

Evaluating the Impact of an Expanded Sophomore Design Curriculum for
Aerospace Engineering Students

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Abstract and Research Question

The aerospace engineering curriculum includes a series of discipline-specific design courses: a sophomore-level course covering aircraft design principles (AE 2780) and senior-level courses providing a choice of aircraft (AE 4780/4781) or spacecraft (AE 4790/4791) projects. An additional sophomore-level course in spacecraft design (AE 2790) was recently developed with the goals of increasing student motivation and persistence, helping students make informed choices regarding their upper-level coursework, and aiding students in professional development by exposing them to spacecraft design techniques that are applicable to internships and research. This project investigates the effects of AE 2790 on student preparedness, course selection, motivation, and career aspirations.

We have two main questions: (1) Will the addition of the sophomore spacecraft design course better prepare students for the spacecraft senior design course sequence and (2) Will the addition of the sophomore spacecraft design course influence students' selection of upper division electives and senior design course? This project requires a coordinated effort between the instructors of all courses in the aerospace engineering design sequence to ensure that the impact of this new course is thoroughly evaluated and the objectives of this curriculum change are met.

Purpose of project

The purpose of this project is to evaluate the impact of a curriculum change that took effect in the aerospace engineering program for S&T students beginning Fall 2017 (sophomores in the 2018-19 academic year). This curriculum change included the addition of a required, sophomore-level design course in spacecraft design (AE 2790), which had previously only been offered as an elective (enrollment of 10-30 students per year). This course was designed to expose sophomores to a broader range of design topics, allowing them to make more informed choices about their upper division courses, in particular the senior design sequence. In addition, it is hypothesized that this course may increase student preparedness, motivation, and persistence, especially for those students interested in spacecraft-related careers, who previously had to wait until their upper division coursework for a formal introduction to these topics.

The sophomore and senior design course sequence provide important experiential learning opportunities for S&T students. The goal of adding AE 2790 to the curriculum was to provide an additional experiential learning opportunity in an area that past students were not formally exposed to until senior year (and then, only if they chose the spacecraft design option). By evaluating the impact and effectiveness of this new course, and in doing so taking a closer look at the design course sequence in our department as a whole, we aim to ensure that these experiential learning activities are meaningful for students, aiding in their development of applicable skills and professional development.

Beginning Spring 2019, sophomores in the aerospace engineering program were required to take two design courses, AE 2780 (2 credit course in aircraft design) and AE 2790 (newly-required 2 credit course in spacecraft design). Previously students took only the introductory aircraft design course. For students taking this new course the objective is to finish the course with a sound background in the basics of spacecraft design. This knowledge should allow them to make an

informed decision about which area of aerospace engineering they want to focus on in senior design and better prepare them for the senior spacecraft design course if they choose to go that route. In addition, we believe that early exposure to a broader range of engineering design challenges will be engaging for the students and provide them with additional skills and knowledge they could utilize in co-ops, internships, or even on campus design and research activities.

This project aims to evaluate this new course (AE 2790) as well as take a closer look at the department's design sequence as a whole by surveying design students at the beginning and the end of the design courses to assess gains in knowledge and skills as well as possible changes in attitude. In addition, this project lays the foundation to continue to track this first cohort of students taking AE 2790 as a required class as they progress through the aerospace engineering curriculum.

Methodology

In the 2018-2019 academic year, we began administering surveys to the students at the beginning and end of the sophomore design courses (spring semester) and senior design course (year-long). While none of the seniors surveyed in the current data had AE 2790 as a required course when they were sophomores, we still felt it was valuable to begin surveying the seniors now, as a number of them had completed AE 2790 as an elective. Survey questions for the sophomores included which senior design course they intend to enroll in, which area of aerospace engineering they plan to seek employment or graduate opportunities in, as well as five-point Likert scale questions about the students' perceived preparedness for the sophomore-level design courses and interest seeking in co-op or internship activities. Survey questions for the seniors included five-point Likert scale questions about the influence of their sophomore design courses on their choice of senior design course and technical electives and their perceived preparedness for senior design and future employment. The full surveys are included in Appendix A and were administered during class time on paper. The surveys took approximately 10-15 minutes to complete, and although students were informed that completion of the surveys was voluntary, the majority of students in each course completed all questions on the survey. Tracking of student enrollment in each senior design track (aircraft vs. spacecraft) as well as the number of students in that cohort who completed AE 2790 is ongoing as these students progress through the program.

