Course Syllabus

Aerospace Senior Projects (ASEN 4018 & 4028)
Fall 2018 and Spring 2019

1 Document Scope

This document is the Syllabus for the two-semester Aerospace Engineering Sciences (AES) Department Senior Projects sequence. This sequence includes *ASEN 4018 Senior Projects I: Design Synthesis* (4 credits) and *ASEN 4028 Senior Projects II: Design Practicum* (4 credits). The sections below provide basic course information and define how projects are formulated and how grades are determined.

2 Aerospace Engineering Program

The Senior Project course provides a capstone experience, integrating the disciplinary knowledge from previous courses to conduct a realistic engineering design/build/test project to satisfy a well-defined customer need. The course teaches system engineering and project management methods by first-hand experience carrying out a non-trivial project with challenging performance objectives under firm time and budget limitations.

The Senior Project course also plays a key role in the evaluation of the AES curriculum and provides a method for direct student knowledge and abilities assessment that is used to continuously monitor and improve the entire AES curriculum, and to provide accreditation information as required by ABET (http://www.abet.org/). Overall program objectives and the specific objectives of the Senior Design course are outlined below. More details can be found in the AES department webpage http://www.colorado.edu/aerospace.

2.1 AES Program Educational Objectives

During their first few years after graduation, Aerospace Engineering Sciences graduates will have:

- *Established themselves in professional careers or received a graduate degree;*
- *Demonstrated ethical leadership, project management, and/or innovation; and*
- *Played significant roles in the research and development of engineering systems and products.*

2.2 Desired Outcomes

To meet the AES desired outcomes it is expected that students completing the undergraduate degree in Aerospace Engineering will be knowledgeable in the following areas and possess the stated skills:

K1 - The professional context of the practice of aerospace engineering and expectations of new graduates in aerospace engineering organizations, including an awareness of ethics issues, economics, and the business environment;

K2 - The history of aerospace engineering, providing a perspective on current events;
K3 - Aerospace engineering as a highly multidisciplinary endeavor, requiring a systems perspective to integrate technologies and manage complexity; and
K4 - Major principles and scientific methods underlying the technologies comprising aerospace vehicles and systems.

In addition, students will have developed the following general skills and abilities:
A1 - Written, oral, and graphical communication skills;
A2 - An ability to quantitatively estimate, model, analyze, and compute;
A3 - An ability to define and conduct experiments using modern laboratory instruments, and to interpret experimental results;
A4 - An ability to seek out and gather information, enabling independent and lifelong learning;
A5 - Interpersonal and organizational skills that enable individuals to work effectively in teams;
A6 - An ability to identify needs, requirements, and constraints, and to design appropriate engineering solutions;
A7 - An ability to formulate technical problems clearly, and to correctly apply appropriate methods and procedures for their solution;
A8 – An ability to program computers, and skills in the use of modern engineering analysis, simulation software and operating systems.

3 Senior Design Course Description

3.1 Objectives and learning goals

The overall course objective of the AES Senior Projects sequence (ASEN 4018/4028) is to teach students how to apply their undergraduate academic knowledge to the professional practice of engineering, with a focus on the aerospace field. Although there are many ways this could be done, ASEN 4018/4028 has been designed to focus on the following main learning goals:

1) Student's learning in the course should be organized around an engineering design project to develop an engineering solution to a well-defined customer need. Although engineering analysis is used, the focus of the course is on the synthesis of a solution with a recognized value to industry or society.
2) Learning should be first-person and experience-based, by doing rather than by hearing or seeing. Accordingly, students should have ownership of their project, with freedom to make their own decisions in the course of the project, and primary responsibility for the outcome. Customers should not dictate how to do the design, only what a successful product should do. Faculty should act as resources (domain expertise, application experience, development guidance) and interim evaluators of the quality of the work, but should not direct the work.
3) A broad, end-to-end engineering experience is desired, so that design decisions can be made in the context of the overall practicality and success in serving the prescribed need. The scope of the project should therefore include project definition, articulation of success criteria, conception of credible design options, selection of the best options relative to the project needs and constraints, predictive model development, feasibility analysis, detailed design requirements development, detailed design and component selection, procurement,

manufacturing, integration, verification testing, and functional validation in a representative environment.

4) Student's design work should be informed by current industry best practices. A variant of the systems engineering method, suited to the constraints of the course, should be taught, both to assist in the project development itself, and to provide students with some experience in its use. Similarly, a representative set of development milestones and design products should be utilized to break the process down into manageable steps, and to develop experience in documenting and communicating the design progress according to professional engineering standards.
5) Projects should be complex enough that the nature of modern engineering endeavors can be experienced, where cooperation within large teams is needed, and a wide range of skills must be brought to bear to produce a viable solution. Accordingly, projects should be multidisciplinary, requiring a breadth of expertise covering mechanical, electrical, and software engineering aspects, distinct roles to be identified on the team, and significant organization and cooperation within the team.
6) Provide a significant opportunity for all students to develop leadership skills. Each student should have a recognized leadership role on the team that could be in team organization, financial management, systems engineering, safety, testing, or various discipline-specific technical leadership positions.

