

# Student Perspectives of Aerospace Engineering Macroethics Issues and Education

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**Abstract**—This work-in-progress research paper investigates undergraduate aerospace engineering students’ perceptions of macroethics issues and education. *Macroethics* refers to the real-world ethical implications of engineering technology and the collective social responsibility of the engineering profession. Over the past two years, our research team, consisting of undergraduate students, engineering education researchers, and aerospace teaching faculty, have developed and implemented a one-day introductory macroethics lesson in a required sophomore aerospace engineering course at the University of Colorado Boulder, a large, public, research-intensive university in the Western U.S. One of our motivations for offering this macroethics lesson is our hypothesis that students are aware of macroethical issues in aerospace engineering but feel that their undergraduate education ignores these issues. This paper is a first attempt to gather data to investigate that hypothesis through an anonymous survey given to undergraduate aerospace engineering students. In this paper, we present initial analyses of our quantitative survey data as a basis for discussion with the engineering education research community. These results, along with future analyses and survey refinements, will inform future iterations of the macroethics lesson and motivate the need for the integration of macroethics across the aerospace curriculum.

**Keywords**—aerospace engineering, undergraduate, ethics, survey

## I. INTRODUCTION

The field of aerospace engineering has a large impact on society, both positively and negatively. Aviation makes the world a smaller place, but aircraft emissions also contribute to climate change. Satellite internet megaconstellations provide internet access to places that were previously unconnected, but also contribute to light pollution that negatively impacts astronomy. And, many career pathways in the aerospace industry relate to military and weapon technology design, development, operations or maintenance. Absent from the undergraduate aerospace curriculum at the University of Colorado (CU) Boulder was any acknowledgement of these realities in the formal course content. There was little-to-no focus on *macroethics*, “the collective social responsibility of the [engineering] profession and societal decisions about technology” [1, p. 373]. Addressing aerospace macroethics gives the context necessary to understand the role the aerospace

industry plays within society. Without this context, students are left ill-prepared to address challenging questions and issues they will inevitably encounter in the real-world. The importance of macroethics is echoed by its inclusion as a core part of the ABET student outcomes that all undergraduate engineering programs seeking accreditation must address [2]. Student Outcome 4 states that engineering graduates must demonstrate “an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts” [2, Para. 5]. This student outcome explicitly focuses on macroethics, yet there has historically been a lack of macroethics education in undergraduate engineering programs [1], [3], [4].

This lack of macroethics education manifested itself at CU Boulder as several hostile and unproductive conversations in one of the aerospace engineering student group chat forums. This, along with the social justice movements in the summer of 2020, motivated a group of undergraduate aerospace students (including the first and second authors of this paper) to advocate for the inclusion of macroethics and diversity, equity, and inclusion topics in the aerospace curriculum. With the support of several faculty members (including the fourth author), we implemented a macroethics lesson in a required sophomore aerospace class in the spring of 2021. Due to students’ overwhelmingly positive response to the lesson [5], we implemented a second iteration of the lesson again in the spring of 2022.

One of our motivations for offering this macroethics lesson is our hypothesis that students are aware of macroethical issues in aerospace engineering but feel that their undergraduate education ignores these issues (as we believe the curriculum does). This work-in-progress paper is a first attempt to gather data to investigate that hypothesis. Specifically, we designed an anonymous survey to address two research questions:

1. *What is students’ perception and awareness of macroethical issues in aerospace engineering?*
2. *Do students feel that their education is preparing them to address these macroethical issues?*

Addressing these research questions helps us to understand what students already know about macroethical issues in aerospace engineering and what they still need to learn. This is important for developing future macroethics lessons that meet students' needs while still challenging them. Furthermore, if our hypothesis is upheld in the data, we have one more important piece of evidence for broadly adding macroethics to the aerospace curricula.

In this study, we begin with a brief description of the macroethics lesson. Then, we describe our survey and our design decisions and present initial survey results from aerospace students at a large, public, research-intensive university in the Midwestern United States. We conclude by discussing our future work on this survey.