Results

Within the Spring 2019 sophomore class, 55 students were enrolled concurrently in both AE 2780 and 2790, while 16 were enrolled in AE 2780 only. The 16 students who were not enrolled in AE 2790 were exempt from the requirement for various reasons which include dual major status and admission to the aerospace engineering program prior to 2017. Survey responses suggested that exposure to both design courses helped students choose focus areas for their future design coursework. On end-of-semester surveys, 20% of students completing both design

courses (2780/2790) responded that they were undecided about which senior design course they will take compared to 27% of students completing only AE 2780 (Figure 1).

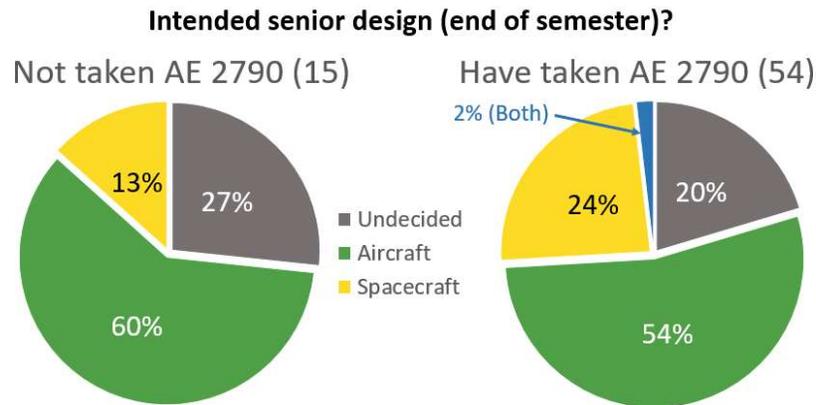


Figure 1. Intended senior design course enrollment for Spring 2019 sophomores. These results reflect responses at the end of the Spring 2019 semester for students who were enrolled in 2780 only (left) and both 2780 and 2790 (right).

It should be noted that although completion of AE 2790 appeared to aid students in their decision of which design course to enroll, it did not increase student interest in enrolling in the spacecraft track for senior design or in pursuing a spacecraft-related career. In fact, there seemed to be a trend of increased interest in an aircraft related career path at the end of the sophomore design courses compared to the responses at the beginning of the semester (Figure 2).

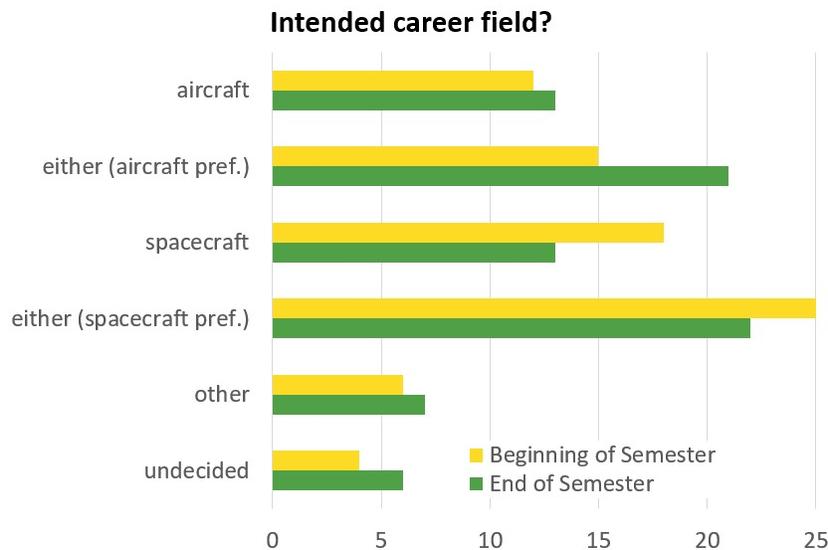


Figure 2. Intended career field for Spring 2019 sophomores at the beginning of the semester (yellow bars) and end of semester (green bars)