Clearly, this set of learning goals touches on the ABET knowledge categories K1-K3, and all eight of the ABET Abilities (Section 2.2). Specific knowledge sub-categories under K4 that Senior Projects fulfills have been defined based on input from industry leaders as follows:

K4.1 - Development of engineering specifications from system level requirements.
- The design process, phases and approach
- Setting system goals and requirements
- Defining function, concept and architecture

K4.2 - Engineering design trades and system compromises
- Tradeoffs, judgment, risk and balance in resolution
- Disciplinary, multidisciplinary and multi-objective design
- Prioritization and focus
- System modeling to ensure goals can be met

K4.3 - Design and development of mechanical drawings and specifications
K4.4 - Design and development of software diagrams and specifications
K4.5 - Design and development of electrical schematics and specifications
K4.6 - Fabrication techniques and manufacturing processes
K4.7 - Development of fabrication and integration plans
K4.8 - Experimental measurement techniques & instrumentation
K4.9 - Development of experimental test and verification plans
K4.11 - Development of project management plans
K4.10 - Project management techniques and practices
K4.12 - Technical presentations and documentation

All students are expected to have a basic level of proficiency, defined as "*an ability to participate and contribute to*", all of the topics listed above at the completion of the AES senior projects sequence. Additionally, students should also gain a depth of knowledge, defined as "*skilled in the practice or implementation of*" one or more of these topics.

This course provides the opportunity for students to focus on a complex engineering problem (chosen from a slate of customer-sponsored projects) from conception through testing. Through this process students will learn and have the opportunity to apply fundamental concepts of engineering design, manufacturing and testing. Additionally, students will be expected to apply the knowledge they have learned from previous courses and develop their professional engineering skills during the course.

By the completion of senior projects, students are expected to be able to participate in and contribute to the core knowledge area (K4) in addition to K1-K3 and A1-A8 that constitute the learning goals for the course.

These learning goals are based on input from leaders of industry and academia that represent the skills a practicing engineer will require to be competitive over the next decade in any discipline of engineering.

3.2 Course Overview

ASEN 4018/4028 provides a hands-on experiential learning process where students are guided through an end-to-end process to conceive, design, manufacture, verify and validate an aerospace related system to satisfy a customer-defined need.

AES students have had some experience working on design cases studies in previous courses, where the objective is to show how a particular technical concept or method can be applied. The objective of senior projects is to design a solution to a larger problem (prescribed need), where the engineering concepts/technologies/methods are not known in advance, and must be determined by the design team based on sound engineering reasoning/modeling/analysis. Also, the course intends to go beyond theory to develop practical solutions that can be manufactured, operated, and tested to directly measure the appropriateness of the chosen approach and quantify its capabilities relative to the prescribed need.

Project ideas can be of two types: design of a new device, vehicle, or system to solve a particular problem, or design of an experimental testbed to characterize new technologies or physical processes. Both of these projects utilize established technology and design principles; they are not, in and of themselves, research projects.

Each project must have a specific ***customer*** who articulates a need and establishes overall goals of the design project, including functional objectives and appropriate constraints. Customers can be industry professionals or AES faculty. Student proposed projects are not accepted; however students may actively recruit a customer who takes on the following responsibilities:

1) to submit a *Notice of Intent* to the Course Coordinator (CC) for the academic year,
2) to collaborate with the students on a Project Definition Document that details *Customer Project Requirements* and required student skills,
3) to provide funding for the project.

The Customer Guidelines document, which is available from the web or from the CC, discusses the customer's role and responsibilities in more detail. Deadlines for project proposal submission will apply.

Because every project is different, the course teaches students about the engineering process using a "mentoring" approach, as opposed to the familiar "lecture/lab" method. Each group will have one faculty advisor who shall meet weekly to guide students through the process, offer advice as needed, and evaluate individual student contributions to the group effort. Lectures in support of design development are offered by AES faculty and guest speakers from industry. Workshops are conducted, as needed, to provide specific technical assistance that benefits multiple projects. These and other resources are used by the project teams to carry out their design to meet customer objectives and satisfy the course deliverables. It is important to note that *the conduct of each project is the responsibility of the student team*.

Individual and group work on each project is evaluated by the ***Project Advisory Board***, composed of the project faculty advisors, the CC, and AES technical staff. The PAB conducts formal reviews of project milestones at specific times during the semester, and these results are the primary source of data for compiling the team grade. Individual grades will be computed as differential adjustments from the team grade, using faculty and external mentor evaluations, peer and self-evaluations, lab notebooks, and PAB discussions. The evaluation process is based on the specific learning goals listed in sections 2.2 and 3.1. Not all learning goals will be assessed at each milestone, so students will receive specific details on the aspects to be evaluated in each assignment. More details on grading can be found in section 6.0.

The graded deliverables in the course are as follows.

3.2.1 Project Definition Document (PDD)

- Written document
- Define specific project objectives and scope

3.2.2 Conceptual Design Document (CDD)

- Written document
- Define project functional requirements
- Conceive of several top-level design approaches and conduct trade studies to select a baseline approach.

3.2.3 Preliminary Design Review (PDR)

- Oral team presentation based on a PowerPoint document
- Provide engineering evidence of feasibility of the proposed baseline design

3.2.4 Critical Design Review (CDR)

- Oral team presentation based on a power point document
- Identify and address critical project elements for success
- Preliminary prototyping and testing results
- Detailed design trade-offs and selections
- Test planning
- Costing and program planning

3.2.5 Fall Final Report (FFR)

- Comprehensive written report for the Fall design synthesis portion of the project
- Details of the design trades, analyses, and specifications development
- Collected detailed information: drawings, schematics, code, manufacturer's spec sheets, preliminary test data

3.2.6 Manufacturing Status Review (MSR)

- Oral team presentations based on a PowerPoint document
- Status report on parts procurement and fabrication
- Detailed system integration plan

