes in groundwater, *Journal of Environmental Engineering*, 141(6), DOI: 10.1061/(ASCE)EE.1943-7870.0000923, 2015. Lackey, G.D., R.M. Neupauer, and J. Pitlick, Effects of streambed conductance on stream depletion, *Water*, 7, 271-287, doi:10.3390/2/7010271, 2015. Neupauer, R. M., J. D. Meiss, and D. C. Mays, Chaotic advection and reaction during engineered injection and extraction in heterogeneous porous media, *Water Resour. Res*., 50, doi:10.1002/ 2013WR014057, 2014. Griebling, S.A. and R.M. Neupauer, Adjoint modeling of stream depletion in groundwater-surface water systems, *Water Resources Research*, 49, doi:10.1002/wrcr.20385, 2013.
PROFESSIONAL DEVELOPMENT ACTIVITIES	Boulder Faculty Assembly Leadership Institute, 2013-14.

Harihar Rajaram, Professor

EDUCATION	B. Tech, Indian Institute of Technology, Madras, 1985 MS, Civil Engineering, University of Iowa, 1987 Sc.D., Civil Engineering, Massachusetts Institute of Technology, 1991
ACADEMIC EXPERIENCE	University of Colorado Boulder: President's Teaching Scholar, 2012-present; Professor, 2004 – present; Associate Professor, 2000-2004; Assistant Professor, 1993-2000; Affiliate Faculty Member, Applied Mathematics, 1996-present
NON-ACADEMIC EXPERIENCE	None
PROFESSIONAL REGISTRATIONS	None
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Geophysical Union Society for Industrial and Applied Mathematics
HONORS AND AWARDS	President's Teaching Scholar, University of Colorado, 2012 Clarence Eckel Prize for Faculty Excellence, 2016 College of Engineering Faculty Research award, 2016 Editor, Water Resources Research, 2013-present
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	Editor, Water Resources Research, 2013-present ICESat2 Science Definition Team Review Panel, NASA, 2014. **University Service** Dept. of Civil, Environmental, & Architectural Engineering (CEAE) Executive Committee. 2014-present. College of Engineering at the University of Colorado - Boulder First-Level Review Committee, 2012-2014. Faculty Research Committee, 2013-15. University of Colorado Research Review Board, 2014-present Faculty Teaching Excellence Program Associate, 2014-present
PRINCIPAL PUBLICATIONS OF THE LAST FIVE YEARS	·Pandey, S. and H. Rajaram, Modeling the influence of preferential flow on the spatial variability and time-dependence of mineral weathering rates, *Water Resources Research*, 52, doi: 10.1002/2016WR019026, 2016 ·Colgan, W., H. Rajaram, W. Abdalati, C. McCutchan, R. Mottram, M. S. Moussavi, and S. Grigsby, Glacier crevasses: Observations, models, and mass balance implications, , *Rev. Geophys.*, 54, 119–161, 2016. doi:10.1002/2015RG000504 ·Birdsell, D. T., H. Rajaram, D. Dempsey, and H. S. Viswanathan, Hydraulic fracturing fluid migration in the subsurface: A review and

	expanded modeling results, Water Resour. Res., 51, 2015. doi:10.1002/ 2015WR017810 ·Pandey, S.N., A. Chaudhuri, H. Rajaram, S. Kelkar, Fracture transmissivity evolution due to silica dissolution/precipitation during geothermal heat extraction, *Geothermics* 57, 111–126, 2015. doi: 10.1016/j.geothermics.2015.06.011 ·Phillips, T; Rajaram, H; Colgan, W; Steffen, K; Abdalati, W: Evaluation of cryo-hydrologic warming as an explanation for increased ice velocities in the wet snow zone, Sermeq Avannarleq, West Greenland; *Journal Of Geophysical Research-Earth Surface* 118(3), 1241-1256 DOI: 10.1002/jgrf.20079, 2013
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	None

Zhiyong (Jason) Ren Associate Professor

EDUCATION	BS, Environmental Engineering, Tianjin Ins. Urban Construction, 2000 MS, Environmental Engineering, Tianjin University, 2003 Ph.D., Environmental Engineering, Penn State University, 2008
ACADEMIC EXPERIENCE	University of Colorado Boulder: Associate Professor, 2013 - present; University of Colorado Denver: Assistant Professor, 2008-2013; Director, Center for Sustainable Urban Infrastructure, 2012-2013; National Renewable Energy Lab, Visiting Professor, 2009-10; 2015-present Penn State University, Research Assistant, 2004-2008, part time
NON-ACADEMIC EXPERIENCE	Bioelectric, Inc, Denver, CO, CTO, 2013-2015, part time North China Municipal Eng. Design and Research Institute/Spring Environmental, LLC, Environmental Engineer, 2013-2014
PROFESSIONAL REGISTRATIONS	E.I.T., Ohio, 2006 to present.
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	Association of Environmental Engineering & Science Professors (AEESP) American Chemical Society (ACS) Water Environment Federation (WEF)
HONORS AND AWARDS	2015 Research Development Award, CEAE, CU Boulder 2015 New Inventor of the Year Award, CU Technology Transfer Office 2013 (Faculty Advisor) Graduate School Outstanding Ph.D Dissertation Award (Wang) 2012 Excellence in Review Award, Environmental Science & Technology (ES&T) 2012 University Award for Excellence in Research and Creative Work, CU Denver 2012 Outstanding Faculty in Research Award, CEAS, CU Denver 2012 Chang Junior Faculty Achievement Award, CEAS CU Denver
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	Association of Environmental Engineering and Science Professors (AEESP) Education Committee – Co-chair Chinese-American Professors in Environmental Engineering and Science (CAPEES) President, Chairman Denver Metro Wastewater Reclamation District CPG Committee Peer Reviewer and Panelist for NSF, DOE, EPA, USDA, and many academic journals Reviews in Environmental Science and Biotechnology, publisher Springer Netherlands; Editorial Board, 2009 – present. International Journal for Service Learning in Engineering (IJSLE), Editorial Board 2011-present. **University Service** Boulder Faculty Assembly, Diversity Committee, 2015- Member, Task Force for Bioengineering Department and Degrees, College of Engineering, 2014