While this was not the expected result, there were several contributing factors that may have driven more students to express a preference for aircraft design over spacecraft design at the end of the sophomore design course sequence. In the spring of 2019, the sophomore spacecraft design course was taught by two PhD students, and anecdotally, it seems that some of the projects that were assigned late in the semester were perceived to be much more difficult than the

work assigned in the corresponding aircraft design course. In addition, some of the content of AE 2790 relies heavily on a knowledge of circuits, and some sophomore students have not had much exposure to this topic prior to the course and may have felt overwhelmed. This coming spring, AE 2790 will again be taught by a faculty member, Dr. Jill Schmidt, and special attention will be paid to ensuring that the difficulty of the assignments is appropriate for sophomore-level students and that the basic circuitry concepts are covered early in the course to start all students off on equal footing. These surveys will be repeated for the sophomore classes of 2020 and 2021 and it may be that the adjustment to the difficulty of AE 2790 will result in different trends in student intent.

Although completion of AE 2790 did not increase interest in the spacecraft senior design path or spacecraft related careers in general, exposure to the AE 2790 course material did appear to increase student interest in getting involved with hands-on projects on campus related to spacecraft design. Of the 55 students enrolled in both AE 2780 and AE 2790, nine joined a spacecraft-related design team on campus during the semester compared to only one student enrolled in AE 2780 alone. We will survey these same students again as seniors to get a clearer picture of their paths through the program and observe any longer term influences of AE 2790.

In addition to surveying the spring 2019 sophomore class, we administered surveys to the 2018-2019 and 2019-2020 senior design classes as well. Within the 2018-2019 senior design class, 17 students completed AE 2790 as an elective prior to enrolling in senior design, while 41 completed only the required sophomore-level aircraft design course. Within the 2019-2020 senior design class, 27 students completed AE 2790 as an elective prior to enrolling in senior design, while 43 completed only the required sophomore-level aircraft design course. The beginning of semester survey responses for these two cohorts were combined for this analysis. The survey responses from these senior design students indicated that students who completed both sophomore design courses reported a stronger impact of their sophomore design experience on their selection of upper division courses and post graduate plans compared to their peers who only completed the aircraft sophomore design course (Figure 3).

For students enrolled in the spacecraft senior design sequence (AE 4790/AE 4791), students who had completed AE 2790 felt that they were more prepared for the senior design course than their peers who had not enrolled in the elective course at the sophomore level (Figure 4). There was no major difference in students' perceived preparedness for employment in the field of spacecraft design. The end of year results for the 2018-2019 cohort showed similar trends, and the end of year results for the 2019-2020 cohort will be collected at the conclusion of the current academic year. These promising results motivate our continued investigation into the impact of this course now that it is a required component of the curriculum.

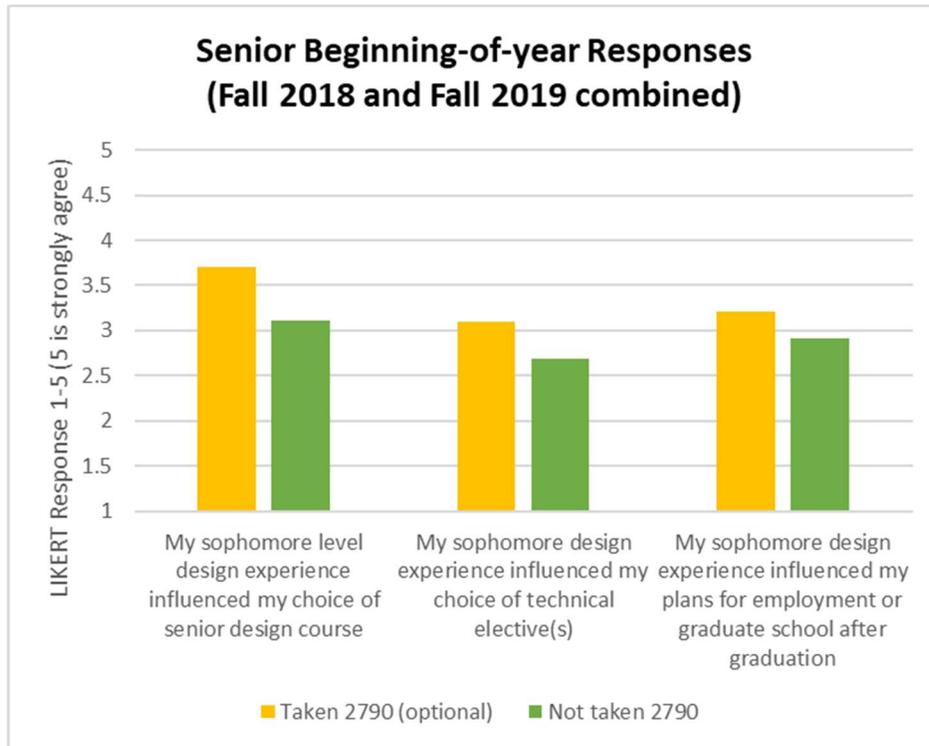


Figure 3. Senior beginning-of-year responses for students who had taken AE 2790 (yellow bars) and had not taken AE 2790 (green bars)