3.2.7 Test Readiness Review (TRR)

- Oral team presentation based on a PowerPoint document
- Review test objectives, designs, and plans
- Safety analysis of test plans

3.2.8 Spring Final Review (SFR)

- Oral team presentation based on a PowerPoint document
- Comprehensive description of the whole project
- Emphasis on test results and evaluation relative to project objectives and requirements.
- Validation of engineering models
- Convey an in-depth understanding of the project

3.2.9 Project Final Report (PFR)

- Comprehensive written document covering the whole project
- Serves as the basis for future work
- Provides an in-depth discussion of main project elements
- Provides an archive of detailed project information
- Lessons learned and best practices

3.2.10 Senior Design Symposium (SDS)

- Symposium open to industry and other invitees
- Brief oral presentations to convey project highlights
- Poster presentation session to demonstrate project and discuss details

3.2.11 AIAA Region V Conference Paper (or equivalent with permission)

- Required paper written according to AIAA guidelines
- Submission and presentation at the AIAA Region V Student Conference is voluntary (based on advisor recommendation)

3.3 Pre-Requisites

3.3.1 Pre-Requisites for ASEN 4018

Students in ASEN 4018 (4 credits) are required to have senior academic standing at the beginning of the fall semester. Senior standing in AES implies that you have completed all the Aerospace Engineering Sciences required courses through the junior year with a grade of C or better. If you are deficient in any of the pre-requisites for this course you must submit a course petition form to your AES undergraduate advisor, who can provide guidance and details on this process. The petition will be reviewed by the Associate Chair of Undergraduate Studies and a decision will be made in a timely manner. The student must provide a compelling reason why an unmet pre-requisite would not hamper the conduct of a Senior Project for a petition to be considered.

3.3.2 Pre-Requisites for ASEN 4028

ASEN 4018 (with a C grade or better) and the consent of the senior projects CC are pre-requisites for ASEN 4028**. Students who have not successfully completed ASEN 4018 with at least a grade of C will not be allowed to register for ASEN 4028.** In such cases students will be required to begin the course sequence again in the next academic year starting with ASEN 4018.

3.4 Course Meetings

3.4.1 ASEN 4018, Fall semester

Lectures: generally Mondays (50 minutes)
Workshops: generally Wednesdays (50 minutes)
Labs (generally team meetings): Tuesdays, Thursdays (110 minutes each)
(see the course calendar for specific instances and times)

3.4.2 Attendance for ASEN 4018

Students are required to attend all lecture and lab periods during the first three weeks of the semester. These are of critical importance to team formation and project definition. After the third week of the semester students are expected to attend ALL Monday lectures and any Wednesday workshops that are applicable based on their team role. **The calendar shows mandated attendance as lecture and lab times colored in red.** Not attending those may have serious consequences for your team, the success of your design, and for your grade. Updates in the Syllabus and other course announcements will be posted on course Canvas web site. Multiple technical workshops may be held during the scheduled Wednesday timeslot and students can choose the most applicable one. Students are required to attend all of their scheduled team meetings; this includes additionally scheduled team meetings where the advisors are not present. During the preliminary and critical design review weeks, students are expected to attend ALL labs and lecture periods to listen to the presentations from all teams, unless otherwise stated by the CC. This is an important way to observe effective techniques, and to avoid unfortunate mistakes.

3.4.3 ASEN 4028, Spring semester

Lectures: Weekly lectures on Monday.
Labs: Tuesdays, Wednesdays, and Thursdays
(see calendar; dates/times subject to change)

3.4.4 Attendance for ASEN 4028

During the spring semester students will be working with their teams on fabrication and construction. There are no regular lectures scheduled at this time, but opportunities for industry speakers sometimes arise. Team meeting times will be determined by each team (with consent of the CC) but will nominally be held during the regular class meeting times. A schedule will be posted in the Spring calendar. **The calendar shows mandated attendance as lecture and lab times colored in red.**

3.4.5 Scheduling of Reviews

All reviews will be scheduled during the regular class times, both labs, workshops, and lectures. **All students must attend all major reviews (PDR, CDR, SFR)**, unless a prior arrangement has been made with the CC. Attendance at reviews is a component of your individual grade (See Section 0). The Manufacturing Status and Test Readiness Reviews (ASEN 4028) must be attended by the presenting teams only; other students are welcome to attend if they wish.

Because the reviews start the day after the assignments are submitted, and it is necessary to process and distribute the reviews to the PAB, **late review materials will not be accepted**. If you have not completed your review preparations, you should submit what you have by the deadline. To maintain fairness, only the submitted review materials may be presented. No supplements after the deadline will be allowed. However, articles may be brought in to show during the presentations.

Projects with industry and other external customer support may schedule additional reviews, with CC approval.

3.5 Major Course Dates

A course calendar will be made available on the course Canvas web site. Students should utilize this resource for detailed scheduling information. However, the tentative dates for major course milestones are listed below.

3.5.1 ASEN 4018

- Team Formation: week 1
- Project Definition Document, week 3
- Conceptual Design Document, week 5
- Preliminary Design Review, weeks 8, 9
- Critical Design Review, weeks 15,16
- Fall Final Report, week 17

3.5.2 ASEN 4028

- Manufacturing Status Review, week 4
- Test Readiness Review, week 8
- AIAA Paper, week 9
- Last Machining Day, week 10
- Spring Final Review, weeks 15, 16

- ITLL Expo – voluntary, recommended
- Senior Design Symposium, week 14
- Project Final Report, week 16
- Final Check Out form, week 16

3.6 Course time commitment

AES senior projects is a 4 credit course each semester, and like all courses students are expected to commit 4 hours per week for each credit. This means students should expect to commit at least **16 hours** each week to senior projects. This includes class and group meeting times. However, accomplishments are graded, not time spent, and they often require additional time outside of class and group meetings. In many cases motivated students commit over 20 hours each week to senior projects.