	Member, Graduate Committee, Civil, Environmental and Architectural Engineering, 2013-present
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	1. Lu, L., Hou, D., Wang, X., Jassby, D., Ren, ZJ. Active H2 Harvesting Prevents Methanogenesis in Microbial Electrolysis Cells, *Environmental Science & Technology Letters*, 2016, 3 (8), 286-290. 2. Wang, X., Zhou, L., Lu, L., Lobo, F., Li, N., Wang, H., Park, J., Ren, ZJ. Alternating Current Influences Anaerobic Electroactive Biofilm Activity. *Environmental Science & Technology*, 2016, 50 (17), 9169-9176 3. Mao, D., Lu, L., Revil, A., Zuo, Y., Hinton, J., Ren, ZJ. Geophysical Monitoring of Hydrocarbon-Contaminated Soils Remediated with a Bioelectrochemical System, *Environmental Science & Technology*, 2016, 50 (15), 8205-8213 4. Hou, D., Lu, L., Ren, ZJ. Microbial Fuel Cells and Osmotic Membrane Bioreactors Have Mutual Benefits for Wastewater Treatment and Energy Production, *Water Research*, 2016, 98, 183-189. 5. Ren, ZJ*., Umble, AK. Water Treatment: Recover Wastewater Resources Locally. *NATURE*, 2016, 529, 25. 6. Huggins, TM., Haeger, A., Biffinger, JC*., Ren, ZJ*. Granular biochar compared with activated carbon for wastewater treatment and resource recovery *Water Research*, 2016, 94, 225-232. 7. Lu, L., Huang, Z., Rau, G., Ren, ZJ* Microbial Electrolytic Carbon Capture for Carbon Negative and Energy Positive Wastewater Treatment. *Environmental Science & Technology*, 2015, 49, 8193-8201. 8. Lu, L., Zeng C., Wang, L., Yin, X., Jin S., Lu, A., Ren, ZJ Graphene Oxide and H2 Production from Bioelectrochemical Graphite Oxidation. *Scientific Reports*, 2015, 5, 16242. 9. Wang, H., Park, J., Ren, ZJ*, Practical Energy Harvesting from Microbial Fuel Cells: A review. *Environmental Science & Technology*, 2015, 49, 3267-3277. 10. Wang, H., and Ren, ZJ*. Bioelectrochemical metal recovery from wastewater: A review. *Water Research*, 2014, 66, 219-232.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	Grand Challenges in Environmental Engineering Workshop, April, 2016 AEESP Workshop on Environmental Engineering Education, July, 2015

Fernando Rosario-Ortiz **Associate Professor**

EDUCATION	BS, Chemistry, University of Puerto Rico, 1999 MS, Chemistry, California Institute of Technology, 2002 D. Env., Environmental Science and Engineering, University of California, Los Angeles, 2006
ACADEMIC EXPERIENCE	University of Colorado Boulder: Associate Professor, 2015 – present; Assistant Professor, 2008-2015 Visiting Professor, Institute of Biochemistry and Pollutant Dynamics, Environmental Chemistry Group, ETH, Zurich, 2015-2016 Visiting Scientist, Swiss Federal Institute of Aquatic Sciences and Technology, EAWAG, Dübendorf, Switzerland, 2015-2016 Post Doctoral, Southern Nevada Water Authority, Henderson, Nevada, 2006-2008
NON-ACADEMIC EXPERIENCE	Instructor, Environmental Charter High School, Lawndale, California, 2003
PROFESSIONAL REGISTRATIONS	N/A
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Chemical Society (1995-present) American Water Works Association (2003-present) International Ozone Association (2007-present) International Water Association (2008-present) Association of Environmental Engineering and Science Professors (2008-present) International Humics Substances Society (2005-present)
HONORS AND AWARDS	University of Colorado, Boulder, Provost Faculty Achievement Award, 2016 Shaye Faculty Fellowship, University of Colorado, Boulder 2016-2019 Best paper award, Journal of the American Water Works Association, 2016 College of Engineering and Applied Science Dean's Award for Outstanding Junior Faculty, University of Colorado Boulder, 2015 University of Colorado Boulder Faculty Assembly Faculty Recognition Award, 2015 National Science Foundation CAREER award, 2015 College of Engineering and Applied Science Dean's Award for Professional Development, University of Colorado Boulder, 2014 Excellence in Review Award, Environmental Science and Technology, 2014 Faculty research development award, Department of Civil, Environmental and Architectural Engineering, University of Colorado Boulder, 2014 American Water Works Association, Water Science & Research Division Volunteer Recognition Award, 2014 Outstanding Faculty Award, Student Leadership Council, College of Engineering and Applied Science, University of Colorado Boulder, 2013

	ASCE Fellowship to attend the ExCEEd workshop, Florida Gulf Coast University, July 21-26th, 2013
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	Member of the Bounder Faculty Assembly Faculty Affairs Committee, 2015 Chair of interview committee for CEAE, 2014 First year mentoring student program, including being a member of the ad-hoc executive committee for the program, Boulder Faculty Assembly, Fall 2013-2015 Environmental Engineering Program Steering Committee (2011-2012) Reviewer for numerous journals, including Environmental Science and Technology, Water Research, Chemosphere, Journal of the American Water Works Association. Organizer for numerous scientific symposia for the American Chemical Society and the Association of Environmental Engineering and Science Professors
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	McKay, G.; Couch, K.; Mezyk, S. P.; Rosario-Ortiz, F. L. Investigation of the coupled effects of molecular weight and charge transfer interactions on the optical and photochemical properties of dissolved organic matter. Environmental Science and Technology, 2016, 50, 15, 8093-8102 Rosario-Ortiz, F. L.; Rose, J. B.; Speight, V. L.; von Gunten, U.; Schnoor, J. How do you like your tap water? Science, 2016, 351, 6276, 912-914 Arias, M.; Cawley, K.; Rosario-Ortiz, F. L. Enhanced DOC removal using anion and cation ion exchange resins. Water Research, 2016, 88, 1, 981-989 Korak, J. A.; Rosario-Ortiz, F. L.; Summers, R. S. Evaluation of optical surrogates for the characterization of DOM removal by coagulation. Environmental Science: Water Research and Technology, 2015, 1, 493-506 McKay, G.; Rosario-Ortiz, F. L. Temperature dependence of the photochemical formation of hydroxyl radical from dissolved organic matter. Environmental Science and Technology, 2015, 49, 7, 4147-4154 Cawley, K.; Korak, J. A.; Rosario-Ortiz, F. L. Quantum yields for the formation of reactive intermediates from dissolved organic matter samples from the Suwanee River. Environmental Engineering Science, 2015, 32, 1, 31-37
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	ASCE EXCEED Workshop, 2013

Joseph N. Ryan   Professor

EDUCATION	B.S., Geological Engineering, Princeton University, 1983 M.S., Civil and Environmental Engineering, Massachusetts Institute of Technology, 1988 Ph.D., Civil and Environmental Engineering, Massachusetts Institute of Technology, 1992
ACADEMIC EXPERIENCE	University of Colorado Boulder: Professor, 2004-present; Associate Professor, 2000-2004; Assistant Professor, 1993-2000; Director, EVEN Program, 2001 to 2006 and 2012 to 2013 University of Canterbury, Christchurch, NZ (sabbatical), 2008 Yale University, New Haven, CT (sabbatical), 2001 U.S. Geological Survey, postdoctoral research associate, 1992-1993 Massachusetts Institute of Technology, Graduate Research Assistant, 1985-1992, part time
NON-ACADEMIC EXPERIENCE	Staff Engineer/Geologist, 1983 to 1986, Earth Water and Air, Inc., Minneapolis, MN
PROF. REGISTR.	
SCIENTIFIC AND PROFESSIONAL SOCIETIES	Association of Environmental Engineering and Science Professors American Chemical Society American Geophysical Union
HONORS AND AWARDS	Bennett-Lindstedt Endowed Faculty Fellow, 2013-2018, Department of Civil, Environmental, and Architectural Engineering, University of Colorado Boulder Distinguished Achievement Award, 2009, Civil, Environmental, and Architectural Engineering, University of Colorado Boulder Boulder County Pacesetter Award (Science/Health/Medicine), 2008, Boulder *Daily Camera* National Notable Achievement Award, 2006, U.S. Environmental Protection Agency, Member of the Left Hand Watershed Revitalization Team
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	**University Service** Environmental Engineering Program, director, 2012-2013 Civil, Environmental, and Architectural Engineering Department, Graduate Committee, 2012-2013 College of Engineering and Applied Science, First-Level Review Committee, 2014-present University of Colorado Boulder, Outreach and Engagement Committee, 2006-present **Professional Service** Association of Environmental Engineering and Science Professors, Newsletter Editor, 2009-2012 **National Service** U.S. Environmental Protection Agency, Science Advisory Board sub-panel on Hydraulic Fracturing Study, 2014-2016.

PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	Sherwood O.A., Rogers J.D., Lackey G., Burke T.L., Osborn S.G., and Ryan J.N., 2016. Groundwater methane in relation to oil and gas development and shallow coal seams in the Denver-Julesburg Basin of Colorado. *Proceedings of the National Academy of Sciences* **113**(30), 8391-8396. Mohanty S.K., Saiers J.E., and Ryan J.N., 2016. Colloid mobilization in a fractured soil: Effect of pore water exchange between preferential flow paths and soil matrix. *Environmental Science & Technology* **50**(5), 2310-2317. Webster J.P., Kane T.J., Obrist D., Ryan J.N., and Aiken G.R., 2016. Estimating mercury emissions resulting from wildfire in the western United States. *Science of the Total Environment* **568**, 578-586. Mohanty S.K., Saiers J.E., and Ryan J.N., 2015. Colloid mobilization in a fractured soil during dry-wet cycles: Role of drying duration and flow path permeability. *Environmental Science & Technology* **49**(15), 9100-9106. Poulin B.A., Aiken G.R., Nagy K.L., Manceau A., Krabbenhoft D.P., and Ryan J.N., 2015. Mercury transformation and release differs with depth and time in a contaminated riparian soil during simulated flooding. *Geochimica et Cosmochimica Acta* **176**, 118-138. Rogers J.D., Burke T.L., Osborn S.G., and Ryan J.N., 2015. A framework for identifying organic compounds of concern in hydraulic fracturing fluids based on mobility and persistence in groundwater. *Environmental Science & Technology Letters* **2**, 158-164. Mohanty S.K., Saiers J.E., and Ryan J.N., 2014. Colloid-facilitated mobilization of metals by freeze-thaw cycles. *Environmental Science & Technology* **48**, 977-984. Poulin B.A., Ryan J.N., and Aiken G.R., 2014. The effects of iron on optical properties of dissolved organic matter. *Environmental Science & Technology* **48**, 10098-10106. Writer J.H., Antweiler R.C., Ferrer I., Ryan J.N., and Thurman E.M., 2013. In-stream attenuation of neuro-active pharmaceuticals and their metabolites. *Environmental Science & Technology* **47**(17), 9781-9790. Craven A.M., Aiken G.R., and Ryan J.N., 2012. Copper(II) binding by dissolved organic matter: Importance of the copper-to-dissolved organic matter ratio and implications for the biotic ligand model. *Environmental Science & Technology* **46**(18), 9948-9955. McCleskey R.B., Nordstrom D.K., Ryan J.N., and Ball J.W., 2012. A new method of calculating electrical conductivity with applications to natural waters. *Geochimica et Cosmochimica Acta* **77**, 369-382.
PROFESSIONAL DEVELOPMENT IN THE LAST FIVE YEARS	

JoAnn Silverstein Professor

EDUCATION	BA, Psychology, Stanford University, 1967 BS, Civil Engineering, University of California, Davis, 1977 MS, Civil Engineering, University of California, Davis, 1980 Ph.D., Civil Engineering, University of California, Davis,, 1982
ACADEMIC EXPERIENCE	University of Colorado Boulder: Professor, 1998 – present; Associate Professor, 1989-1997; Assistant Professor, 1982-1988; Founding Faculty Director Sustainable By Design Residential Academic Program, 2011-2014; Director, Program in Environmental Design, 2012-2015; Chair, Dept. Civil, Environmental and Architectural Engineering, 2002-2010; Board of Directors, Center of the American West, 2015 – present. University of California, Davis, Graduate Research Assistant, 1980 – 1982.
NON-ACADEMIC EXPERIENCE	California Department of Water Resources, State Water Project Division of O & M: Intern, 1976-1977; Assistant Engineer, 1978-1980. Applied Environmental Services, consultant, 1996 – 2000.
PROFESSIONAL REGISTRATIONS	P.E., Civil Engineering, Colorado, #26151, 1988 to present.
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Academy of Environmental Engineers and Scientists ((AAEES) American Society of Civil Engineers (ASCE) American Water Works Association Association of Environmental Engineering & Science Professors (AEESP) International Water Association (IWA) Society of Women Engineers (SWE) Water Environment Federation (WEF) Tau Beta Pi, Chi Epsilon
HONORS AND AWARDS	Distinguished Service Award, AEESP, 1997 Distinguished Engineering Educator, SWE, 2000 Keynote Speaker, AEESP National Meeting, 2014 Eminence Member, AAEES, 2006 CU-LEAD Alliance, Faculty Appreciation Award, 2006
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	AAEES: Eminence Member Selection Committee, 2005 – present. External Promotion and Tenure Reviews (~ 3 per year for faculty at US universities) **University Service** Dept. of Civil, Environmental, & Architectural Engineering (CEAE) Personnel Committee. 1998-present. Chair of three Primary Unit Evaluation Committees for tenure and promotion. Faculty mentor to two assistant professors. Awards Committee. Chair. 2015-16. College of Engineering at the University of Colorado - Boulder Boulder Campus. Program Review: Environmental Design, Theater and Dance Department (2011 and 2016. Director, Program in Environmental Design, 2012-2015

	Office of Diversity, Equity and Community Engagement (ODECE), Faculty Advisory Council, 2011-present.
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	Kohler, L.E., J. Silverstein, B. Rajagopalan (2016) Predicting Life Cycle Failures of On-Site Wastewater Treatment Systems Using Generalized Additive Models, Environ. Eng. Sci., 33(2):112-124. Kohler, L.E., J. Silverstein, B. Rajagopalan (2016) Risk-Cost Estimation of On-site Wastewater Treatment Systems Using Extreme Value Analysis, Water Environment Research, in press. Kohler, L.E., J. Silverstein, B. Rajagopalan (2016) Modeling On-site Wasewater Treatment System Performance Fragility to Hydroclimate Stressors, Wat. Sci. Technol., in press. Suchetana, B., B. Rajagopalan, J. Silverstein (2016) Hierarchical Modeling Approach to Evaluation of Spatial and Temporal Variability of Wastewater Treatment Compliance with Biochemical Oxygen Demand, Total Suspended Solids, and Ammonia Limits in the United States, Environ. Eng. Sci., 33(7):514-524. Weirich, S.R.,* J. Silverstein, and B. Rajagopalan, (2015) Resilience of Secondary Wastewater Treatment Plants: Prior Performance is Predictive of Future Process Failure and Recovery Time. Environ. Eng. Sci. 32(3):222-231. Weirich, S.R.,* J. Silverstein, and B. Rajagopalan, (2015) Simulation of effluent BOD and ammonia for increasingly decentralized networks of wastewater treatment facilities. Environ. Eng. Sci. 32(3):232-239 ***Weirich, S. R.,* Silverstein, J., & Rajagopalan, B. (2011). Effect of average flow and capacity utilization on effluent water quality from US municipal wastewater treatment facilities. Water Research, 45(14), 4279-4286. Doi:10.1016/j.watres.2011.06.002***. Yacob, T.*, Pandey, S.,* Silverstein, J. Rajaram, H. (2013) Soluble Microbial Products Decrease Pyrite Oxidation by Ferric Iron at pH < 2, Environmental Science & Technology, 47(15):8658-8665, 2013.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	Univ. Colorado, Boulder, Peak-to-Peak Workshops on integration of sustainability into undergraduate curriculum, 2012 – 2013. Center of the American West Workshop on Urban Sustainability in Western Cities, Portland, OR, September 2015. Center of the American West, Workshop on Integration of Agriculture, Water Resources, and Public Lands, Fresno, CA, September 2016.