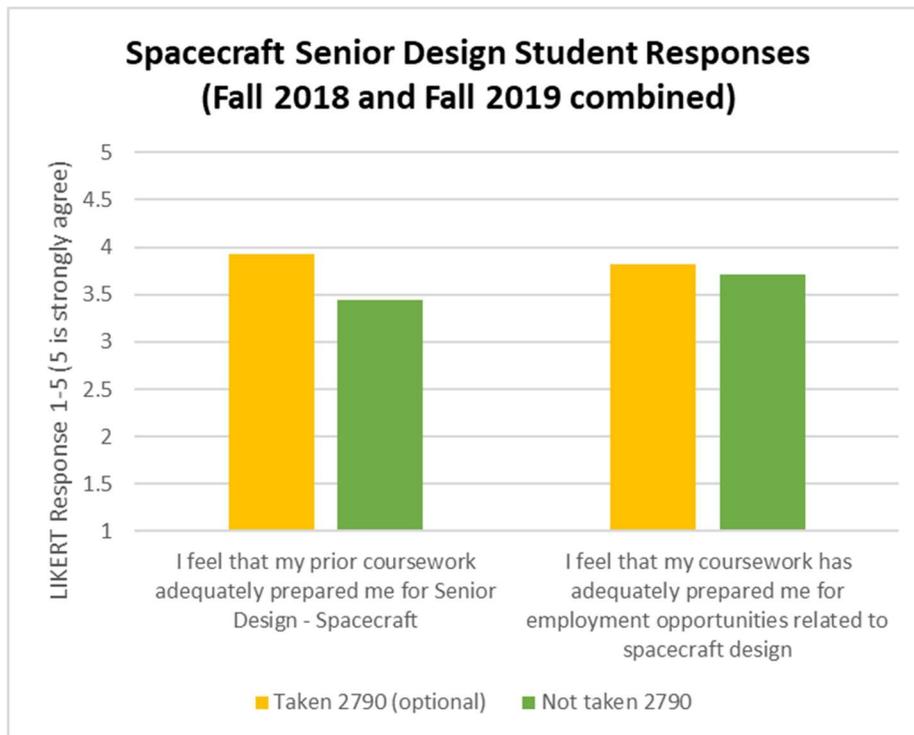


Figure 4. Responses for students in AE 4790/4791 Senior Design - Spacecraft who had taken AE 2790 (yellow bars) and had not taken AE 2790 (green bars)

Conclusions and Future Work

At this time, only one full year of survey responses have been collected and recorded, and we plan to continue administering these surveys to incoming cohorts of sophomores and again when those sophomores reach senior year. These preliminary results have been presented at the American Society for Engineering Education Midwest Section Conference this past fall, as well as the Teaching and Learning Technology Conference on the Missouri S&T campus. The largely positive student response and consistent enrollment in the Spacecraft Senior design course serve as an early indicator that this course is well-received by the students and may be supporting their preparation for design work at the senior level and beyond, although perhaps the difficulty of the sophomore spacecraft design course needs to be adjusted now that the course is required rather than elective. Additional years of data collection will help to confirm or challenge these early trends. Although the initial deployment of AE 2790 as a required course did not immediately result in an increased interest in spacecraft design, it remains to be seen whether the exposure to spacecraft design concepts at the sophomore level has a lasting impact on these students as they progress through the program and ultimately into their chosen careers.

