# *Customer Guidelines AY 2016/17*

*Senior Projects (ASEN 4018 & 4028)*

## 1.0 Introduction

All undergraduates in Aerospace Engineering Sciences (AES) are required to take a two semester capstone projects course sequence. This sequence includes *ASEN 4018 Senior Projects I: Design Synthesis* (Fall semester) and *ASEN 4028 Senior Projects II: Design Practicum* (Spring semester). The course is taught by a team typically consisting of 5 faculty members[1] and three staff members, called the Projects Advisory Board (PAB), along with the course coordinator.

This document provides guidelines for the scope of a typical Aerospace Engineering Sciences (AES) Senior Design project along with customer benefits and expectations. When defining a project, customers should understand that the purpose of the AES Senior Projects curriculum is to provide undergraduate students with a first-hand experience with a ***requirements-based design process*** carried out by largely ***self-directed teams***, employing ***fundamental engineering principles*** to make design choices and to develop and communicate an ***engineering understanding*** of the system they design. All project concepts should have a **clear purpose** with a recognized value to industry or society with **specific functional objectives**, yet provide **significant design challenges** that allow students to explore various design solutions and make design choices based on **sound engineering reasoning**. At the same time, projects and aims must have a level of complexity that is compatible with 8 person teams of engineering seniors working an average of 16 hours each per week for 28 weeks.

Customers can view deliverables of projects from previous years at the Senior Design Projects website: http://www.colorado.edu/aerospace/industry-home-page/senior-design-projects.

## 2.0 Senior Projects Course Content

Senior Projects is the capstone course in the Aerospace Engineering Sciences (AES) curriculum at the University of Colorado at Boulder. While a capstone experience is required by all accredited engineering programs[2] the AES department offers a rigorous two-semester course where students move through a **requirements-based design process** from concept to detailed design to manufacturing to test and validation. Students work in **self-directed teams**. A team typically consists of eight Aerospace Engineering students of senior standing. Each team is assigned one faculty advisor from the Project Advisory Board (PAB) pool. These faculty members cover a wide range of technical skills and a variety of design experience to guide the teams through the design process for their particular project. Advisors will formally meet with their teams for at least one hour each week.

Projects are expected to provide an integrative design experience that includes topics typically of an aerospace nature that allow for creative latitude in arriving at a final design. All projects must include design elements from **mechanical, electrical, and software** subsystems. The course seeks to expose students to systems engineering principles and the multidisciplinary nature of modern engineering problems; hence each of these three components must represent a substantial part (at least 25%) of the design work. The projects begin with a **requirements definition phase** and students will make use of the technical and design skills developed throughout the undergraduate Aerospace Engineering Sciences curriculum. All projects must lead to a physical prototype that is **manufactured and tested,** leading up to a **verification** of the initially-defined requirements and some level of **validation** that the design serves the intended purpose. Given the difficulty of testing

[1] Number of faculty on the PAB depends on number of available projects and the size of the senior class.
[2] See http://www.abet.org for more information.

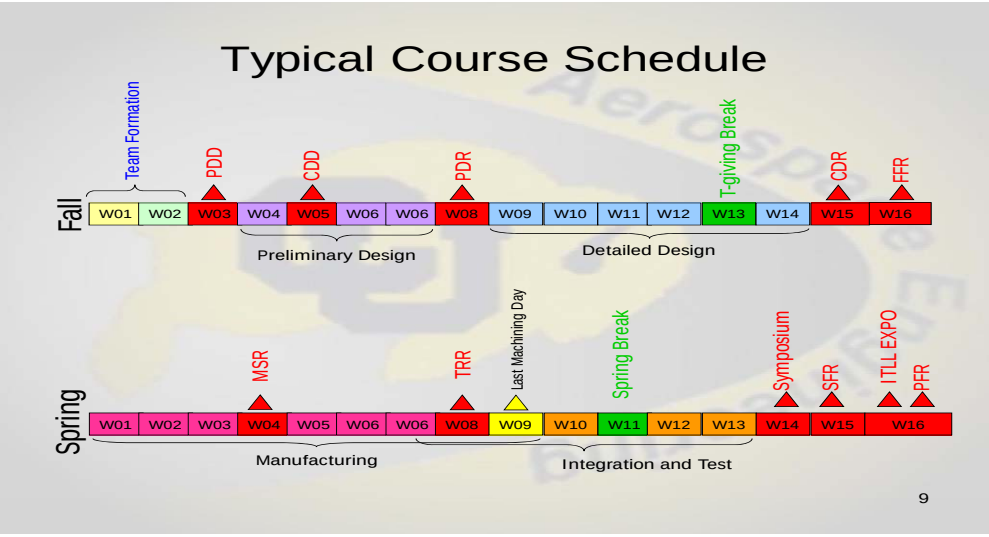
complete aerospace systems in a relevant environment, many projects focus only on important aspects of an entire system that can be safely tested under laboratory or limited flight conditions.