R. Scott Summers Professor

EDUCATION	B.S., Civil Engineering, University of Cincinnati, 1975 M.S., Environmental Engineering, University of Cincinnati, 1977 Ph.D., Environmental Engineering & Science, Stanford University, 1986
ACADEMIC EXPERIENCE	University of Colorado-Boulder: Professor, 1998-present; Director, Environmental Engineering Program, 2013-present; Program Coordinator, Graduate Environmental Engineering Program, 2000-2010, 2012- 2014; Director, DeRISK Center, 2014-present, Director, Center for Drinking Water Optimization, 1997-2004; University of Cincinnati: Associate Professor, 1993-1998; Assistant Professor, 1988-1993; Program Coordinator, Water, Waste Water and Hazardous Waste Program ,1988-1998; University of Crete, Greece, Visiting Fulbright Professor, (sabbatical), 1995 Universitat Karlsruhe, Germany, Research Associate (post-doctoral fellow), 1986-1988 Stanford University, Research Assistant, 1979-1985 University of Cincinnati, Research Assistant, 1975-1977
NON-ACADEMIC EXPERIENCE	U.S. EPA, Municipal Environmental Research Laboratory, Cincinnati, OH; Visiting Research Scientist, (sabbatical), 1996; Project Engineer, 1977-1979 Summers & Hooper, Inc., Technical Director (part time), 1995-2000
PROFESSIONAL REGISTRATIONS	EIT, Ohio, 1975.
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	Association of Environmental Engineering & Science Professors (AEESP) American Water Works Association (AWWA) American Society of Civil Engineers (ASCE)
HONORS AND AWARDS	Water Quality Division Best Paper Award, Journal AWWA, 2016 A.P. Black Award, American Water Works Association, 2013 CEAE Department, University of Colorado; Service Award, 2011; Student's Favorite Professor Award, 2010; Teaching Award, 2009; Research Award, 2007 Academic Achievement Award, MS or PhD advisor, American Water Works Association, 1993, 1995, 1996 (2), 1998, 1999, 2000
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	American Water Works Association: Water Science and Research Division, 2004-2010 Trustee; Water Quality and Technology Conference Planning Committee, 2007-2010, Activated Carbon Committee, 1994-current; Biological Drinking Water Treatment Committee, 2000- current; Biotreatment Symposium Organizing Committee, 2013; VOC Workshop Organizing Committee, 2011

	University Service Dept. of Civil, Environmental, & Architectural Engineering (CEAE) Personnel Committee, 1998-present; Graduate Committee, 2000-2003, Chair 2008-2012; Environmental Engineering Graduate Program Coordinator, 2000-2011, 2013-present Environmental Engineering (EVEN) cross-disciplinary degree program, 1998- present; Director. 2014 - present College of Engineering at the University of Colorado - Boulder Undergraduate Education Council. 2014-present
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	Hohner, A. K., Cawley, K., Oropeza, J., Summers, R. S., & Rosario-Ortiz, F. L. (2016). Drinking water treatment response following a Colorado wildfire. *Water Research*, *105*, 187-198. Samson, C. C., Rajagopalan, B., & Summers, R. S. (2016). Modeling Source Water TOC Using Hydroclimate Variables and Local Polynomial Regression. *Environmental Science & Technology*, *50*(8), 4413-4421. Kempisty, D. M., & Summers, R. S. (2016). Effect of Influent Groundwater Quality on Adsorption of Low Concentrations of 1, 2 Dichloroethane by Granular Activated Carbon. *Journal of Environmental Engineering*, *142* (12), 04016064. Shimabuku, K. K., Kearns, J. P., Martinez, J. E., Mahoney, R. B., Moreno-Vasquez, L., & Summers, R. S. (2016). Biochar sorbents for sulfamethoxazole removal from surface water, stormwater, and wastewater effluent. *Water Research*, *96*, 236-245. Thompson, K. A., Shimabuku, K. K., Kearns, J. P., Knappe, D. R., Summers, R. S., & Cook, S. M. (2016). Environmental Comparison of Biochar and Activated Carbon for Tertiary Wastewater Treatment. *Environmental Science & Technology*, *50*(20), 11253-11262. Summers, R.S., Finau-Starkey, L. (2016), Work-in-Progress – Development of a student-based mentorship program for first-year environmental engineering students, Proceedings First-Year Engineering Experience (FYEE) Conference, Columbus, OH. Saunders, J.F., Hohner, A.K.., Summers, R.S., Rosario-Ortiz, F.L., (2015) "Regulating Chlorophyll a to Control DBP Precursors in Water Supply Reservoirs," *J. Amer. Water Works Assoc*., http://dx.doi.org/10.5942/jawwa.2015.107.0153, 107 (11) E603-E612. Kennedy, A.M., Summers, R.S., (2015) Effect of DOM Size on Organic Micropollutant Adsorption by GAC, *Environmental Science & Technology*., **DOI:** 10.1021/acs.est.5b0041149 (11), pp 6617–6624.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	Association of Environmental Engineering and Science Professors (AEESP) Conference, Department Chairs and Directors Workshop, 2013. First-Year Engineering Experience (FYEE) Conference, July 31 – August 2, 2016, Columbus, OH