We intend to keep recording this data for at least three more years, until two full cohorts of sophomores have completed the degree program. In addition, we are working to obtain and track metrics such as time to graduation and number of students completing the degree vs. transferring to other programs to note any trends after this addition to the curriculum. By measuring the impact of this course and gaining a better understanding of students' progression through the design course sequence, we hope to gain new insight about the impact of these experiential learning opportunities on students' educational trajectories and use the results to improve AE 2790 specifically and the design curriculum as a whole. Once the data collection period is complete, we plan to disseminate these results in a larger forum such as the American Society for Engineering Education Annual Conference or in a peer-reviewed journal in the field of engineering education in the hope that our experience can help guide other aerospace engineering programs as they seek to incorporate experiential learning opportunities into their curriculum.

Reflection

This project has provided us with a chance to take a closer look at the student experience throughout the entire aerospace engineering design course sequence. As a result of this project we have been made aware of students' perceived preparedness for each of the design courses and have been able to identify areas of concern, particularly with regards to prerequisite knowledge and difficulty of the AE 2790 course. Adjustments are underway to the course content for AE 2790 for the upcoming semester, and we are eager to see if these changes result in an improved student experience for the current sophomore cohort. In addition, although we were encouraged to find that seniors who had taken AE 2790 as an elective felt more prepared for the senior design spacecraft courses, we plan to continue to improve the alignment between the sophomore and senior design courses in both the aircraft and spacecraft tracks. In upcoming years we will be able to use the student feedback to guide changes to the content covered in the sophomore

courses to best prepare the students to take on more complex challenges as seniors. Although we will need to continue to collect data and track our cohorts of students as they advance through the program, some of the early promising results indicate that by exposing students to a hands on project in spacecraft design during sophomore year, we may be giving them the confidence and/or motivation to seek out additional experiential learning opportunities through spacecraft-related design teams and research projects on campus. It is our hope that through additional cycles of feedback and adjustment we will be able to continually improve these courses to best serve our students at all levels of the aerospace engineering undergraduate program.

Appendix A: Surveys

Consent document provided with sophomore surveys

Project Title: Evaluating the Impact of an Expanded Sophomore Design Curriculum for Aerospace Engineering Students

Certificate of Informed Consent

Overview and Procedures. This study evaluates the impact of adding AE 2790: Introduction to Spacecraft Design as a required course in the undergraduate aerospace curriculum. You will be asked to fill out a survey answering questions about your experience as an aerospace engineering undergraduate both before and after completing the sophomore-level design course(s) in which you are currently enrolled and before and after completing your senior-level design course. The expected time commitment for each survey is less than 15 minutes.

Risk and Benefits. This study involves no more risk to your physical or psychological health beyond those encountered in the normal course of everyday life. The potential benefit of this study is curriculum improvement for aerospace engineering undergraduates. No other risks or benefits are anticipated.

Confidentiality. Any information obtained in this study will be kept strictly confidential and used solely for research purposes. You may choose not to include your name on the survey. However, if you do choose to include your name, identifying information will be kept separate from survey responses so that your responses remain anonymous for analysis and publication. After you have exited the aerospace engineering undergraduate program, any link between your identifying information and your responses will be deleted permanently.

Compensation. No compensation is provided for participating in this survey.

Your Rights. Your decision to participate in this survey is completely voluntary. You can withdraw from the study at any time without penalty or loss of benefits. You do not have to answer any questions you do not want to, including providing your name at the top of the survey.

Contact Information. If you have any questions about this research project, please contact Dr. Jill Schmidt at schmidtjb@mst.edu. For additional information regarding human participation in research, please contact Dr. Kathryn Northcut, Director of the Missouri S&T IRB Office, at (573) 341-6498 or IRB@mst.edu.

You must be 18 years of age or older to participate in this research study.

Please sign below to indicate that you consent to participate in this research study:

Signature of participant

Date

Signature of experimenter obtaining consent

Date

Please let the experimenter know if you would like a copy of this form for your records.

