Developing and Implementing an Aerospace Macroethics Lesson in a Required Sophomore Course.

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***Abstract*—This innovative practice full paper details the creation and implementation of a macroethics lesson into a required sophomore-level aerospace engineering course at a large research university. The primary, novel learning objective for this macroethics lesson is for students to analyze how their own ethical philosophy and personal values influence their perspective on an ethical issue in aerospace engineering.**

This paper begins with a review of the literature used to guide the development of this macroethics lesson. Next, the outline and content of the lesson is presented which consisted of two distinct activities. The first was an introductory presentation on ethics and identifying personal values. This was followed by students choosing an "issue brief" (written by the authors of this paper) on a current macroethical issue in aerospace engineering. The brief topics were the military-industrial complex, space sustainability and orbital debris, and space settlement and resource utilization. After reading their selected brief, students engaged in a structured discussion on the issue in which they identified and ranked stakeholders, and reflected on how their own values were reflected in their ranking of stakeholders. This paper concludes with a discussion of the impact and effectiveness of the lesson with reflections from the authors, and presents quantitative and qualitative survey data from the sophomore students who completed the macroethics lesson.

***Index Terms*—Ethics, Social Responsibility, Sophomore, Aerospace Engineering**

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I. Motivation

Aerospace engineering is a highly white male dominated profession with 81% of the industry being male and 79% identifying as white [1]. The Ann H.J. Smead Department of Aerospace Engineering Sciences at the University of Colorado, Boulder, is no exception with 82% of graduates between 2010 and 2020 being male and 75% identifying as white [2]. It was this lack of diversity that led us, a group of upperclass engineering undergraduates (the first six authors of this paper and some of our peers), to discuss how to work on changing the culture of the department to lead to a more welcoming environment. We were further motivated by the social justice movements of the summer of 2020 and incidents where some of our peers had hostile and unproductive conversations in our cohort group chat around these challenging issues. In response, we sought ways in which diversity, equity, and inclusion could be cemented into the aerospace curriculum. In our engineering education and personal lives we find ourselves consistently faced with challenging questions and issues pertaining to the real-world ethical implications of aerospace engineering, known as *macroethics* [12]. However, these macroethical topics were almost completely absent from the required courses taught throughout our undergraduate curriculum. Therefore, we felt neither ourselves nor our peers had the tools necessary to think critically about these ethical issues and to productively discuss the issues with each other.

The importance of macroethics education is not just something we have identified–it is a core part of the ABET student outcomes that all undergraduate engineering programs must achieve. 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" [20]. This student outcome explicitly focuses on macroethics, yet there has historically been a lack of macroethics education in undergraduate engineering programs [12], [21], [22]. And, research has shown that students' engagement with public welfare concerns decreases over the course of their undergraduate education [23], which may be due in part to seeing engineering course content as technical, rather than social [24]. Researchers and instructors have addressed these concerns through various macroethics activities and pedagogies such as in-class discussions [14], project-based learning with a social justice focus [25], role-playing activities [6], [15], [26], stakeholder value mapping [17], and case studies [8], [16], [27], [28].

This paper discusses the collaborative efforts of our team–consisting of undergraduate engineering students and aerospace instructors–to build upon previous work and develop a macroethics lesson for undergraduates within a required sophomore-level aerospace vehicle design course. The purpose of the 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. The implementation of this lesson along with the results are outlined in the following paper.

II. Background

Formally, macroethics is defined as "the collective social responsibility of the [engineering] profession and to societal decisions about technology" [12, p. 373]. Informed by existing literature on engineering macroethics lessons, the aerospace instructors developed six learning objectives for our lesson: 1) Describe basic differences between ethical lenses, 2) Deduce the most-important values they hold, 3) Identify the stakeholders for a macroethical issues in aerospace engineering, 4) Analyze the impact of an engineered system of the various stakeholders, 5) Determine your own ranking of the importance of the various stakeholders, and 6) Analyze how your positionality influences your perspective on the issue. These learning objects all drew from different literature, as there was no single macroethics lesson that fit our goals. In this section we discuss this prior work that informed each learning objective and the overall structure of the lesson.