Michael E. Walker Instructor

EDUCATION	BS, Chemistry, University of Illinois, 2004 Ph.D., Chemical Engineering, Illinois Institute of Technology, 2012
ACADEMIC EXPERIENCE	University of Colorado Boulder: Instructor, 2014 – present Northwestern University, Evanston IL, Postdoctoral Fellow, 2012-2014 Illinois Institute of Technology, TA/RA, 2007-2012, part time
NON-ACADEMIC EXPERIENCE	United States Gypsum, Libertyville, IL, Technical Staff L1, 2005-2006 Valent Biosciences Corp., Long Grove, IL, Assistant Tech., fall 2004
PROFESSIONAL REGISTRATIONS	
SCIENTIFIC AND PROFESSIONAL SOCIETIES OF WHICH A MEMBER	American Chemical Society (ACS) American Institute of Chemical Engineers (AIChE) Association of Environmental Engineering & Science Professors (AEESP)
HONORS AND AWARDS	Big Dog Award - Food & Beverage Environmental Conference 2014 ChBE Departmental Excellence in Teaching Award (TA of the Year) 2010 ChBE Departmental Excellence in Teaching Award (TA of the Year) 2009 ChBE Departmental Excellence in Teaching Award (TA of the Year) 2008 ARCS Scholarship Award 2011 ARCS Scholarship Award 2010
INSTITUTIONAL AND PROFESSIONAL SERVICE IN LAST FIVE YEARS	American Institute of Chemical Engineers (AIChE). Environmental Division: Leg & Reg co-chair (2014-16); 2nd Vice Chair of programming for Environmental Engineering: Midwest Regional Conference (2015); Chair – Energy, Sustainability and the Environment: Midwest Regional Conference (2014) **University Service** Civil Environmental and Architectural Engineering (CEAE) Computing Committee. 2016-present Environmental Engineering (EVEN) Curriculum Committee. 2015-present College of Engineering at the University of Colorado - Boulder Energy Engineering Minor Committee. 2015-present
PRINCIPAL PUBLICATIONS AND PRESENTATIONS OF LAST FIVE YEARS	**Publications and Technical Reports** Briam, R.B.; Walker, M.E.; Masanet, E. (2015). A Comparison of Product-based Energy Intensity Metrics for Cheese and Whey Processing. Journal of Food Engineering, 151, 25-33. Walker, M.E.; Arnold, C.S.; Lettieri, D.J., et al. (2014). Energy Intensity Comparisons of Concentrated Food Products. *Environmental Science & Technology*, 48(20), 12370-12377. Walker, M.E., Lettieri, D.J., Romanin, V., et al. (2013). Establish GHG Emissions Efficiency Benchmarks for Covered Industrial Sectors. Prepared for the California Air Resources Board and the California

	Environmental Protection Agency by Northwestern University, University of California, Berkeley, and Ecofys. June 30, 2013. Walker, M.E.; Lv, Z.; Masanet, E. (2013). Industrial Steam Systems and the Energy-Water Nexus. *Environmental Science & Technology*, 47(22), 13060-13067. Masanet, E.; Walker, M.E. (2013). Energy-Water Efficiency and U.S. Industrial Steam. *AIChE Journal (Cover Article)*, 59(7), 2268-2274. Walker, M.E.; Theregowda, R.B.; Safari, I., et al. (2013). Utilization of Municipal Wastewater for Cooling in Thermoelectric Power Plants: Evaluation of the Combined Cost of Makeup Water Treatment and Increased Condenser Fouling. *Energy*, 60, 139-147. Safari, I.; Walker, M.E.; Abbasian, J., et al. (2013). Utilization of Municipal Wastewater for Cooling in Thermoelectric Power Plants. Fuel, 111, 103-113. Walker, M.E.; Safari, I.; Theregowda, R.B., et al. (2012). Economic Impact of Condenser Fouling in Existing Thermoelectric Power Plants. *Energy*, 44, 429-437. Hsieh, M.K.; Walker, M.E.; Safari, I., et al. (2012). Ammonia Stripping in Open-Recirculating Cooling Water Systems. Environmental Progress & Sustainable Energy, 32(3), 489-495. Walker, M.E.; Abbasian, J.; Chmielewski, D.J.; Castaldi, M.J. (2011). Dry Gasification Oxy-Combustion Power Cycle. *Energy & Fuels*, 25, 2258-2266 **Presentations** Grand Challenges Facing the Implementation of Carbon Cap-and-Trade Policy for Complex Manufacturing Industries. Food & Beverage Environmental Conference: Napa, California – March, 2014. Industrial Boiler Systems and the Energy-Water Nexus. AIChE Annual Meeting: San Francisco, California – November, 2013. Economic Evaluation of Freshwater Conservation Strategies for Thermoelectric Power Plants. AIChE Annual Meeting: San Francisco, California – November, 2013 Development of Product-Based Energy Intensity Metrics for the California Food Industry. Carbon Management Technology Conference: Alexandria, Virginia – October, 2013.
PROFESSIONAL DEVELOPMENT ACTIVITIES IN THE LAST FIVE YEARS	Food & Beverage Environmental Conference. March, 2014. AIChE Annual Meeting. November, 2013. Carbon Management and Technology Conference. October, 2013.

Appendix C – Equipment

The major pieces of equipment used by the architectural engineering program in courses to support instruction are summarized in the tables below.

Equipment Used in **Required Courses** for All AREN Students:

Course	Major Equipment Used
AREN 2120 – Fluid Mechanics & Heat Transfer	- Hobos
AREN 4550 – Illumination I	- Konica Minolta illuminance meters T-10
CVEN 2012 Geomatics	- Tripods – ca. 10 Wild type (5/8X11 screw), ca. 4 Kern type - Levels – 8, including Leica, K&E, Wild types - Theodolites – 8 electronic theodolites - Total Stations – 6 Leica: 4 "Builder," 2 earlier models - Corner prism EDM reflectors – ca. 8 useable - Stadia Rods – 7 - Range poles/reflector poles - 3 - Tapes: 6 fiberglass, 100' and 200' - Tapes: 4 metal, mostly with broken tips but still usable - Metal detector - Misc. Flagging and marking equipment - GPS: 2 Leica GS14 antennas and one Leica CS20 controller, plus accessories for base station/RTK rover configuration
CVEN 3161- Mechanics of Materials I	- Three MTS universal testing machines for tension and compression testing of structural and geological materials, with capacities of 22 kN, 500 kN, and 4.5 MN. - Tinus Olsen Torsional Testing Machine with 2000 in-lb capacity - Concrete mixer, scale - Whitemann displacement gage, dial gages, strain gages, LVDTs

Equipment used in **Proficiency** Courses for AREN Students

Course	Major Equipment Used
AREN 4110 – HVAC Design	- IR thermographic camera - Blower door
AREN 4550 – Illumination II	- Minolta illuminance meters T-1 (10) - Minolta luminance meter LS-100 (1) - Spectrometer - Various lamps and lamp holders - Manual dimmers (1)

Equipment used in **Concentration** Courses for AREN Students

Course	Major Equipment Used
AREN 4010 – HVAC System Modeling and Control	- Direct digital control (DDC) modules to teach development of HVAC control strategies for air handling units and chilled water plants
CVEN 4161 – Mechanics of Materials II	- Instron machine in ITLL and ABAQUS software - Torsion Instron machine in ITLL - Module with a large frame, a beam-column, restraint beam, counterweight, load arm, load tray and several rulers along the inside of the frame

Equipment used in **Technical Elective** Courses for AREN Students

Course	Major Equipment Used
AREN 4830 – Sustainable Materials & Structures	- Instrom machine in ITLL
AREN 4130 – Optical Design	- Konica Minolta illuminance meters T-10 - Konica Minolta luminance meter LS-100 - CL-500A Konica Minolta Spectrometer - Omega HH309A digital thermometer - 36" Integrating sphere - Optical bench & various mounting hardware - Manually operated, 8' arm, goniophotometer - Various LED modules and luminaires - Lambda 0-150V DC power supply - Interpower 500VA multi-frequency AC power supply - Elgar 120V AC power supply - Laser cutters in ITLL - 3D printer in ITLL
AREN 4350 – Advanced Lighting Design	- Moveable ceiling in lighting lab - ETC programmable 7-color LED theatrical luminaires (4) - ETC Source Four Mini theatrical luminaires (6) - Theatrical tripod stands with T-Bar (8) and floor stands (8) - Theatrical lamp holders with options for gels and gobos (24) - Various beam-angle lamps and lamps holders - Manual dimmers (10)
CVEN 3708 Geotechnical Engineering 1	- Triaxial cells and consolidometers - Proctor and modified Proctor test equipment - Atterberg limit apparatus - Constant head and falling head permeability setup - Mechanical sieve shaker, sieve stacks, and hydrometers
CVEN 3718 Geotechnical Engineering 2	- Direct shear test machine with shear box, weights, displacement gauges - Triaxial test cells with load cells, pressure gauges, LVDT, computer