Each student must have a well-defined role on their design team, and **demonstrate leadership** in at least one aspect of project development.

## 3.0 Senior Projects Course Structure

At the beginning of the first semester (Fall) of the course (ASEN 4018) students are presented with the slate of available projects identified by the customer- provided **Notice of Intent (NOI)** forms, and described by short customer presentations in the first week of class. Students then self-select a project through two rounds of voting so that the projects are approximately evenly staffed. Teams and their projects are finalized by the second week of class. After selecting their projects, teams work with customers to develop the **Project Definition Document (PDD)** that defines the project and its top level functional requirements and articulates the measures of success for the project. Teams then begin the design process by generating top level design concepts and conduct initial trade studies to identify a baseline architecture and corresponding design requirements. This is documented in the **Conceptual Design Document (CDD).** This baseline design is then analyzed for feasibility, in preparation for the **Preliminary Design Review (PDR).** Projects deemed to be feasible by the PAB then progress to subsystem requirements development, detailed design, budgeting, scheduling, and preparation for the **Critical Design Review (CDR)** at the end of the fall semester. At CDR, each team has one hour (including questions) to present the key design elements of the project and convince the PAB that the project is likely to succeed and parts are ready to be ordered or manufactured. The fall term concludes with a written **Fall Final Report (FFR).**

The spring term begins with parts ordering (long lead items can be ordered earlier), electrical and mechanical manufacturing, and detailed software development. A formal **Manufacturing Status Review (MSR)** is held in the first month of the spring term. The teams continue to fabricate and assemble their projects, and develop detailed test plans in preparation for **the Test Readiness Review (TRR)** in the second month. Testing to verify design requirements and validate the suitability of the design occupy the third month of the term, in preparation for the **Spring Final Review (SFR)** near the end of the term. The course concludes with a written **Project Final Report (PFR)**. A final course requirement is to present their project at a one day **Student Projects Symposium** for professional engineers and recruiters. The presentation to the general public at the Integrated Teaching & Learning Laboratory (ITLL)[3] Design Exposition is optional.




[3] http://itll.colorado.edu/design_expo

# 4.0 What is Expected from Project Customers?

Corporations, companies, small businesses, national laboratories, R&D organizations, and academic faculty members may become project customers.

Within the framework of the Senior Design course, all projects are conducted on a ***best effort*** basis by students, guided by a member of the AES Projects Advisory Board (PAB). The customer should understand that our primary goal is the education of aerospace engineering students, and as such *exploratory* or *proof-of-concept* projects can be quite successful as an undergraduate capstone senior project. Projects which are in the customer's critical path generally cannot be accepted as Senior Design projects unless customer takes full responsibility for the outcome. "Good-to-have" results and "off-ramp" studies are more likely to be suitable. Sponsoring a project should also be seen as a "**training-on-the-job**" activity and a "**9 month interview**" for potential future employees. Although faculty and students endeavor to make every project a success, the University of Colorado cannot take any responsibility for results deemed by the customer as "insufficient."