A. Learning Objective 1

Ethical lenses, or ethical frameworks, describe different standards of right and wrong that dictate what a person should do when interacting with others and making decisions. Different people may hold to different ethical lenses, leading them to act differently in the same situation. Wareham, Elefsiniotis, & Elms [6] discuss creating a civil engineering "structured controversy" in which students role-play different people involved in a mock public meeting about a proposed development that impacts the local environment. The four roles each hold to a different ethical lens. For example, one student role-plays as a developer who believes that the ends justify the means (a telelogical lens), while another student role-plays a consulting engineering who believes in seeking the greatest good for the greatest number of people (a utilitarian lens). Wareham et al. taught students about these ethical lenses after the mock public meeting, and write that they "have repeatedly seen illumination reflected in the students' eyes as they begin to appreciate that their behaviour as a stakeholder related to different ethical frameworks. They also begin to appreciate that to build consensus amongst groups having disparate views (a key engineering skill), it is necessary to understand these frameworks as part of the dialogue process" [6, p. 657]. While the students in our macroethics lesson were not role-playing, the last part of this quote describes the importance of still teaching our students different ethical lenses. Dempsey, Stamets, & Eggleson [15] describe a similar macroethics workshop in which students role-played stakeholders who held to different ethical lenses.

B. Learning Objectives 3 & 4

Stakeholders are "the people, communities, businesses, and environments that experience the direct or indirect effects from the implementation of a decision" [7]. In the literature, many macroethics lessons focus on identifying stakeholders and/or discussing the impact of an engineered system on the stakeholders. Gupta [14] describes a macroethics lesson they developed for the first day or a first-year engineering design course. In this activity, developed over ten semesters, students brainstormed technological solutions to reduce the checkout line length at a grocery store. The class then chose one solution and discussed the impact of this solution on stakeholders while Gupta drew a stakeholder network on the board. Gupta describes how this activity allowed them to stress that "the work of engineers is situated in communities of people and has consequences, for better and for worse, for people not unlike them; that improvement in quality of life is not the inevitable outcome of technological development, at least not for everyone" [14, p. 7].

Andrade & Tomblin [17] discuss a similar activity in which students conducted stakeholder value mapping exercises to learn about the social dimensions of sustainability in an sophomore civil engineering course. The authors developed three sequential activities, and in the final activity students read articles about autonomous and electric vehicles and identified stakeholders. The students then discussed potential issues for each stakeholder, the relationship of each stakeholder to infrastructure, and what they thought the stakeholder's position would be on autonomous and electric vehicles. In assessing these activities, Andrade & Tomblin found that "when the focus was on a few stakeholders, students made more empathetic expressions" [17, p. 10]. Following this result, we asked students to identify a large group of stakeholders, but then we focused on the impact of the engineered system on a smaller group of stakeholders (approximately four).

C. Learning Objectives 2, 5, & 6

Lastly, students in our macroethics lesson were asked to reflect on their own values and positionality, which "is the notion that personal values, views, and location in time and space influence how one understands the world. [...] Consequently, knowledge is the product of a specific position that reflects particular places and spaces." [9]. Mejia, Chen, Chapman [11] describe an activity in which students reflected on their own personal values and the relationship between these values and their engineering identity. The authors used a "values card" activity in which students started with 83 cards listing different values. The students used a formalized grouping process to sort the cards down into their five most important values. While this activity focused on engineering identity and Discourse, rather than macroethics, it provided an example of how to help students identify their own values. Gupta, Elby, Turpen, Phillip [13] present research on how students take different perspectives during focus groups on socio-scientific issues. The authors find that students' "perspective-taking is entangled with students' epistemic and moral stances towards a situation" [13, p. 1]. They further define students' moral stance as "what claims they seem to be making, tacitly or explicitly, about what is morally acceptable or valued," which we see relating to a students' values and positionality [13, p. 4-5].