3.7 Assignments and Requirements

3.7.1 The following assignments will be given, corresponding to each deliverable:

Fall Semester:
Assign. 1: Project Definition Document (PDD)
Assign. 2: Conceptual Design Document (CDD)
Assign. 3: Preliminary Design Review (PDR), accompanied by a peer review and self-evaluation
Assign. 4: Critical Design Review (CDR), accompanied by a peer review
Assign. 5: Fall Final Report (FFR), accompanied by a self-evaluation

Spring Semester:
Assign. 6: Manufacturing Status Review (MSR)
Assign. 7: Test Readiness Review (TRR), accompanied by a peer review and self-evaluation
Assign. 8: AIAA Paper
Assign. 9: Spring Project Review (SPR), accompanied by a peer review
Assign. 10: Symposium Presentation and Poster (SPP)
Assign. 11: Project Final Report (PFR), accompanied by a self-evaluation

3.7.2 Presentation/Report Requirements.

Presentations are given by the team. However, due to time constraints, only a portion of the team can present at each review. **Each student is required to orally present at least once each semester. The maximum number of student presenters per review is 6**. In ASEN 4018 there are 2 opportunities and in ASEN 4028 there are 3 opportunities to present.

Final reports (Fall and Spring) are written by the whole team. **Each team member must be lead author of at least one substantial section of each of these major reports**. Team members may be co-author on one or more sections. These contributions must be properly attributed, in a separate section for that purpose, as report authorship is used in part to establish individual grade adjustments from the group grades.

4 Resources

4.1 Available meeting, design and construction space

4.1.1 Lockheed-Martin (LM) Room (ECAE 1B16)

The Lockheed-Martin room is reserved exclusively for the use of AES projects courses. This room may be scheduled for weekly team and advisor meetings or used for breakout work. A room schedule is posted on the AES Department website. The LM room may also be scheduled for regular PAB meetings. All students enrolled in senior projects must sign the **Lockheed Martin Room Policy** to receive card access to the LM room. Access to LM is restricted and entry is registered electronically. LM is a shared meeting room and it is expected you will keep this space clean. **Construction of any kind is prohibited in the LM room**.

4.1.2 Senior Project Lab (ECAE 1B55)

Each team will be assigned space in the senior projects lab for construction and assembly of their projects. Please respect your peers and do not disturb any items that do not belong to your team. Each team will also have a storage cabinet where they can put any supplies or sensitive equipment. Remember this is a shared space and you should return tools and clean up any messes when finished. Use of paints, thinners, epoxies or other potentially hazardous materials is not permitted in this space without prior approval of Matt Rhode or Trudy Schwartz. All work conducted in this space must be in accordance with all pertinent university safety policies.

4.1.3 Senior Projects/BioServe Conference Room (ECAE 1B14)

The small conference room on the northwest corner of the senior projects lab is accessible from the senior projects lab. This room is not currently scheduled but is available for student meetings.

4.1.4 AES Machine Shop (ECAE 1B35)

The AES machine shop is accessible daily when Matt Rhode, Adrian Stang or a designated assistant is available, and after completing the required safety training and machining workshop.

4.1.5 AES Electronics Shop (ECAE 1B26)

The AES electronics shop can provide limited space for electronics fabrication, integration and test. Access must be requested through Trudy Schwartz and space will be provided as available.

4.1.6 AES Electronics and Manufacturing Shop (ECNT 1B19)

The AES electronics and Manufacturing shop can provide limited space for electronics fabrication, integration and test. Access must be requested through Bobby Hodgkinson and space will be provided as available.

4.1.7 AES/ME Composites Lab (ECME 1B35)

The AES and ME departments have developed a composite fabrication lab to be shared by the two departments and to be used for both teaching and research. Contact Matt Rhode to obtain access to the shop.

4.1.8 ITLL Resources

All AES students have access to the ITLL, which includes the lab plazas, breakout rooms, student meeting rooms, electronics shop and the machine shop. Some software, such as SolidWorks, LabVIEW, etc. are available in the lab plaza. Equipment for prototyping is available. Students must contact Kai Amey (ameyexc@colorado.edu) or Dan Godrick (Daniel.Godrick@colorado.edu) if ITLL resources are needed. Senior Projects students can also use these spaces for their computer work, but are encouraged to use AES resources first to reduce the load on ITLL.

4.1.9 Faculty Labs / Special Equipment

In some cases, e.g., when faculty are acting as project customers, research labs may be made available for student use. This option is typically assessed on a project by project basis. If you are working in a faculty lab please respect the fact that others, most likely graduate students, may be using the same space for their research. Please coordinate with the faculty who is providing the lab to learn the rules and expectations for people using the lab.

4.2 Web Sites

The course web site can be found at https://canvas.colorado.edu/. All course materials will be posted there, as well as announcements, assignments, and the corresponding grades. Grades are visible only to individual students.

The archive web site is: http://www.colorado.edu/aerospace/current-students/undergraduates/senior-design-projects. You may need to copy and paste the link directly into your browser. Teams have the opportunity to develop their own team websites on that server. Links to deliverables from previous projects may be helpful in the development of your own reports and presentations.