Appendix A: Surveys

Spring Semester Survey – Sophomores in both 2780 and 2790

Administered at beginning of semester

Please indicate the degree to which you agree or disagree with the following statements:

5. I feel that my prior coursework has adequately prepared me for AE 2780.
 - a. Strongly Agree
 - b. Agree
 - c. Neutral
 - d. Disagree
 - e. Strongly Disagree

6. I feel that my prior coursework has adequately prepared me for AE 2790.
 - a. Strongly Agree
 - b. Agree
 - c. Neutral
 - d. Disagree
 - e. Strongly Disagree

7. I plan to apply for co-op and/or internship opportunities during my undergraduate career.
 - a. Strongly Agree
 - b. Agree
 - c. Neutral
 - d. Disagree
 - e. Strongly Disagree

Appendix A: Surveys

Spring Semester Survey – Sophomores in both 2780 and 2790

Administered at end of semester

Please indicate the degree to which you agree or disagree with the following statements:

4. I feel that my prior coursework adequately prepared me for AE 2780.
 - a. Strongly Agree
 - b. Agree
 - c. Neutral
 - d. Disagree
 - e. Strongly Disagree

5. I feel that my prior coursework adequately prepared me for AE 2790.
 - a. Strongly Agree
 - b. Agree
 - c. Neutral
 - d. Disagree
 - e. Strongly Disagree

6. I plan to apply for co-op and/or internship opportunities during my undergraduate career.
 - a. Strongly Agree
 - b. Agree
 - c. Neutral
 - d. Disagree
 - e. Strongly Disagree

Appendix A: Surveys

Spring Semester Survey – Sophomores in only 2780, Introduction to Aircraft Design

Administered at beginning of semester

Name: _____

1. Have you taken AE 2790 (formerly AE 2001) Introduction to Spacecraft Design in a previous semester?
 - a. Yes
 - b. No

2. Please list any design teams or research experience you have been involved with during your time at Missouri S&T prior to the beginning of this semester.

3. Which course do you intend to enroll in for senior design?
 - a. Undecided
 - b. AE 4780 – Aircraft
 - c. AE 4790 – Spacecraft
 - d. Both AE 4780 and AE 4790, (not typical, generally results in an extra year to graduation)

4. If offered, would you have taken AE2780: Introduction to Aerospace Design during the Fall semester instead of Spring? (Note: AE 2861: Aerospace Vehicle Performance is a prerequisite for AE 2780 and the two courses can't be taken concurrently).
 - a. Yes
 - b. No

5. I intend to seek employment opportunities or pursue a graduate degree related to (circle all that apply)
 - a. Undecided
 - b. Aircraft
 - c. Spacecraft
 - d. Both, but prefer aircraft
 - e. Both, but prefer spacecraft
 - f. Other applications aside from aircraft/spacecraft

Appendix A: Surveys

Spring Semester Survey – Sophomores in only 2780, Introduction to Aircraft Design

Administered at beginning of semester

Please indicate the degree to which you agree or disagree with the following statements:

6. I feel that my prior coursework has adequately prepared me for AE 2780.
 - a. Strongly Agree
 - b. Agree
 - c. Neutral
 - d. Disagree
 - e. Strongly Disagree

7. I plan to apply for co-op and/or internship opportunities during my undergraduate career.
 - a. Strongly Agree
 - b. Agree
 - c. Neutral
 - d. Disagree
 - e. Strongly Disagree

Appendix A: Surveys

Spring Semester Survey – Sophomores in only 2780, Introduction to Aircraft Design
Administered at end of semester

Please indicate the degree to which you agree or disagree with the following statements:

5. I feel that my prior coursework adequately prepared me for AE 2780.
 - a. Strongly Agree
 - b. Agree
 - c. Neutral
 - d. Disagree
 - e. Strongly Disagree

6. I plan to apply for co-op and/or internship opportunities during my undergraduate career.
 - a. Strongly Agree
 - b. Agree
 - c. Neutral
 - d. Disagree
 - e. Strongly Disagree

Appendix A: Surveys

Fall Semester Survey – Seniors in 4780, Senior Design – Aircraft

6. My sophomore level design experience (AE 2780 and/or AE 2001/2790) influenced my choice of technical elective(s)
 - a. Strongly Agree
 - b. Agree
 - c. Neutral
 - d. Disagree
 - e. Strongly Disagree

7. My sophomore level design experience (AE 2780 and/or AE 2001/2790) influenced my plans for employment or graduate school after graduation
 - a. Strongly Agree
 - b. Agree
 - c. Neutral
 - d. Disagree
 - e. Strongly Disagree

8. I feel that my prior coursework adequately prepared me for AE 4780/4781, Senior Design – Aircraft
 - a. Strongly Agree
 - b. Agree
 - c. Neutral
 - d. Disagree
 - e. Strongly Disagree