## II. STUDY CONTEXT

The macroethics lesson took place during one 110-minute lab section of a sophomore-level aerospace vehicle design course. The goal of this lesson was to "...give students a space to analyze how their own ethical philosophies and personal values would influence a future career in the aerospace industry" [5, p. 2] For a much more thorough description of the lesson's design and content, please refer to [5]. Before the lesson, students completed a survey, which is described in the next section. The lesson, delivered remotely by the fourth author, covered the motivation for including this content in the course, ethical frameworks, the concept of positionality, identifying personal values via the Rokeach Value Survey [6], and an overview of the concept of stakeholders.

Next, students broke into three groups based on the macroethical issue they wished to discuss: the Military-Industrial Complex (MIC), Is Space a Global Commons?, and Space Settlement and Resource Utilization. After reading a two-page issue brief, students engaged in a Socratic seminar discussion on their chosen topic. These discussions were moderated by one of the students who co-wrote the issue briefs. A faculty member was also present in each discussion.

There were two major changes made to the macroethics lesson between 2021 and 2022. First, in 2021 the lesson occurred over Zoom due to the COVID-19 pandemic, but in 2022 the lesson occurred in person. In 2021, Miro collaborative online whiteboards were used to collect students' thoughts and to drive discussions [7]. In 2022, Miro boards were not used, as we believed that holding class in person was sufficient to generate engagement.

The second difference was that the 2021 issue brief on orbital debris was expanded in scope and renamed "Is Space a Global Commons?". This was done both because of the lower turnout for this topic in 2020 and because the topic of orbital debris only becomes more nuanced when considering policy solutions instead of the problem itself. To address this nuance, we expanded the topic to include the regulation of the space environment in general. The updated issue brief covered how modern structures of governance developed to set the stage for the current state of outer space regulation [8], an explanation for the term "global commons" [9], the United Nations Outer Space Treaty [10], Kessler Syndrome, and Executive Order 13914 [11] and NASA's Artemis Accords [12] as examples of recent

developments within the U.S. to address the regulation of outer space.

The other two issue briefs are described in detail in [5]. The MIC issue brief discussed the relationship between the military and the aerospace industry. It included information about the Department of Defense research and development budget, the increasing militarization of space, and the creation of the U.S. Space Force. The Space Settlement and Resource Utilization issue brief discussed the impacts of Martian settlements, the resources needed to maintain life on celestial bodies like the Moon and Mars, and the possibility of life on planets that are being considered for settlement.

## III. SURVEY CONTENT

We began to address our research questions through an anonymous survey administered online prior to the macroethics lesson. The survey was designed to capture students' perspectives on macroethical issues in aerospace engineering.

The survey, which is both quantitative and qualitative, contains Likert scale items related to the two research questions. Some items were adapted from existing research on engineering ethics [13], [14], and others were written by the authors. Other survey items query participants' beliefs related to diversity, equity, and inclusion in aerospace engineering and their knowledge and beliefs about Wernher von Braun, a leader of rocket technology for Nazi Germany and the United States. An open-ended response section probes respondents' beliefs pertaining to both specific macroethical issues in aerospace engineering as well as macroethics in aerospace engineering in general. Additionally, the survey asks respondents to report demographic information to investigate if there are disproportionate responses from minoritized students. This paper will report primarily on responses to items related to the two specified research questions, and future work will analyze students' responses to the rest of the survey items."

The survey had 176 respondents at the University of Colorado Boulder. The results are not reported in this paper, as IRB approval was not received prior to data collection. However, these pilot results were utilized by the authors to reflect upon the content of the survey. Survey items were then edited for improved clarity and alignment with research questions. The refined survey, along with data types of each item and any alterations made from the pilot version of the survey, can be found at <https://shuttlelab.engin.umich.edu/macroethics/>.

## IV. INITIAL RESULTS FROM SECOND UNIVERSITY

With IRB approval, the refined survey was sent out to all undergraduate students majoring in aerospace engineering at a large, public, research-intensive university in the Midwestern United States. There is currently no macroethical content included within this university's undergraduate aerospace curriculum. We received 44 responses to the survey, the results of which are analyzed in the following section. The majority of respondents were split between sophomores (29.5%), juniors (25%), and seniors (29.5%). Most respondents also self-identified as white (70%), male (80%), and straight (66%). However, not all students who completed the survey provided demographic information.