4.3 Email List Server

The course roster provided by the University as part of the **myCUinfo** system will be utilized as the course email list. You do not need to subscribe to that list. Messages will be sent to your official CU email account. Replies to this email will not go to the group but will be directed to the CC.

Any course-wide announcements or postings will be available on the class Canvas web site.

4.4 Senior Design Mailbox

Each team will receive a project mailbox located in the Lockheed Martin Room on the East wall. Mailboxes are used to deposit and return reports and notebooks. These are not intended to be used for messages for the PAB; use e-mail for this purpose.

4.5 Project Costs

Details about the financial requirements and expectations for senior projects can be found in the **Financial Management Requirement Document** which is available through the course website. A brief overview is provided below.

4.5.1 Budget

All projects are allotted a budget of $5,000 (AY 2017/2018) for project purchases. The budget will come from funds committed by a customer. Customers may provide additional operational funding as delineated in the **Customer Requirements Document** which is available from the CC or the course website.

In many cases students apply for additional support from

- the EEF and UROP programs within the University of Colorado.
- Corporations often provide in-kind donations or university discounts.

It is the responsibility of the teams to inquire about such support.

If students would like to pursue other external funding opportunities they must coordinate those efforts with the CC and the customer before proceeding.

4.5.2 Procedures

All teams are required to have a Financial Lead (FL) who will be responsible for their team following the established procedures in the **Financial Management Requirement Document** and accounting for all the financial transactions.

5 Student Requirements

5.1 Project Teams

The AES department will endeavor to provide enough projects through external and internal funding sources to support **10-12 person teams**. The intent is to staff each project with an approximately equal number of students; exact numbers depend on current enrollment. Students will be placed on project teams from the slate of current projects through a self-selection process. The process will give students the opportunity to work on a project of interest to them, but just as important, it will strive to ensure that each project is staffed with individuals who either possess or is willing to develop the skills needed to make the project a success. In the event that projects are under or over staffed after the self-selection process, the CC with input from the PAB has final authority on team composition to ensure reasonable balance among teams.

Teams that form in advance of the senior year, e.g. to explore project ideas of interest and funding, will have priority in selection for that project, but only up to groups of five (5) students

listed on the Notice of Intent form for that project. However, there is no guarantee that any such project will be among the slate of approved projects.

In the first week of class, the slate of projects will be presented, and students should rank projects according to their interest. Some iteration is typically needed to formulate teams with the required expertise and evenly balanced numbers of team members across groups. Once formed, each team shall choose a Project Champion to lead team meetings until final selection of a Project Manager is made later in the semester.

Every team member must take a leadership role in the project, and each of the following roles must be represented. No person can perform more than one of these key roles.

- Project Manager (PM)
- Systems Engineer (SE)
- Manufacturing Lead (ML)
- Test/Safety Lead (T/SL)
- Financial Lead (FL)
- Technical Leads (these are project-specific, but must cover the major design areas in the course: mechanical (includes fluid/thermal/optical), electronics, and software)

All members of the team must have a technical contribution to the project. Team organization may be changed as project needs evolve, but each member must have a clear leadership role in the project at all times.

5.2 Safety

Safety shall be a primary concern for all students, faculty, and staff in Senior Projects. Students must take the required training if they plan to use Department and/or ITLL shops, and all students must attend an environmental health and safety training workshop. Any work conducted in senior projects must be done in accordance with all university safety policies which can be found at http://ehs.colorado.edu/. Any activity on the project that has a potential safety impact will be first cleared by Matt Rhode, Bobby Hodgkinson and Trudy Schwartz.

5.3 Text

There is no required text for this course. Recommended reading includes:

"*TeamWork, what must go right/what can go wrong*" by C.E. Larson, F.M.J. Lafasto, SAGE Publications, 1989.
"Decision Making & Problem Solving Strategies", John Adair, Kogan-Page, 2007.
"Design-Driven Innovation", Robert Verganti, Harvard Business Press, 2009.
"Design-Inspired Innovation", James Utterback, et al., World Scientific, 2007.
"Open Innovation", Henry Chesbrough, Harvard Business School Press, 2003.

Project managers are encouraged to read

"*The TEAM Handbook*," by P.R. Scholtes, B.L. Joiner, B.J. Streibel, Oriel Inc. 2003.
"Just Enough Project Management" by Curtis R. Cook, McGraw-Hill 2005.
"Guide to the Preparation of Operational Concept Documents", ANSI/AIAA G-043A-2012

Systems Engineers are encouraged to read

"*Systems Engineering and Analysis*," B.S.Blanchard, and W.J.Fabrycky, Prentice Hall, 2006.
NASA Systems Engineering Website: http://spacese.spacegrant.org/

5.4 Design Notebooks

Design work today occurs in a variety of ways and through many different computer tools. In many cases, design goes directly from an idea to a CAD drawing. This is an efficient approach if the design idea is simple, e.g. a small component of the system, such as a mechanical bushing or software device driver. For larger project aspects, such as formulating major design approaches, better methods are needed to create, communicate, and refine these ideas. Despite all the computer design aids available today, there remains no better medium for this creative process than sketching ideas on paper. This ranges from initial ideas on the proverbial "back of the envelope", to detailed diagrams, free body force/moment analyses, musings about functional modes, ideas for test fixtures, etc. Accordingly, in this course, all students are required to use a design notebook for the bulk of their design work. This facilitates one of the most difficult aspects of large projects: getting ideas out of the head of team members and into a form the whole group can understand and effectively work on. A white board is also useful, but its results must be captured in a more permanent form, e.g. in a notebook. Once these design ideas are communicated and refined to the point they solve the problem at hand, they are typically converted to a more formal representation (flow chart, solid model, etc.) for presentation.