D. Overall Lesson Structure

The structure of the lesson was based on a modified version of the Engineering Professional Skills Assessment (EPSA). Schmeckpeper, Kranov, Beyerlein, McCormack, & Pedrow [16] describe how students are presented wtih an EPSA scenario and discuss stakeholders, impacts, unknowns, and possible solutions. The scenario presented to students is a 1-2 page document of facts about an ethical issue, such as the Fukushima nuclear power plant disaster and the future of nuclear power. Students read this document in class and then have a 30-40 minute breakout session in small groups of approximately seven students. Four of the students in the group actively participate in the discussion with each other, answering questions such as "Who are the major stakeholders and what are their perspectives?" and "What are the potential impacts of ways to address the problems raised in the scenario?" [16, p. 4]. The other three students do not participate in the discussion; rather, they use an EPSA rubric to evaluate the discussion on a number of ABET student outcomes. Typically the instructor will do two days of EPSA activities, giving each student an opportunity to act as a discussant and an evaluator. While our macroethics lesson did not use the EPSA rubric or ask students to evaluate their peers' discussion, we gave students a 1-2 page "issue brief" and based our discussion questions on the EPSA questions. To write the issue briefs we used a list of seven criteria for writing an effective EPSA scenario from Schmeckpeper, Kelley, Kranov, Beyerlein, & McCormack [8].

III. Lesson Overview

Our macroethics lesson took place during a 110-minute lab section situated between the first half of the course, which focuses on aircraft, and the second half, which focuses on spacecraft. There were three lab sections, and so the macroethics lesson was repeated three times. The lesson started with a 45 minute introductory presentation where students were introduced to ethical frameworks, identifying personal values via the Rokeach Value Survey [10] and an overview of the concept of stakeholders. Following the presentation, students could pick one of the three topics to think about and discuss in a smaller group for 45 minutes: the military-industrial complex (MIC), space sustainability and orbital debris, and space settlement and resource utilization. Each topic was held in its own Zoom breakout room and was facilitated by one of the course instructors and some of the student authors on this paper. The lesson ended by debriefing the three discussions to all students in the lab section, followed by a summary of the most important take-aways from the lesson. Additionally, students were surveyed before and at the end of the lesson. This served as a way to assess how students felt the lesson went and gave them an opportunity to provide any feedback or thoughts on the lesson.

A. Introductory Presentation

The introductory presentation began by asking students to complete the first survey question, in which they were asked to define ethics in aerospace engineering. The lesson then started by defining macroethics as, " ... [applying] to the collective, social responsibility of the [engineering] profession and to societal decisions about technology" and contrasting macroethics with microethics, which considers "individuals and internal relations of the engineering profession" [12]. The next slides gave the learning objectives, outline, and motivation for the lesson. The motivation included examples of recent news articles featuring aerospace-related issues and the items mentioned in the motivation section above. Next, ethical lenses, positionality, values, and stakeholders were addressed in slides written by one of the student authors of this paper. The goals of these slides were to give students the ability to reflect inwards on their own lives, experiences, circumstances and choices as well as outwards to the companies and things that they may dedicate their lives to.

The ethics slides featured three different ethical lenses: utilitarianism, contractarianism and virtue theory [5]. These three were chosen because they can easily be applied to situations where an individual's decisions affect others, making them very applicable to macroethics. The three lenses were then applied to the following theoretical situation to show how different ethical lenses may affect one's decisions: "A large LEO [low-Earth orbit] satellite has had its mission technology knocked out by a burst of radiation and is slowly leaking its remaining propellant, what do you do?" It was emphasized that none of the decisions based on the three lenses were wrong and that the point of the example was that someone's values affect what they think should be done. Following the satellite example, three organization's codes of ethics were cited to give examples of how companies or professional organizations use ethics to guide their decisions. The organizations cited were: the American Society of Civil Engineers (ASCE), the American Institute of Aeronautics and Astronautics (AIAA) and Lockheed Martin.

Following the ethics introduction, positionality was introduced and defined. Positionality was included to remind students that their peers may have different experiences and values than they do, thereby causing them to disagree. Given the student authors' experiences having unproductive conversations around these issues, an explicit reminder was given to not dismiss students who disagree with you. Rather, students were encouraged to consider how and why they might have come to the position they have.

Next, students were given ten minutes to complete the Rokeach Values Survey [10] on their own. In the Rokeach Values Survey, students are asked to rank a set of terminal values, describing a person's long-term goals, and a set of instrumental values, describing means to these terminal values. Students were also encouraged to ponder why they have their values and what could have influenced them. They were reminded that these are their values today, they have changed and will continue to change throughout their lives. Students were never asked to share their list of values; these were only for the students' use in the following discussion.