In this section, we present initial results from our survey. For each survey question, students who strongly agreed or agreed with the statement were grouped together, and students who strongly disagreed or disagreed were grouped together. The remaining students, who neither agreed nor disagreed with the statement, were kept separate and are referred to as “neutral” responses.

#### A. Research Question 1

Table I displays the results for the five Likert scale survey questions addressing RQ1, *What is students’ perception and awareness of macroethical issues in aerospace engineering?*. In the rightmost column, we assess whether students’ answers generally show an awareness of macroethics. This was assessed by comparing the percent of students who disagreed and agreed with the statement. Because some of the questions were reverse-coded, it is not always immediately clear which response indicates this awareness. So, we have highlighted the response that indicates an awareness of macroethics in gray. Taking the first question as an example, students with an awareness of macroethics should disagree with this statement. As more students agreed with this statement (52%) than disagreed (39%), we consider students’ responses to this question to *not* show an awareness of macroethics.

We find students’ responses to a number of these questions encouraging. Students overwhelmingly recognize that ethical issues pertain to new aerospace technology. Over half of the students who responded to the survey also see aerospace companies engage in unethical practices. We asked students to describe these unethical practices, and examples include “valu[ing] profits and faster timelines over customer safety,” “violations of consumer’s privacy,” “quality control issues,” “anti-union practices,” and government lobbying. However, the largest answer given was engagement in the military-industrial complex. There are also results that suggest students aren’t aware of macroethics. A majority of respondents said that social and political issues are tangential to engineers’ work and answered the fourth question with a social determinist perspective [16], saying that technology can’t be good or bad in itself.

#### B. Research Question 2

Table II displays the results for the five Likert scale survey questions addressing RQ2, *Do students feel that their education is preparing them to address these macroethical issues?* In the rightmost column, we assess whether students’ answers generally indicate that more macroethics education is needed. In the same manner as Table I, we made this assessment by comparing the percent of students who disagreed and agreed with the statement. We have also highlighted in gray the response that indicates a need for more macroethics. We frame the result this way because we, as authors, believe that aerospace engineering education needs more macroethics.

These results show that students agree with the need for more macroethics education in several ways. First, a majority of respondents say that there has not been substantial emphasis on this topic in their education, and that they would like more. Furthermore, most respondents say that they have not had the opportunity to initiate discussions about this topic in their classes. On the contrary, other results indicate that students have

not seen their professors avoid discussions about macroethical issues, and that professors have expressed concerns about macroethical issues. This is encouraging, but professors expressing concern for macroethical issues in class does not necessarily mean that these were impactful learning experiences for students. The majority of respondents also report that they feel prepared to engage in respectful and challenging dialogue with their peers and to consider macroethical issues in the aerospace industry today. However, *feeling* prepared for these challenging activities is not necessarily the same as engaging in macroethics discussions and considering these issues when choosing a career. Future research will investigate these questions more to further explain these mixed results of RQ2.

### V. FUTURE WORK

We will continue to analyze and iterate upon the survey itself. Our eventual goal is to develop a validated mixed-methods survey that can be sent out nationwide to assess aerospace students’ perceptions of macroethical issues and education. Such a survey will allow us to make more robust conclusions. We will begin by further analyzing the data we have already collected from both universities. Future work will also include factor analyses of survey results. Because we collected demographic information from respondents, we will also analyze whether minoritized students (those who are non-white, non-male, and/or non-heterosexual) respond differently than other students.

We will also qualitatively analyze the open-ended survey responses, which ask general questions like, “What does the phrase “Diversity in aerospace engineering” mean to you?” and questions about specific macroethical issues in aerospace engineering like, “How do you feel about the fact that so much of the aerospace industry is involved in national defense?” The last question in particular appears to show a wide range of interesting responses, as is demonstrated by these varied responses:

“Completely fine. That’s where I want to work and have no issue with it. That’s where the money is, where else would it be coming from?”