9. I feel that my coursework has adequately prepared me for employment opportunities related to aircraft design
 - a. Strongly Agree
 - b. Agree
 - c. Neutral
 - d. Disagree
 - e. Strongly Disagree

10. I intend to seek employment opportunities or pursue a graduate degree related to (circle all that apply)
 - a. Aircraft
 - b. Spacecraft
 - c. Both, but prefer aircraft
 - d. Both, but prefer spacecraft
 - e. Other applications aside from aircraft/spacecraft
 - f. Undecided

Appendix A: Surveys

Spring Semester Survey – Seniors in 4781, Senior Design – Aircraft

6. My senior design experience influenced my choice of technical elective(s) for Spring 2019.
 - a. Strongly Agree
 - b. Agree
 - c. Neutral
 - d. Disagree
 - e. Strongly Disagree

7. My senior design experience influenced my plans for employment or graduate school after graduation.
 - a. Strongly Agree
 - b. Agree
 - c. Neutral
 - d. Disagree
 - e. Strongly Disagree

8. I feel that my prior coursework adequately prepared me for AE 4780/4781, Senior Design – Aircraft
 - a. Strongly Agree
 - b. Agree
 - c. Neutral
 - d. Disagree
 - e. Strongly Disagree

9. I feel that my coursework has adequately prepared me for employment opportunities related to aircraft design
 - a. Strongly Agree
 - b. Agree
 - c. Neutral
 - d. Disagree
 - e. Strongly Disagree

10. I intend to seek employment opportunities or pursue a graduate degree related to (circle all that apply)
 - a. Aircraft
 - b. Spacecraft
 - c. Both, but prefer aircraft
 - d. Both, but prefer spacecraft
 - e. Other applications aside from aircraft/spacecraft
 - f. Undecided

Appendix A: Surveys

Fall Semester Survey – Seniors in 4790, Senior Design – Spacecraft

6. My sophomore level design experience (AE 2780 and/or AE 2001/2790) influenced my choice of technical electives
 - a. Strongly Agree
 - b. Agree
 - c. Neutral
 - d. Disagree
 - e. Strongly Disagree

7. My sophomore level design experience (AE 2780 and/or AE 2001/2790) influenced my plans for employment or graduate school after graduation
 - a. Strongly Agree
 - b. Agree
 - c. Neutral
 - d. Disagree
 - e. Strongly Disagree

8. I feel that my prior coursework has adequately prepared me for AE 4790/4791, Senior Design – Spacecraft
 - a. Strongly Agree
 - b. Agree
 - c. Neutral
 - d. Disagree
 - e. Strongly Disagree

9. I feel that my prior coursework has adequately prepared me for employment opportunities related to spacecraft design
 - a. Strongly Agree
 - b. Agree
 - c. Neutral
 - d. Disagree
 - e. Strongly Disagree

10. I intend to seek employment opportunities or pursue a graduate degree related to (circle all that apply)
 - a. Aircraft
 - b. Spacecraft
 - c. Both, but prefer aircraft
 - d. Both, but prefer spacecraft
 - e. Other applications aside from aircraft/spacecraft
 - f. Undecided

Appendix A: Surveys

Spring Semester Survey – Seniors in 4791, Senior Design – Spacecraft

6. My senior design experience influenced my choice of technical elective(s) for Spring 2019.
 - a. Strongly Agree
 - b. Agree
 - c. Neutral
 - d. Disagree
 - e. Strongly Disagree

7. My senior design experience influenced my plans for employment or graduate school after graduation.
 - a. Strongly Agree
 - b. Agree
 - c. Neutral
 - d. Disagree
 - e. Strongly Disagree

8. I feel that my prior coursework adequately prepared me for AE 4790/4791, Senior Design – Spacecraft
 - a. Strongly Agree
 - b. Agree
 - c. Neutral
 - d. Disagree
 - e. Strongly Disagree

9. I feel that my coursework has adequately prepared me for employment opportunities related to spacecraft design
 - a. Strongly Agree
 - b. Agree
 - c. Neutral
 - d. Disagree
 - e. Strongly Disagree

10. I intend to seek employment opportunities or pursue a graduate degree related to (circle all that apply)
 - a. Aircraft
 - b. Spacecraft
 - c. Both, but prefer aircraft
 - d. Both, but prefer spacecraft
 - e. Other applications aside from aircraft/spacecraft
 - f. Undecided