Then, two slides were presented on stakeholders. The class was asked to give examples of who they thought the stakeholders were in their university's decision to replace spring break with two separate days off. This yielded responses that covered many different types of stakeholders of varying size (individuals vs groups) and closeness to the university (directly vs indirectly impacted). This demonstrated how one's personal values influence who they see as stakeholders in decisions. To put stakeholders into an aerospace context, a slide with a hypothetical example was presented that discussed who Boeing may consider to be stakeholders when they build a new plane. Additionally, the FAA performing stakeholder engagement around SpaceX's Boca Chica launch facility was cited as an example of how some government agencies consider the public to be stakeholders in their work [4].

Before presenting the issue briefs and going into the various breakout rooms, a slide was presented that reminded students that these issues are real, current, and may not be easy to consider and discuss. We stressed that students should be uncomfortable with their own thoughts and that discomfort is a part of critical thinking. We also emphasized the importance of remaining respectful to one's peers, and the importance of positionality. The introductory presentation contained a few debrief slides shown after the breakout discussion time was over. These slides gave additional resources related to ethics and reiterated the learning objectives of the lesson. The debrief slides also asked the students to take the remaining survey questions, which asked them to define ethics in aerospace engineering again, to respond to Likert scale questions about their opinion on the lesson and what they learned, and to provide open-ended feedback on the lesson.

Throughout the lesson, students were encouraged to participate, but they were told they were not graded, assessed, or judged on their participation. They did, however, receive bonus points for just attending the lesson, even if they did not participate. We chose to not push students into a discussion to ensure that no students felt isolated, singled out, or disrespected during the lesson. This was our primary concern, particularly because this was the first macroethics lesson attempted by any of the authors. This led to some instances where no students talked and the authors led the discussion, which was less than ideal. But, we admittedly lowered the potential ceiling of the lesson in order to raise the floor and ensure that no student had a bad experience.

B. Brief Methodology

The structure of the lesson and briefs were based on the Engineering Professional Skills Assessment (EPSA) framework [8]. An issue brief was written for each of the three topics by 1-3 student authors working in groups. The briefs followed EPSA scenario criteria which includes interdisciplinary scope, a relevant problem with diverse perspectives and stakeholders. The briefs included technical complexity, statistics, and a reference section so that the reader was provided more resources about the topic and could investigate the positionality of the sources. The briefs aimed to provide a non-biased presentation of a scenario or problem, use language that can be understood by engineering undergraduates, and take between 5-7 minutes to read. The goal was to provide a starting point for discussions where students were asked to identify primary and secondary stakeholders and their perspective, and identify unknowns in the problem.

C. Summary of Briefs

Below are summaries of the briefs given to students for starting the in class discussion. Specific attention was given to trying to make the briefs balanced in their presentation of the issues by including multiple viewpoints where appropriate. The authors of this paper reviewed, discussed, and edited the briefs before they were finalized. To view or download each issue brief, please see https://www.colorado.edu/faculty/johnson/macroethics.

1) Space Sustainability and Orbital Debris: This brief discussed orbital debris. It presented current statistics, consequences, geopolitical challenges and mitigation/remediation strategies. The reader was first provided with context and metrics. Orbital debris is currently managed though politics and relationships established by agencies like NASA and the European Space Agency (ESA). There also exist multinational groups such as the Interagency Space Debris Coordination Committee which publishes agreed-upon guidelines for best practices. According to ESA, as of January 8, 2021 there were 6,250 satellites in space, only 3,600 of which were still functioning. Debris orbits the Earth at approximately 17,500 miles per hour so even small debris pose a threat to missions. Orbital debris includes upper stages of launch vehicles, mission related objects, and solid rocket motor particles. It also includes fragmentation from in-orbit collisions; for example, the first accidental collision in 2009 between an active American Iridium communications satellite and a defunct Russian military satellite generated more than 2,300 trackable fragments. Collisions pose a global risk to stakeholders in public, civic and private sectors. Then the brief discussed consequences and findings from the NASA Office of Inspector General January 2021 audit about orbital debris. The ultimate consequence of an unstable orbital debris environment is Kessler Syndrome, where the density of objects is high enough to cause a runaway cascade of collisions that damage all space infrastructure and make low earth orbit completely inaccessible. The audit concluded that mitigation-only strategies and prevention would not be effective in stabilizing the rapidly-growing orbital debris environment.

Next, geopolitical and economic challenges were considered. There is a challenge to incentivize orbital debris clean up and fund debris removing projects as well as international collaboration between the United States, China, and Russia who are major contributors to orbital debris. Stakeholders are multinational and diverse because they include policy makers, research institutions, operators in space-faring nations, service-providing companies with a for-profit business model and the general public who consume and depend on satellite services. Finally, technology to remove debris was discussed, it is early in development for commercial and international agencies.