## 4.1 Customer Participation in the Course

The customer provides a one to two page project definition on the **Notice of Intent (NOI)** form to the AES Senior Projects Coordinator and develops a more detailed **Project Definition Document (PDD)** with the students. During the two-semester senior projects course, the sponsor has many opportunities to mentor and help train a group of about eight students. All customers are expected to become **active participants** in their sponsored project. Customers should name a **contact person** for the project who can dedicate an average of least one hour per week to the project. Close contact with the teams during the early project definition phase, in particular, is critical for success of the proposed project. The period leading up to PDD is often considered the most difficult learning stage by students, who are exposed to a rigorous requirements-based design process for the first time. Customer involvement in the course review process (PDR, CDR, SFR) is essential, either in person, or in separately arranged customer reviews of the materials.

In summary, project customers are expected to:

- Complete a Notice of Intent form (NOI), and work with the course coordinator to establish funding for the project in a timely manner.
- Review and negotiate the Project Definition Document (PDD) with the students.
- Provide the project team with advice and feedback on submitted documents and presentations.
- Participate in major project reviews (PDR, CDR, SFR) or, if possible organize separate reviews.
- Provide input to the advising faculty who determine the grades for teams and individual students.

## 4.2 Project Resources Available to Customers

Customers are asked to provide adequate resources for their proposed project. In return, AES facilities, students, staff, and faculty become resources for the customer.

The customer's prime resources in the project are the senior students. The customer has the opportunity closely observe the student's capabilities while mentoring them toward project success. Over the course of two semesters (28 weeks), a student team of 8 members is required to spend

3580 person-hours working[4] on their senior project. In the past, students have spent even more time on average working on their project, as documented in weekly timesheets.

Each team is assigned one faculty advisor from the Project Advisory Board (PAB) pool. Each faculty member of the PAB spends about 110 hours advising a particular project. The PAB faculty and staff members each contribute another 15-20 hours per project during the reviews and evaluations of all projects, providing expertise and feedback on project technical and organizational aspects.

All senior design teams have priority access to the Aerospace Engineering Sciences machine shop and electronics lab. The students receive design and manufacturing guidance from a full-time machinist and a full-time electronics technician. These two department staff members contribute a substantial number of hours (ranging from 60-100% of their time) with the teams to help make their projects successful; thus a portion of their salaries and those of auxiliary support staff must be covered by the senior design project funding.

Over the past decade of teaching senior projects, the AES department has committed a considerable amount of general funds resources to develop the curriculum and materials for the Senior Projects course. Budgetary constraints require that external funding be sought to supplement department costs so that our program remains sustainable.

All faculty members of the Aerospace Engineering Department have agreed to support senior design teams if approached with project-related questions, providing a broad and deep base of expertise and experience for the students to draw upon. Students are also encouraged to seek out other sources of expertise, information, and advice from industry and the engineering literature to support their design decisions.

Each project is required to provide a total cost projection at the end of the course, under the assumptions that the work was carried out in an industry setting with entry level engineers. These projections regularly total more than $300,000.

## 4.3 Project Resources

The department of Aerospace Engineering Sciences has established a preferred avenue for customers who would like to support a two-semester senior design project, and a corresponding standard contact template. An outline of this support is provided below:

**Customer support**. An AES Senior Design Project requires a **minimum funding level** of **$20,000**, which is subdivided as follows:

- Project-specific expenditures for project-specific materials, parts, software: $5000 minimum. Amount varies by project at the discretion of the customer as well as project needs.
- Department infrastructure and labor fees for the senior projects (shop staff salary, maintenance for manufacturing shop, electronics shop, computer labs, materials, supplies, disposables): $15,000.
- Additional in-kind support (e.g. lending of hardware, access to test facilities, etc.) is sometimes needed, depending on the focus and scope defined for the project. The customer shall clearly define the specifics of the in-kind support.

Support agreements are handled either as contracts through the University of Colorado office of Contracts and Grants or as gifts through the CU Foundation. The support agreement must be in place no later than at the start of the Fall semester, so that only viable projects are presented to the students for team selection.