	- Instructional Centrifuge and demonstration models, data acquisition system

Appendix D – Institutional Summary

1. The Institution

a. Name and address of the institution:

The University of Colorado Boulder
College of Engineering and Applied Science
422 UCB
Boulder, Colorado 80309-0422

b. Name and title of the chief executive officer of the institution:

Bruce D. Benson - President of the University of Colorado System
Philip P. DiStefano - Chancellor of the Boulder Campus
Russell L. Moore - Provost and Executive Vice Chancellor for Academic Affairs
Robert D. Braun - Dean of the College of Engineering and Applied Science

c. Name and title of the person submitting the self-study report:

Submitted by:

Robert D. Braun, Dean
College of Engineering and Applied Science
University of Colorado Boulder
Boulder, Colorado 80309-0422
(303) 492-7006
Bobby.Braun@Colorado.EDU

Contact for ABET matters:

Ken Anderson, Associate Dean for Education
College of Engineering and Applied Science
University of Colorado Boulder
Boulder, Colorado 80309-0422
(303) 492-2066
Ken.Anderson@Colorado.EDU

d. Name the organizations by which the institution is now accredited and the dates of the initial and most recent accreditation evaluations:

The University of Colorado Boulder's general regional accreditation is from the Higher Learning Commission (HLC) of the North Central Association of Colleges and Schools (NCA). The University of Colorado has been accredited by NCA since 1913. Every 10 years, a team of leading external educators visits the University's campus to evaluate the university's programs, policies, and practices and to provide recommendations for continuous improvement. The most recent review took place in 2009-2010, and on August 16, 2010, the Institutional Actions Council of the Higher Learning Commission voted to continue accreditation for the University of Colorado Boulder. For more information, see: http://www.colorado.edu/accreditation/. The most recent self-study is at: http://www.colorado.edu/accreditation/downloads/CUBoulderSelfStudy2010.pdf.

2. Type of Control

The University of Colorado is a state-supported institution, governed by an elected Board of Regents under the Colorado Commission on Higher Education.

3. Educational Unit

a. **Campus Administration**

The Dean of the College of Engineering and Applied Science reports to the Provost and Executive Vice Chancellor for Academic Affairs, who reports to the Chancellor and Chief Executive Officer of the Boulder Campus. The Chancellor and Chief Executive Officer reports to the President of the University of Colorado system. Additional details can be found at: http://chancellor.colorado.edu/chancellors-administrative-organization.

b. **College Administration**

The Chief Executive Officer of the College of Engineering and Applied Science is the Dean, Robert D. Braun. The Associate Dean for Education is Ken Anderson; the Associate Dean for Research is Keith Molenaar; and the Associate Dean for Faculty Advancement is JoAnn Silverstein. The Assistant Dean for Inclusive Excellence is Sarah Miller; the Assistant Dean for Advancement is Ann Bishop Shoup; the Assistant Dean for Communications, Strategy and Planning is Phil Larson; the Assistant Dean for Students is Mary Steiner; The Assistant Dean for Programs and Engagement is Doug Smith; and the Assistant Dean for Administration is Cherie Summers.

4. Academic Support Units

The degree programs in the College are supported by a number of other departments and programs, including Applied Mathematics, Physics, Chemistry and Biochemistry, the Herbst Program of Humanities and the Program for Writing and Rhetoric. In addition, the supporting units also teach these courses to other majors throughout the university. The names and titles of the individuals responsible for these units are as follows:

- Applied Mathematics, Keith Julien, Department Chair
- Physics, John Cumalat, Department Chair
- Chemistry and Biochemistry, Carl A. Koval, Department Chair
- Herbst Program of Humanities for Engineers, Leland Giovannelli, Director
- Program for Writing and Rhetoric, John-Michael Rivera, Director

The courses provided by these academic support units are regularly reviewed by the College of Engineering and Applied Science's Undergraduate Education Council, which is chaired by the Associate Dean for Education. The Council is composed of the associate chairs (or chairs of curriculum committees) or his/her designee for each program, the undergraduate staff advisors for each department, the Assistant Dean for Inclusive Excellence, the Assistant Dean for Students, the Director of the Herbst Program of Humanities, the Director of Assessment and Accreditation, the Director of International Programs, and the Co-Directors of the Integrated Teaching and Learning Laboratory (ITLL). This group meets regularly throughout the year to coordinate matters of common interest and concern with respect to the College's undergraduate programs.

5. Non-academic Support Units

The programs of the College of Engineering and Applied Science are served by several essential campus-wide support units:

1. University Libraries, overseen by James Williams II, Dean of the CU-Boulder Libraries; Leonard Gemmill Engineering Library, overseen by Emily Fidelman, Operations Manager
2. Information Technology Services (ITS), Larry Levine, Assoc. Vice Chancellor and Chief Information Officer;
3. Career Services, Lisa Severy, Assistant Vice Chancellor of Student Affairs and Director

In addition, there are several mechanisms in place to support student academic success:

1. Broadening Opportunity through Leadership and Diversity (BOLD) Center, overseen by Sarah Miller, Assistant Dean for Inclusive Excellence
2. Student Academic Success Center (SASC) for tutoring and academic excellence support services, Corinna Rohse, Director
3. Supplemental peer-based advising is provided by the college's "Engineering Ambassadors"; overseen by Chris Anderson, Student Services Coordinator and Amanda Parker, Director of Access and Recruiting
4. The Engineering Quadrangle Living & Learning Community is a first-year housing option for engineering and pre-engineering students; college liaison is Vanessa Dunn, Director of Student Engagement and Community Building

6. Credit Unit

One semester credit normally represents one class hour or two laboratory hours per week. The campus operates year round, with fall and spring semesters of 16 weeks each, a 10-week summer session, a three-week "Maymester" academic period between spring semester and summer session, and a three-week "Augmester" academic period between summer session and fall semester. All programs require 128 semester hours to graduate.

7. Tables

Table D-1. Program Enrollment and Degree Data
Table D-2. Personnel

Table D-1. Program Enrollment and Degree Data

Architectural Engineering

	Academic Year		Enrollment Year					Total Undergrad	Total Grad	Degrees Awarded			
			1st	2nd	3rd	4th	5th			Associates	Bachelors	Masters	Doctorates
Current Year	2016	FT	34	23	29	40	15	141	38	N/A	29	7	3
		PT	0	1	0	1	3	5	3				
1	2015	FT	24	37	32	34	15	142	33	N/A	40	5	3
		PT	0	0	0	0	3	3	3				
2	2014	FT	31	32	29	42	14	148	25	N/A	34	10	4
		PT	0	0	0	1	4	5	3				
3	2013	FT	32	27	33	41	17	150	20	N/A	43	1	1
		PT	1	0	0	2	1	4	5				
4	2012	FT	23	32	33	38	18	144	0	N/A	58	0	0
		PT	0	2	0	1	3	6	0				

Official fall term enrollment figures (head count) for the current and preceding four academic years and undergraduate and graduate degrees conferred during each of those years. The "current" year means the academic year preceding the on-site visit.