Diligent use of a notebook helps develop skills in communication via sketches, drawings, diagrams, equations, etc. It also provides a record of your design contributions to the project that will be used by you (for your own design work, and the self-evaluations), your peers (for the benefit of the project, and for the peer evaluations), and your advisors (for the notebook evaluations) to assess the value of your work on the project during grading. Notebooks should be kept at hand, so all your design thinking can be done in them, so you can use them to work through ideas with your team, and so your advisor can review your individual work periodically. Notebooks are formally graded by your advisor at the end of the term. The AES Department will provide one standard notebook to each student for each term. Generally, students fill at least one notebook per term.

5.5 Weekly Time Sheets

In industry your work is often divided among several projects with separate sources of funding. Time cards are widely used to associate efforts with the proper accounts. This is not the case in senior projects, with one source of funding and no billing for personnel time. However, a variant of time cards will be used in this course to assist in managing your time wisely. The weekly time sheet (WTS) records the number of hours spent on the project, as well as a brief summary of the week's accomplishments and your plans for the next week. This helps maintain a healthy level of effort for project success, and encourages everyone to assess and plan their own work. The WTS should be a succinct summary reflecting the accomplishments and planning already in the design notebook, and should take only about 5 minutes to prepare each week. The WTS will be submitted to the Canvas web site, and a Course Assistant will collate these for distribution to the teams and advisors. A template for the WTS will be posted.

6 Course Faculty and Staff

6.1 Course Coordinator (CC)

Jelliffe Jackson
Office: ECOT 612
Office Phone: 303-492-3702
Email: jelliffe.jackson@colorado.edu (preferred over phone)
Office Hours: during lab hours, by appointment, or just knock at my door.

6.2 Project Advisors (2018/19)

Dennis Akos Office: DLC 209 Office Phone: 303-735-2987 Email: dma@colorado.edu	**Marcus Holzinger** Office: TBA Office Phone: 303-735-6659 Email: marcus.holzinger@colorado.edu
John Mah Office: ECST 207 Office Phone: 303-492-7651 Email: John.Mah@colorado.edu	**Donna Gerren** Office: ECAE 198 Office Phone: 303-735-4870 Email: donna.gerren@colorado.edu
Francisco Lopez-Jimenez Office: ECAE 185 Office Phone: 303-492-1047 Email: Francisco.LopezJimenez@colorado.edu	**Kathryn Wingate** Office: TBA Office Phone: 303-735-7631 Email: Kathryn.Wingate@colorado.edu

6.3 Support Staff

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6.4 Other Course Resources

Course Assistant **Christine Reilly** Email: christine.reilly@colorado.edu	Course Assistant **Ian Cooke** Email: ian.cooke@colorado.edu
Financial Accounting **Joan Wiesman** Office: ECAE 197 Office Phone: 304-492-3098 Email: joan.wiesman@colorado.edu	

6.5 Course Faculty and Staff Roles

Course faculty and staff roles and responsibilities are defined in the Faculty Advisor Guidelines document. This is briefly summarized below.

The CC, in agreement with the Chair of the Department, will select and approve the slate of senior design projects for the academic year based on financial support and course compatibility. The CC will work with potential customers to define projects suitable for the course.

The CC will ensure that all project teams are viable and have approximately the same number of students.

The CC will update and distribute the course materials, as needed, for the current academic year, and will organize the course workshops, lectures, and PAB reviews and grading activities.

The CC will maintain, post, and submit all grades in the course, with the assistance of the Course Assistants.

The Projects Advisory Board (PAB) consists of one Team Advisor for every two projects, the CC, and the department machine shop and electronics shop supervisors. The role of the PAB is:

- to provide advice and guidance to the project teams
- to provide a cross section of relevant professional expertise in the evaluation of the student projects
- to provide timely, actionable feedback on the quality of team progress, and
- to determine group and individual grades for the course.

Students should look to the faculty and staff for:

- Experience in engineering analysis, design, development, and testing using a systems engineering approach.
- Expectations of professional practice, communications, project management, and organizational skills
- Specific technical expertise in various areas, and suggestions where additional expertise may be found.

The PAB members do not, however, run the projects. They have no decision-making authority in the conduct of the project. This authority and responsibility lies with the students in the corresponding project team. Faculty will provide feedback and will ask teams to defend their

decisions with engineering arguments in an effort to help them make the informed design choices that lead to a successful project.

6.6 General AES Faculty support

All faculty members in the AES department are committed to providing students in senior projects with technical guidance in their area of expertise, if provided with reasonable requests. Contact information and a short overview on the technical interests of each faculty member can be found on the AES department webpage. Additional information can be found on the research center and individual faculty web pages.

If you have difficulties reaching a faculty member whom you would like to meet with you, contact the CC or your faculty advisors who can help to coordinate this effort.

7 Grades

7.1 Grading Procedures

The requirements for each graded product in the course are specified in the corresponding assignment document. These are provided on the course Canvas web site. The grades are determined based on the criteria found there.

All grades are determined by your faculty advisor in agreement with the Project Advisory Board (PAB) as a whole, along with the CC. In the event that consensus cannot be reached, the CC has the final authority in setting grades.