2) Space Settlement and Resource Utilization: This brief addressed the impacts of both space settlement and resource utilization, outlining the costs and benefits to topics such as settling on Mars, the resources needed to be cultivated and maintained to live on celestial bodies such as the Moon and Mars, and possibility of life we don't understand on planets that are being considered for settlement. Readers were first introduced to the history of settlement like that of Europeans to North American and how the destruction of Indigenous Peoples cultures allowed the United States to flourish. Settlement of future bodies was considered, with one point of view making the case to encourage settlement in a future Martian city by employing indentured servitude. Contrasting this view, the benefits of a Martian settlement were discussed, including saving the human species from an extinction event, as well as technological improvements that would improve life on Earth and could help feed Earth's population.

Next, resource utilization was considered, with benefits including providing resources to an Earth desperately in need. Issues with the current resource extraction policies were presented, as it was pointed out that corporations could exploit the system that has no oversight including no labor or taxation regulations. Then students were asked to consider microbial life with the following sentences, "As potential life may exist in forms we do not understand, it is important to consider whether other planets have rights to their own evolutionary track. By altering another microbiome, we are furthering the existence of humankind, but this may alter the existing evolutionary progress of other species we are unaware of." Finally, students were introduced to the International Council for Science's Committee for Space Research (COSPAR) Policy and Guidelines that are the current form of planetary protection policy that has arisen as a way to regulate stakeholders who hope to benefit from space settlement and protect Earth and other planetary systems' biospheres.

3) Military-Industrial Complex: This brief addressed the relationship between the military and the aerospace industry, the military-industrial complex (MIC). First, the origin of the term was presented to the reader, as the idea was popularized after President, and former World War II general, Dwight D. Eisenhower gave warning of its potentially detrimental effects in his 1961 farewell address. Then, the Department of Defense's (DoD) budget of $705.1 billion was discussed, outlining the amount of money allocated to aerospace related fields and how the money subsequently flows to private industry, academia, and government agencies. The increasing focus on militarizing space was discussed, touching on the creation of the U.S. Space Force and the goal of the military branch to "maintain, protect, and expand the U.S. fleet of advanced military satellites that form the backbone of U.S. global military operations" [18]. This branch will primarily focus on protection of U.S. space assets ranging from GPS, communication, and weather satellites. Next, the DoD investment in research and development was presented to the reader, with the current R&D budget for 2021 at $106.6 billion, with emphasis on hypersonics, autonomy, and artificial intelligence. The R&D funding reaches academia through research grants and awards to various university research groups. The presence of this relationship was highlighted by our university's recent research initiatives in hypersonics [19].

The brief then presented an overview of how DoD investments have resulted in many technologies that ultimately benefit the public, ranging from radio communications, microwaves, the internet, and GPS. The two main positions on this matter were discussed. First, the argument which supports having a "defense industrial base" in case the country enters wartime and must respond was introduced. It was mentioned that this argument emphasizes that the level of defense spending is necessary to progress public technology and protect the American population. The second position discussed that the MIC is an entity which prevents peace through unnecessary justification of continued defense funding and contracts, even without serious conflicts. Additionally, the brief discussed political lobbying and how defense companies have groups of lobbyists whose jobs are to influence legislation, regulation, or other government decisions, actions or policies on behalf of the company employing them.

The intention of the brief was to present facts about the state of the aerospace industry's funding and how closely tied the industry is to military spending. The hope is to ensure engineers going through the curriculum have a critical perspective on the industry they will be entering and better understand the ethical questions that lay in the field.