FT--full time
PT--part time

Table D-2. Personnel

Architectural Engineering

Year[1]: Fall 2016

	HEAD COUNT		FTE[2]
	FT	PT	
Administrative[2]		4	1
Faculty (tenure-track)[3]	43		14
Other Faculty (excluding student Assistants)	7		3
Student Teaching Assistants[4]	28		6
Technicians/Specialists	2	1	0
Office/Clerical Employees	12	1	4
Others[5]			

The Head Count data represent the CEAE Department as a whole. These were multiplied by the percentage of time devoted specifically to architectural engineering (as opposed to civil or environmental engineering), resulting in the values shown in the FTE column. For faculty, the percentages listed in Table 6-2 were used. Student Teaching Assistants are based on serving as TAs for courses required for AREN students (or split if the course is also required for civil and/or environmental engineering). Staff helping equally with all three programs were split equally, and allocated 33% to AREN.

APPENDIX E –Rubrics related to outcome 2(b) Design and Conduct Experiments

The following rubrics for CVEN 3161 Mechanics of Materials, AREN 2120 Fluid Mechanics and Heat Transfer, AREN 3540 Illumination I are used for direct assessment of the 2[b] design and conduct experiments outcome. These can also be found in the respective course dossiers.

CVEN 3161 Mechanics of Materials – Rubric for Design and Conduct Experiments

	Below adequate	Adequate	Superior
Percentage of total points earned on lab write-up, per guidelines below:	<80%	80-90%	≥90%

1. GENERAL FORMAT (10%)

Format

- The entire report should be stapled or bound and NOT be placed in a folder or cover.
- Text should be 1.0 line spaced and may be done in 11 point or 12 point font.

Figures, Tables, Graphs, and Sections

Figures, Tables and Graphs should each have a title and a number (graph titles are to be label BELOW the graph and table titles are to be label ABOVE the table). Graphs should have white background so data points and trendlines are easy to see. Graphs should have the axes labeled, the scale indicated, and should be of appropriate size for the reader to see the results. It is sometimes necessary to give a graph or table its own page. If placed within the text, tables and graphs should be separated from the text with appropriate borders. These graphs and tables should be referenced in the text. The report should be divided into the sections discussed below. These sections should appear in the order presented.

2. TITLE PAGE

- Report Title.
- Entity presented by (you).
- Group Number/Name.
- Organization that the report was done for (University, Department & Course #).
- Date the Experiment was completed.
- Date report was submitted.

3. ABSTRACT (5%)

- The abstract is a brief description of what is contained in the report. It should cover the main purpose of the experiment, a general description of what was done, a general description of the equipments used, a broad overview of the results that were obtained, and conclusions as to whether the results seem reasonable. The abstract should be able to stand alone from the rest of the report. It should not directly refer to figures or tables or other content of the rest of the report.

4. TABLE OF CONTENTS, LIST OF FIGURES, LIST OF TABLES (5%)

- The Table of Contents should list all the sections and what page they start on.
- List of figures and list of tables should contain all figures and tables including name and number listed in the text and the page they start on.

5. INTRODUCTION (10%)

- Discuss the background necessary to understand the report. This would include brief description of theory, definitions of major terms, objective(s) and purpose of the lab, and any assumptions used during experiment.
- Discuss the properties that are extrapolated or calculated from the test.
- Short description of how the stress-strain graph was created and how the data was obtained.
- Appropriate background so that a common reader can understand the experiment.
- Brief description of the materials used.

6. SPECIMEN PREPARATION (10%)

- Create a list of steps as to how the concrete cylinders were prepared, including the concrete mix design for your group.

7. EXPERIMENTAL PROCEDURE (10%)

- Create a list of steps as to how the experiment was conducted. Include a listing of equipment used, sketches or drawings of the test specimen(s) including dimensions and the testing setup.

8. TEST RESULTS (20%)

Your results should make use of charts and tables, and explain your figures including measured quantities, graphs or charts created for understanding the results, and any properties calculated, such as the cross sectional area (Ao) and the original gauge length of the specimen (Lo, i.e. the height of cylinder).

A minimum of the following should be included:

- Plot of test data force vs. displacement (original data).
- Plot of test data in positive force vs. positive displacement.
- Plot of Stress vs. Strain. The curve should start at (0,0), in other words at zero stain and zero stress.
- "Fix" your data by adding or subtracting to every value the same amount, which represents the deformation of the samples before they are in full contact with the loading heads.

For the compression test, calculate and show the following properties obtained from each specimen and the average values:

- E (Modulus of Elasticity)
- f_c' (Max. stress = the compressive strength of concrete)
- ε_c (The strain corresponding to f_c')

For the splitting tension test, calculate and show the following property obtained from the specimen:

- ft (the tensile strength of concrete measured by the splitting tension test)

Numerical results are best presented in table form. It should be noted which properties were calculated, and which were extrapolated graphically.

9. ANALYSIS AND CONCLUSION (20%)

- Explain the failure mechanisms of concrete under compression and tension
- Explain the fracture surfaces of concrete under compression and splitting tension
- Explain the effect of end constraint on compressive strength of concrete.
- Identify any large errors and attempt to provide explanations of possible causes.
- Include observations from lab.

10. REFERENCES (5%)

Whenever you use a source within the body of the paper, this source should be referenced.

11. APPENDICES (5%)

- Test data: Include the data received from the tests. You are recommended to use Excel Spreadsheets and to show both the originally measured data and the data that you calculated and/or changed. If the raw data is lengthy, you may include only a sampling of it.
- Sample Calculations: Include all sample calculations in this section for any equations that you used in writing the report.

AREN 2120 Fluid Mechanics and Heat Transfer – Rubric for Design and Conduct Experiments

	Below adequate	Adequate	Superior
Percentage of total points earned on lab write-up, per guidelines below:	<80%	80-90%	≥90%

Thermal House Competition (Team work of 3 students) (14 points of 100)

Commented [JZ1]: Strictly, NO more than 3 students per team, 2 is fine, but NO single person per team! It is team work! The team shares the same score regardless of the contributions.

Objective:
Design and build a model house with **comfortable indoor air temperature** for both day and night.

Requirements:
Geometry:
Minimum interior scales: 10in x 10in x 10in (at least 80% usable/empty space)
No requirement on exterior scales but you have to consider the cost

Commented [JZ2]: Can NOT fill more than 20% of inside spaces!

Commented [JZ3]: Can have large insulation/shading etc.

Materials:
Whatever you can find (recycled materials are highly encouraged), painting is allowed

Commented [JZ4]: Donated materials still need a cost estimate, based on fair market price.

Shape:
Free as long as it fits the geometry requirements

Window:
Minimum 20% window-wall-ratio (A_{window}/A_{wall}) for at least ONE wall
No requirement on window materials (but need be transparent)

Commented [JZ5]: For at least one wall, not all the walls!