7.2 Grade Components

The final semester grades are determined from a group grade basis on each assignment, with differential adjustments, based on individual contributions to the group effort, to obtain individual student grades. Grading in Senior Projects is necessarily somewhat subjective, but grades are normalized over the whole class in PAB grading meetings to maintain consistency and fairness. The CC keeps the grades on file, and will post them on Canvas web site for individual student access only. The team adviser will provide feedback to individual students about their grade outcomes upon request. The weighted contribution to the total grade for each element of the course is provided below. Advisors provide evaluations of design notebooks and student performance evaluation at the end of the term.

7.2.1 ASEN 4018 assignment weighting (Fall)

Product	Weight
Project Definition Document	10%
Conceptual Design Document	10%
Preliminary Design Review	20%
Critical Design Review	20%
Fall Final Report	20%

Design Notebooks	10%
Student Performance Evaluation	10%
Total	100%

7.2.2 ASEN 4028 assignment weighting (Spring)

Product	Weight
MSR and TRR Reviews	20%
AIAA Conference Paper	5%
Spring Final Review	20%
Symposium	10%
Project Final Report	25%
Design Notebooks	10%
Student Performance Evaluation	10%
Total	100%

7.3 End of Project Disposition

At the end of the ASEN 4028 teams and students are required to sign a consent document where students agree to allow the Aerospace Engineering Sciences department to copy and distribute materials that were created by the team in ASEN 4018 and ASEN 4028 to future students, future PAB members, aerospace industry members, and to publish them on the department website http://www.colorado.edu/aerospace/current-students/undergraduates/senior-design-projects.

Before final grades are issued, all students must be cleared on the course disposition list showing that all equipment (hardware and software) borrowed during the course has been returned to the appropriate owners, work areas have been cleaned up, and purchasing card accounts have been closed.

7.4 Individual Assessments

7.4.1 Self-Assessment

At select reviews (PDR, CDR, TRR, SFR) all students will be asked to provide a *self-assessment* of their contribution to the current phase of the project. This self-assessment should document the student's technical, design/implementation and management contribution to the projects and will be aligned with the course learning goals outlined in Section 2.1.

Self-assessments will be made available to your team members before the deadline for peer reviews.

7.4.2 Peer Reviews

Each semester two confidential *Peer Reviews* will be solicited from student team members after select major presentations (ASEN 4018: PDR, CDR; ASEN 4028: TRR, SFR). In these peer reviews you will be asked to evaluate the overall contribution of each team member to the success of the project.

Peer reviews will be utilized by the PAB in their assignment of individual grades of select assignments (PDR, CDR, FFR, TRR, SPR, PFR), and in the individual Faculty Performance Evaluation grades at the end of each term. Accordingly, peer evaluations can strongly affect individual student grades, just as individual contributions can strongly affect the quality of a team project. You are encouraged to identify roles in the project where your contributions are meaningful and recognized, and to be fair in your evaluations of your peers.

7.4.3 Design Notebooks

All students must maintain a notebook that reflects the quality and quantity of their individual design activities. The intent is for students to do all their thinking in the notebook. It should contain ideas, sketches, diagrams, equations, calculations, test data, questions, plans, and findings. Its purpose is to help understand and organize the design process. Ideas should be transferred from the notebook to class deliverables, not the other way around. Typically, at least one notebook is filled each semester (see the Design Notebook assignment for an explicit notebook grading rubric). Advisors will review notebooks periodically and provide feedback to ensure that the end of the term notebook grading produces no surprises. Note that the content of the design notebook has a much larger impact than the notebook grade alone, since the work in the notebook is one of the main sources of evidence of individual contribution to the project, which affects differential grading among the team in most of the course assignments.

7.5 Grading Scale

Letter grades are only assigned at the end of each term, not on individual deliverables. Team numerical and letter grades are assigned according to the following absolute scale:

Grade		Interpretation
90-100	93 – A 90 – A-	Excellent work= Exemplary **engineering design** contributions. Likely to meet all major project objectives, and to close the design loop with full project validation. An engineering understanding of the project is evident, and design projects meet professional standards. Exceeds course expectations.
80-89.9	87 – B+ 83 – B 80 – B-	Good work = Good **engineering design** contributions, but non-engineering contributions dominate. Likely to meet some of the major project objectives, and to verify all of the design requirements, but full validation is not likely. An engineering understanding of some project elements is evident, and some design products meet professional standards. Meets course expectations.
70-79.9	77 – C+ 73 – C 70 – C-	Minimal work = some contributions can be identified, but little **engineering design** content is evident Likely that none of the major project objectives will be met and verified. An engineering understanding is lacking, and design products are of generally of substandard quality. Below course expectations. **A C grade is the required minimum in ASEN 4018 to progress to ASEN 4028**.
60-69.9	67 – D+ 63 – D 60 – D-	Poor work = little contribution to the team or to the system design can be identified. Likely that the system will not be completed in time, and that no meaningful testing will be possible. Design products are unacceptable, and little engineering understanding is conveyed. Far below course expectations.
< 60	F	A failed effort.

Note that individual grades can differ substantially from the team (average) grade, based on individual contributions as judged by the PAB, with input from peer evaluations.

7.6 Incomplete Grades

According to University policy incomplete grades (IF) cannot be given in ASEN 4018 or ASEN 4028.

8 Project Formulation

8.1 Project Definition Document

The first assignment for the new student teams is to assess all customer-provided information and to formulate a clear definition of the project that will be carried out. This is articulated in the Project Definition Document (PDD). Specifications for the PDD can be found in the assignment.