D. Issue Discussions

To begin each issue discussion, the students were given five minutes to read the issue brief about the topic and were encouraged to take note of information in the scenario that was new to them and information they thought was missing. Students were then given a link to a Miro discussion board which corresponded to the topic. Miro is an online visual collaboration platform which the students could access anonymously [3]. Once in Miro, students used the "sticky note" feature to anonymously add comments to each discussion panel. Students identified stakeholders and shared their comments about each stakeholder's perspective and impact. Facilitators encouraged students to think about people indirectly affected by the system in question. Next, four stakeholders were selected by the facilitator to be discussed in more depth. These four stakeholders sticky notes were dragged onto the next frame which featured an impact vs power matrix with a third imaginary axis representing importance. A poll was created in the Miro interface which gave each student ten "importance points" to divide between the four stakeholders. The more points a student assigned to a stakeholder, the more importance the stakeholders should have in the student's ideal world, not necessarily what currently exists. The poll results were discussed and students were encouraged to review the personal values that they posted at the beginning of class to see if they were reflected in the way they ranked importance of the stakeholders. Students were then asked to consider the impact of the system on stakeholders if an engineering system was implemented in a certain way. Students also considered the power of each stakeholder and how much power they currently have in the design and implementation of the system. The four stakeholders were then placed on the matrix according to the impact vs power discussions. This power vs impact matrix can be found along with the issue briefs at https://www.colorado.edu/faculty/johnson/macroethics. The final frame of the Miro board prompted students to think about alignment between company and personal values.

1) Discussion Moderation: In order to ensure the students engaged in productive and constructive conversations, there was one facilitator assigned to each room. Each facilitator was a student author of this paper who had done research and written the issue brief on the topic that was being discussed. Therefore, they were able to recenter the conversations if students got off track or became disrespectful in any manner. The facilitators walked the students through each Miro board and asked predetermined questions to spark conversation between the students. In addition to a facilitator, there was also a note-taker in each breakout room who kept track of attendance, patterns throughout the conversations, verbal aspects of the conversations that were not recorded on the Miro boards, comments in the Zoom chat feature, and questions that were asked by the facilitators that were not predetermined. Lastly, each breakout room also had one of the course instructors to help moderate and steer the conversations when needed. In particular, the military-industrial complex discussion was moderated by an instructor who is an US Air Force Veteran with over 20 years of service. As will be elaborated on in the Lesson Impact Section, his ethos established a sense of credibility and balance to this discussion.

E. In-class Survey

A survey was administered anonymously through Google Forms, and students had the option to skip any of the questions. As previously mentioned, before and after the lesson students were asked how they defined "ethics in aerospace engineering." After the lesson students were also given statements asked using the Likert scale of 1 (strongly disagree) to 5 (strongly agree) to informally gauge how they felt various parts of the lesson went. These questions can be seen in Table I.

IV. Assessment of In-class Discussions

Overall, we determined the discussion to be successful due to students' enthusiastic and respectful engagement with each brief. The military-industrial complex and space settlement and resource utilization discussions both had approximately equal participation with 40% of the students in each lab section. The remaining 20% of each lab section attended the space sustainability and orbital debris discussion. Additionally, Table I in the Appendix shows the majority of students responded positively to all post-lesson feedback questions.

A. Space Sustainability and Orbital Debris Discussion Assessment

The three space sustainability and orbital debris discussions had a consistent level of engagement through the use of Miro sticky notes, zoom chat and verbal input. Stakeholders listed across all sections included directly related entities like NASA and commercial space companies like SpaceX and their megaconstillations. Some indirect stakeholders listed by the students were astronauts' safety during extravehicular activities, weather forecasters, astronomers, the United Nations, and taxpayers and nations with developing space industries who could be affected by regulations and increased fees to put a satellite in orbit. The highest level of participation occurred during the discussion of the power and impact matrix.

B. Space Settlement and Resource Utilization Discussion Assessment

In the space settlement and resource utilization discussion, students in all three lab sections mentioned on the "what did you learn" Miro board that they were not aware of indentured servitude being considered to encourage settlement of Mars, and that there are currently no regulations in place for asteroid mining. All sections also identified that stakeholders were missing from this brief, including both powerful and non-powerful nations, and students questioned how discussions were taking place about who should have the power to write the laws and regulations. When listing stakeholders, all sections chose similar groups of people. On the chart of stakeholder impact vs power, private space companies, governments/NASA, microorganisms, and either future colonists or the working class were chosen by the moderator to most accurately represent the types of stakeholders most often listed. The discussion of stakeholders and where they should be placed on the impact vs power matrix was the most active part of the discussion. In all cases, the microorganisms and colonists were thought to have the least power, while governments and private space companies were voted to have the most power. Different ranges of impact were seen throughout the sections for microorganisms and settlers; two of the lab sections decided that microorganisms had a high impact, while the third lab section believed that they had only moderate impact. Colonists were, on average, thought to have moderate impact and power. Discussions broke out over whether governments or private space companies currently had more power, and whether either of them should have more or less power. It was common for a similar group of outspoken students to engage more in the conversation, and it was noted that it was mostly white males (based on the facilitator and note-taker's assessment) participating in the discussions.