Procedure:

1. Assignment released on March 23, 2017
2. Design and construction: March 23 – April 16
3. Self-testing and adjustment: April 10 – April 23 (using Hobo*)
    a. Each team will reserve one Hobo from TA for a 24-hours. First come, first serve!
4. Final testing and write report: April 24 – May 3 (using Hobo*)
    a. The model house will be placed at one dedicated outdoor location with full access of sunshine.
    b. You are allowed to orientate the house at your wish at the beginning of the test (but can not be changed afterwards).
    c. A Hobo will be placed in the house to monitor temperature, relative humidity and light intensity for 24 hours.
    d. You are allowed to operate the house twice (optional) during the test at the moments you decided (e.g., open/close door/window, raise/drop curtain/blinder/overhang, but you can not use any other active measures to heat or cool the house).
5. Paper report and digital video file due date: May 4th class time (please send me by email the youtube link before 5pm on May 3rd)

Commented [JZ6]: Court yard outside the engineering cafe

**Hobo size: 2.4 x 1.9 x 0.8 in; A User Instruction is downloadable from the course web.*

Judge Criteria (100%):

1. Meet design requirements (10%)
2. Thermal performance (45%):
    a. Total hours of day and night temperature within the comfort zone (25%)
    b. $\Delta T = T_{high} - T_{lower}$ (20%)
3. Economic performance (30%):

   a. Cost of the project (20%)
   b. Material selection (10%)
4. Esthetics (10%)
5. Quality of video clip (5%)

Report Requirements:
1. Design descriptions:
   a. Pictures of your design (inside and outside) and geometry descriptions (house interior and exterior scales and window sizes etc.)
   b. Design philosophy and concept (why the house was designed this way and functions of design features)
   c. What materials were used and the cost of the project (donation materials are acceptable but estimated cost need be included)
2. Thermal performance (figures of the varying house interior air temperature and relative humidity values during 24 hours downloaded from Hobo, compared against the outdoor conditions measured by TA – *consider to print and compare indoor and outdoor conditions on the same figure for best visualization;* **total hours** of day and night temperature within the comfort zone, $\Delta T = T_{high} - T_{lower}$, etc.). Outdoor conditions will be posted on the course web everyday.
3. Conclusions (discussion of results, potential improvement approaches, experience and lessons, etc.)

Video Requirement: Please videotape and edit the entire design, construction, test process and outcomes with a 2-minute video clip (BE CREATIVE!). Please write the youtube link in your final report as well as emailing me the link before 5pm on May 3rd (John.Zhai@colorado.edu). We will share these videos in the last class of the semester.

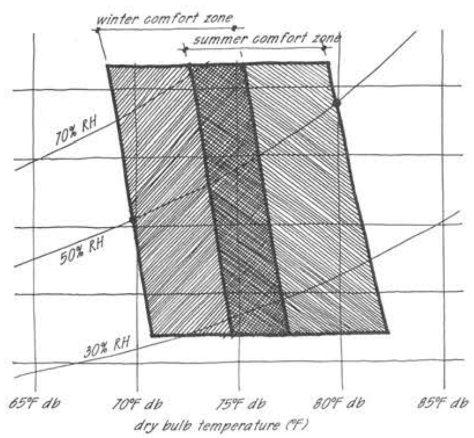


Figure 2.6: Winter and summer comfort zones, for light activity in typical seasonal clothing (winter 0.9 clo, summer 0.5 clo), with minimal air movement (less than 0.15 m/s winter and 0.25 m/s summer), and where dry-bulb air temperature and mean radiant temperature are equal. *(Reproduced from ASHRAE, 1981, by permission.)*

AREN 3540 Illumination I – Rubric for Design and Conduct Experiments

	Below adequate	Adequate	Superior
Percentage of total points earned on lab write-up, per guidelines below:	<80%	80-90%	≥90%

AREN 3540 - Illumination 1
Assignment 7 - Illuminance Field Survey
Assigned: Friday, November 11, 2016
Due: Friday, November 18, 2016 at the beginning of class
[200 points total]

Background:
Modern illuminance meters have solid state photodetector devices that have a special filter that gives them a spectral response that approximates the v(λ) curve. In addition, they have a structure that permits their spatial response to be approximately that described by the cosine incidence law of illumination.

To get a correct reading, the detector must be level and unshaded. As you learned in your survey class, "one measurement is no measurement." At each position where you will be determining the illuminance, you should take at least *3 separate readings*.

Field Survey Procedure:

1. Arrange a meeting with your survey team (Teams of 3-4 people).
2. Find a classroom (large or small) and identify a time when you can survey the illuminance.
3. Make the necessary equipment preparations.
4. Determine horizontal illuminance at (at least) 40 positions at workplane height in the seating area of the classroom.
5. Use Excel to produce an iso-illuminance contour plot of the horizontal illuminance in the room
6. Write a report that briefly describes your findings.
    a. Title page, team member list
    b. Brief outline of the measurement equipment
    c. Brief outline of the measurement process
    d. Data Summary
        i. Average of the illuminances in the room, E
        ii. Mean deviation (the average difference from the average),

$$MD = \frac{1}{N}\sum_{i=1}^{N}|\bar{E} - E_i|$$

        Where N is the number of points
    e. Contour Plot
    f. Original or copy of data sheet taken at the time of the measurements
    g. AutoCAD drawing (to scale) of room showing where measurements were made

Deliverables:
Your team is to produce a formal Illuminance survey report. Your formal report shall be **printed in color, spiral bound** and accompanied by a letter of transmittal.

The report will be assessed and points given; each member of the team will receive that point total.

AREN 3540 – Illumination 1

Assignment 7 Evaluation

[200 points]

Names Elvin Viloria
Ryan White
Sally Glasser
Skyler Fossner

1. Measurements [100]

a.	Team of 3-4 people			0	10	(20)
b.	Minimum of 40 measurements		0	20	40	(60)
c.	Minimum of 3 readings at each location	0	5	10	15	(20)

2. Design & Report [100]

a.	Printed in color	0	2.5	(5)
b.	Spiral bound	0	2.5	(5)
c.	Transmittal page	0	2.5	(5)
d.	Title page, team member list	0	2.5	(5)
e.	Measurement equipment outline	0	2.5	(5)
f.	Measurement process outline	0	2.5	(5)
g.	Data Summary			
i.	Average of the illuminances in the room, E	0	5	(10)
ii.	Mean deviation	0	5	(10)
h.	Contour plot	0	10	(20)
i.	Original data collection sheet from the measurements		0	(10)
j.	AutoCAD drawing			
i.	of room to scale and with dimensions	0	5	(10)
ii.	showing where measurements were made	0	5	(10)

Notes:
- Show luminaires in CAD drawing

Total: 200/200

Signature Attesting to Compliance

By signing below, I attest to the following:

That the Architectural Engineering Program in the Department of Civil, Environmental, & Architectural Engineering has conducted an honest assessment of compliance and has provided a complete and accurate disclosure of timely information regarding compliance with ABET's *Criteria for Accrediting Engineering Programs* to include the General Criteria and any applicable Program Criteria, and the ABET *Accreditation Policy and Procedure Manual.*

_Robert D. Braun____________________
Dean's Name (As indicated on the RFE)

July 1, 2017

________________________________ ________________________

Signature **Date**