Project customers, prospective student team members, and the PAB will collectively review the PDD during the first three weeks of the Fall semester. Once all have agreed to the content of the PDD, the project is deemed approved and the team may proceed. **The PAB must approve the final PDD before the design project may proceed**. The PAB reserves the right to reject unsatisfactory PDDs and, if necessary, to reassign prospective team members to other teams.

8.2 Expected Project Content

All projects are expected to:

- Conceive, design, fabricate, integrate, verify and validate a product, device or system.
- Develop designs using quantitative, engineering tools and methods of appropriate complexity, reflecting the academic background expected of Aerospace Engineering seniors.
- Use standard engineering practices of systems engineering, including the development of design requirements, trade studies, risk analyses and mitigations, predictive models, resource plans, and a comprehensive schedule of work.
- Use an appropriate set of professional project management tools and practices to organize the work to assure objectives are met with the limited time, equipment, budget, and skills available.

8.3 Project Advancement

The systems engineering approach followed in this class was invented by the industry to assist in the development of complex aerospace systems, where a great deal of time and money is at stake. Although a senior project is considerably smaller than most industry projects, it can benefit from the same development and decision-making process, reducing the risk of a poor outcome. Accordingly, several key decision points have been established in the course. Projects cannot move beyond these points until satisfactory progress is evident to the PAB. These decision points are as follows:

- **PDD**: projects must have a clear definition of the objectives of the design, so that the PAB can understand what is being attempted and whether it appears to be of reasonable difficulty and scope.
- **PDR**: projects must present evidence of feasibility, making engineering arguments for technical, logistic, and financial feasibility within the constraints of the senior design course.

- **CDR**: projects must show that they are ready to expend their resources, having identified and addressed all the major elements required for project success, and carried the design to enough detail to make appropriate decisions on procurement or fabrication of all key components.
- **TRR**: projects must show that verification testing has been adequately conceived, designed, and planned, and that the team is ready to conduct the tests safely.

8.4 Multi-Year Themes

Projects may build upon results obtained in previous years. Such projects have the advantage of involving students in overall projects with larger scopes than can be accomplished by one team in one year. Another advantage is that it introduces students to problems involving larger system level interactions and trades.

However, **the project for a given year must be self-contained**. That is, it must lead to the development of a specific new product, device or system. Multi-year projects must also define and maintain a set of higher level project goals and, as required, interface definition documents that clearly define the boundaries for a given year's activities. Duplication of previous work is not acceptable.

8.5 Multi-Departmental Projects

Projects may also be coordinated with seniors working in other departments on their own senior project class. This provides an opportunity for multi-departmental projects with an enhanced sophistication in specific disciplines.

However, a multi-departmental project will need to accommodate the necessary interfaces, both technical and academic, between the two departments. Students in such projects are responsible for drafting a plan to accommodate this issue. The CC must approve such plans.

9 Aerospace Engineering Sciences & University Policies 2019

9.1 Accommodation for Disabilities

If you have a temporary medical condition or injury, see Temporary Medical Conditions under the Students tab on the Disability Services website and discuss your needs with your professor. If you qualify for accommodations because of a disability, please submit to your professor a letter from Disability Services in a timely manner (for exam accommodations provide your letter at least one week prior to the exam) so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities. Contact Disability Services at 303-492-8671 or by e-mail at dsinfo@colorado.edu. If you have a temporary medical condition or injury, see Temporary Injuries under the Quick Links at the Disability Services website and discuss your needs with your professor.

9.2 Religious Holidays

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, you should make arrangements with the instructors at least two weeks in advance if there is a religious observance conflict with exams, quizzes, homework, and laboratory reports. See the campus policy regarding religious observances for full details.

9.3 Classroom and On-Campus Behavior

Students and faculty each have responsibility for maintaining an appropriate learning environment, not only while in class, but also while working outside of class such as in labs and study areas. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with differences of race, color, culture, religion, creed, politics, veteran's status, sexual orientation, gender, gender identity and gender expression, age, disability, and nationalities. Class rosters are provided to the instructor with the student's legal name. We will gladly honor your request to address you by an alternate name or gender pronoun. Please advise us of this preference early in the semester so that we may make appropriate changes to our records. For more information, see the policies on classroom behavior and the student code.

9.4 Discrimination and Harassment

The University of Colorado Boulder (CU Boulder) is committed to maintaining a positive learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct, discrimination, harassment or related retaliation against or by any employee or student. CU's Sexual Misconduct Policy prohibits sexual assault, sexual exploitation, sexual harassment, intimate partner abuse (dating or domestic violence), stalking or related retaliation. CU Boulder's Discrimination and Harassment Policy prohibits discrimination, harassment or related retaliation based on race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. Individuals who believe they have been subject to misconduct under either policy should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127. Information about the OIEC, the above referenced policies, and the campus resources available to assist individuals regarding sexual misconduct, discrimination, harassment or related retaliation can be found at the OIEC website.

9.5 Honor Code

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the academic integrity policy. Violations of the policy may include: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, resubmission, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code Council (honor@colorado.edu; 303-735-2273). Students who are

found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code Council as well as academic sanctions from the faculty member. Additional information regarding the academic integrity policy can be found at the Honor Code Office website.

Students will be required to sign and return the ASEN honor code agreement, that can be found at the following website:
http://www.colorado.edu/aerospace/sites/default/files/attached-files/honor_code_agreement.pdf
For the seniors, the agreement will be administered in senior projects. Students who do not complete the honor code agreement will be administratively dropped from their ASEN courses at the end of the second week of classes.