C. *Military-Industrial Complex Assessment*

The military-industrial complex scenario had the most participants in each of the three sessions in comparison to the other two scenarios.

For the first part of the discussion, the students were asked to read the issue brief and note down any missing or new information. Some students commented that they were unaware of what international national security threats currently exist towards Americans and that this information would have been beneficial to the issue's overview. Other students touched on the fact that the current Secretary of Defense formerly sat on the board of Raytheon Technologies Co., emphasizing the revolving door between the Pentagon and multi-billion dollar defense contractors. New information noted ranged from the environmental impact of the defense industry to the actual size of the US defense budget discussed in the brief.

The discussion then led into asking the students to identify the stakeholders of the military-industrial complex and to consider the impact on each of those identified. Some stakeholders discussed were civilians in conflict regions, defense contractor employees and engineers, US taxpayers, military members, politicians, the climate, and universities getting Department of Defense research funding. The impact of the MIC on international aerospace engineering students was also discussed as the International Traffic in Arms Regulations (ITAR) restricts many international citizens from finding work in the US aerospace industry.

The discussion then led into asking the students to think about where these stakeholders would lie on the impact vs power matrix. Which of the stakeholders have the most say, or power, in the decision making process and who is left out? Who are the most impacted stakeholders, both in terms of monetary gain and personal safety or security? The students were also asked to think about how they would rank the importance of the stakeholders from their personal perspective.

The students were then asked what they would do if their company or group was involved in work that didn't align with personal values. This led to discussion ranging from quitting, striking, starting discussions with those in more powerful positions, switching groups, getting involved with policy, or personally engaging in changing the state of the industry. Some stated that it was not they're personal responsibility for altering the industry as it exists and that financial stability would be prioritized.

V. Impact and Effectiveness of Lesson

A. *Student Survey*

Of the 254 students enrolled in the course, 223 attended the macroethics lesson. Of these 223 students, 101 responded to the student survey. Table I shows the questions students were asked after the lesson. Students responded on a 5-point Likert scale from strongly agree to strongly disagree. Table I also shows what percent of students agreed or strongly agreed with the questions.

1) Written Survey Responses: When asked if they had any feedback about the lesson, the majority of students indicated a positive response to the macroethics lesson (see Table I bottom two rows). There were five to ten students who commented at the end of the issue breakout rooms, saying they greatly enjoyed participating in the ethics day. Ten to fifteen students wrote comments indicating they wished more of these days existed. In fact, one criticism from students was that the lesson was too brief, and more of these discussions were necessary throughout the aerospace curriculum. Five to ten students also mentioned that having the moderator of the military-industrial complex (MIC) discussion be the professor with many years of experience in the military provided very meaningful insight and perspective. While it is not possible to know how it would have gone without him, without his presence some students may have dismissed the scenario as being biased against the military. But, because this professor had the expertise and experience of being in the military, his involvement added the ethos necessary to make the MIC brief seem like both sides of the issue were actually being well represented.

Overall, there were only a handful of negative comments. One student suggested the discussion contained " faux compassion for indigenous and oppressed minorities in the complete scope of these future space mining operations." Another noted the MIC brief focused only on the MIC contribution to weapons and did not mention its contributions to "...communication, weather prediction, medicine, logistics, etc." It should be noted the brief did state the following: "There are argued benefits of the MIC, including the advancement of civilian technology, job creation, economic growth, and the defense industrial base...[and]..some military inventions with civilian applications include GPS, radio communications, microwaves, and the internet." One student claimed "conflict is what provides for our country" but this person acknowledged that "Maybe I am just a twisted capitalist...". Ten to fifteen students' feedback revolved around wanting a more open ended discussion form and that this discussion felt more like a guided lecture. There was also one student who felt that having the instructor with an Air Force background as a moderator biased the MIC discussion. While we are encouraged by the positive response to these macroethics discussions, we are also very appreciative of these comments that illuminate areas for continued improvement.