**Students** may submit proposals to other funding sources in order to supplement their base funding (with customer approval), e.g., the Engineering Excellence Fund of the College. Often other

[4] 8 students x 4 credits x 4 hours/credit/week x 28 weeks (2 semesters)

companies offer in-kind donations, for example software packages or instruments, academic discounts, etc. However, projects must be conceived and scoped so that minimum success does not depend on receipt of supplementary funds that may or may not become available.

**Special Arrangements.** In exceptional cases other arrangements can be negotiated between a customer and the Department of Aerospace Engineering Sciences. See the contact information at the end of this document.

## 4.4 Project Deliverables

Customers receive the following deliverables from their sponsored student team:

1. Fall Final Report (FFR). PDF-document containing a comprehensive description of the design at the CDR level, including mechanical/electronics/software drawing packages
2. Project Final Report (PFR). PDF-document containing a complete description of the project and all test results.

Customers can also download the following publicly available deliverables from all project teams:

3. Project Definition Document (PDD) Data Package (PDF-document)
4. Concept Definition Document (CDD) Data Package (PDF-document)
5. Preliminary Design Review (PDR) Data Package (PDF-document)
6. Critical Design Review (CDR) Data Package (PDF-document)
7. Manufacturing Status Review (MSR) Data Package (PDF-document)
8. Test Readiness Review (TRR) Data Package (PDF-document)
9. Spring Final Review (SFR) Data Package (PDF-document)

Project descriptions and deliverables are posted on the projects website http://www.colorado.edu/aerospace/industry-home-page/senior-design-projects. This is to comply with export control restrictions and the educational mission of the course. Details on the class export control policy can also be found at http://www.colorado.edu/aerospace/sites/default/files/attached-files/aes-srp-export_control_policy_0.pdf.

Separate review presentations (meeting or internet) may be arranged between the customer and their sponsored senior design team, provided they do not conflict with course review schedules.

All components purchased from project funds will remain in the AES department for possible future use in another project or in class. However, surplus project hardware and software may be released to the customer upon request. Please indicate on the NOI whether or not you are interested in receiving surplus project equipment after course completion; be sure to coordinate with the student project team and course coordinator regarding hardware availability and readiness for pickup.

According to the standard contract for Senior Projects, any **Intellectual Property (IP)** rights resulting from the supported senior design project remains with the inventor(s), i.e. the students.

## Contacts:

| | | | |
|---|---|---|---|
| Department Chair | Prof. Penina Axelrad | 303-492-6872 | penina.axelrad@colorado.edu |
| Course Coordinator | Prof. James Nabity | 303-492-3243 | james.nabity@colorado.edu |
| Undergraduate Advisor | Claire Yang | 303-492-2940 | Claire.Yang@colorado.edu |

## Address:

University of Colorado
Department of Aerospace Engineering Sciences
1111 Engineering Drive
429 UCB
Boulder, Colorado 80309-0429
http://www.colorado.edu/aerospace/
Dept. Phone: (303) 492-6417

**Acronyms**

| | |
|---|---|
| NOI | Notice of Intent (form) |
| PDD | Project Definition Document |
| CDD | Conceptual Design Document |
| PDR | Preliminary Design Review |
| CDR | Critical Design Review |
| FFR | Fall Final Report |
| MSR | Manufacturing Status Review |
| TRR | Test Readiness Review |
| SPR | Spring Project Review |
| PFR | Project Final Report |
| ITLL | Integrated Teaching & Learning Laboratory http://itll.colorado.edu/ |

**Recent External Sponsors**

| |
|---|
| Air Force Research Laboratory |
| Aurora Flight Sciences |
| Ball Aerospace & Technologies Corp. |
| Colorado Space Grant Consortium |
| Laboratory for Atmospheric and Space Physics |
| Lockheed Martin Corp. |
| NASA – JPL, LaRC |
| Northrop Grumman |
| Southwest Research Institute |
| Special Aerospace Services |
| Surrey Satellite Technology |

**History of Recent Projects**

Potential customers are encouraged to visit the AES Senior Design course webpage at http://www.colorado.edu/aerospace/current-students/undergraduates/senior-design-projects to browse recent projects and to examine the project deliverables.