“I hate it and feel like it’s just a pipeline for so many smart people to just get shoved into the military-industrial complex when there are so many other more beneficial areas of research. [...] but I feel like if I were offered a position at these companies I would still accept because I feel like I have no other option.”

Further analyzing the remainder of the survey data will inform both our macroethics lessons and future survey questions. Finally, we will further develop the survey by talking with experts in aerospace engineering and macroethics and by interviewing students to learn more depth about their perceptions and awareness of macroethics. This data will suggest ways to remove, refine, and add survey questions to better capture students’ knowledge. We will also follow survey-creating best practices, such as having demographic questions at the end to minimize stereotype threat [17]. With the revised survey, we will have pilot subjects complete think-aloud protocols to tell us how they interpret the questions.

TABLE I. SURVEY RESULTS RELATED TO RESEARCH QUESTION 1.

Question	% Disagree	% Neutral	% Agree	Are students aware of macroethics?
Aerospace engineering is a “technical” space where “social” or “political” issues such as inequality are tangential to engineers’ work.	39	9	52	No
It is easy to be an ethical engineer in the aerospace industry.	48	32	20	Yes
Ethical issues do not pertain to new aerospace technologies or systems.	91	4.5	4.5	Yes
Technology can’t be good or bad in itself. What matters is how people choose to use the technology.	41	7	52	No
I know of aerospace companies that I wouldn't consider working for because their practices are unethical.	27	21	53	Yes

TABLE II. SURVEY RESULTS RELATED TO RESEARCH QUESTION 2.

Question	% Disagree	% Neutral	% Agree	Do we need more macroethics education?
In my engineering coursework thus far there has been a substantial emphasis on macroethics in aerospace engineering.	52	11.5	36.5	Yes
As a whole, my professors have avoided discussions of macroethical issues.	50	18	32	No
In my classes, I have often had the opportunity to initiate discussions regarding macroethical issues.	50	32	18	Yes
My professors have rarely expressed personal concern over macroethical issues in aerospace engineering.	39	25	36	No
I wish there was more emphasis on macroethics in aerospace engineering in my engineering coursework.	29.5	16	54.5	Yes
The ethical curriculum I have received so far has prepared me to engage in respectful and challenging dialogue with my peers.	32	23	45	No
I feel prepared to consider macroethical issues in the aerospace industry today.	25	14	61	No

## VI. CONCLUSIONS

This work represents a first step toward understanding students’ perceptions of aerospace engineering macroethics issues and education. Because this is a descriptive analysis of an unvalidated survey, we refrain from making generalizable conclusions about what this data says and caution the reader against doing so themselves. However, taken together, these results begin to construct an understanding of aerospace engineering students’ current perceptions of macroethics, which is needed to begin to develop effective macroethics curricula. There are responses to every question in Table I that indicate students are already aware of macroethical issues in aerospace engineering. For example, most survey respondents understand that ethical issues pertain to new aerospace technologies or systems. The survey also indicates that students are considering how their personal beliefs and macroethics intersect with their future career, as over half of respondents know of aerospace companies they wouldn't consider working for because their practices are unethical. And, those who are not aware of macroethical issues represent a population who can be

reached. Furthermore, there are responses to every question in Table II that indicate there is a need for more macroethics education.

**Leaving macroethics education out of the curriculum, as is typical in aerospace engineering programs, leaves students ill-prepared to recognize and address challenging ethical questions they will encounter in their future careers. There is a pressing need to put aerospace engineering in its social context and discuss about the collective responsibility of the field.** We are addressing this need by creating future macroethics lessons that inform students about macroethical issues in aerospace engineering and allow them to develop their critical thinking skills. We are also addressing this need by iterating upon our survey to help ensure that the lessons build from students’ current understanding of these issues. With this knowledge, they will be able to make important decisions about their future career in aerospace engineering and to use their engineering knowledge to intentionally and collaboratively build a more just and equitable world.

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