VI. Conclusion

Overall, the macroethics lesson was successful in starting a conversation about ethical lenses, positionality, and how personal values impact choice of career in the aerospace industry. These conversations gave students a chance to better understand their peers' perspectives and how they may make decisions in the future regarding their career or stances on various controversial topics in aerospace. Table I also shows the majority of students enjoyed the lesson and would like more of these lessons throughout the curriculum.

This lesson was originally motivated largely in part due to the social justice movements of the spring of 2020. However, some of the student authors of this paper feel the lesson strayed from this original topic and only addressed it indirectly through comments on positionality and one mention of the lack of diversity in the aerospace engineering program. Given the global pandemic during which this lesson was designed and implemented, we are hopeful that further iterations can include more of a direct focus on diversity, equity and inclusion (DEI). The group also recognizes starting somewhere is better than nowhere, and that it would be necessary to include experts on DEI in academia to appropriately address these issues.

While these discussions had to be held over Zoom due to COVID-19, this format turned out to be helpful in preserving the anonymity of the students when they made comments on the Miro boards. This allowed students to decide whether or not to be open with their peers about their viewpoints because they were still allowed to speak on Zoom or enter a comment throughout the chat feature, both of which are not anonymous. While the virtual aspect of this discussion allowed for anonymity, it also made it difficult for the facilitators to receive verbal participation from many students. When students were participating verbally via Zoom, it was often dominated by a small number of people in that breakout room.

In addition, there were multiple students who felt as though the lesson was not sufficient in covering macroethical topics in aerospace, which is highlighted in the Student Survey subsection above. This lesson was intended to introduce students to ethical lenses and conversations, rather than delve into controversial topics with peers they did not know well. Therefore, it was expected that they would not get as deep into conversations as some students were hoping to, and that these conversations would continue throughout the rest of their undergraduate years in this department.

A. Future Studies and Improvements

The lack of participation during the discussions led us to conclude that smaller groups may be more beneficial for future macroethics discussions. This may make students more comfortable with speaking in front of their peers, which could lead to more engaging discussions. In addition, the student feedback suggested providing questions at the end of the briefs themselves to give facilitators more ways in which to stimulate conversation. Providing some sort of icebreaker to the discussions–such as giving an ethical situation related to the brief and gathering opinions on what could be done–could increase and stimulate conversation.

Initially, there was concern among the student authors that the military-industrial complex (MIC) discussion would be tense and aggressive, which had been the case in the student authors' cohort group chat. It was pleasantly surprising that this was not the case, and that students engaged in thoughtful discussion on this topic without any outburst or alteration occurring. We believe that this was facilitated by writing an issue brief that showed multiple viewpoints on the MIC, and by having the instructor with an Air Force background moderate this discussion. We recommend that whenever future macroethics lessons address the military or the MIC, someone with experience and credibility as a member of the military be included in the process to provide balance and credibility to the discussion.

Lastly, with regards to the level of depth of the student conversations, we encourage administering ethics days during each year of the undergraduate aerospace curriculum. Ideally in the future, ethics and positionality will not be taught as a few discrete lessons, but will be intertwined throughout the aerospace curriculum reflecting the true nature of these issues as being inseparable from the engineering challenges themselves. While this is the first lesson touching on the surface of many of these issues, there is still more that students need to learn about macroethics. Due to the disruption from COVID-19, most of the students do not know one another quite well, that will hopefully not be the case in the future. Through more time spent with peers, students may gain a greater level of trust and respect for one another, as well as increased comfort in talking about difficult ethical topics. Therefore, these discussions have the potential to be deeper and more well-rounded if they are administered multiple times.

VII. Appendix

TABLE I
QUESTIONS ASKED AND PERCENT OF STUDENTS RESPONDING IN AGREEMENT

Question	% Respondents who Agree or Strongly Agree
I learned something about the specific issue I discussed in class.	77.2
I learned something about my own personal values.	60.3
I learned something about ethical lenses.	78.2
I learned something about positionality.	68.3
I learned something about stakeholders	78.2
I learned something about the impact of aerospace systems on society.	77.2
I saw ways in which my personal values were reflected in the way I assigned importance to stakeholders.	81.1
I feel more prepared to discuss aerospace ethical issues like with my peers in an informal setting (like on our class GroupChat).	70.2
I know what I would do if I worked for a company whose values differed from my own.	49.5
I enjoyed today's lesson.	80.1
I would like to have more lessons like this in other aerospace courses.	75.2

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