Engineering A Bridge Across Cultures: Insights to Support Dialogue with Engineering Professionals on Ethical and Social Design Considerations

Abstract: In April 2023, the National Aeronautics and Space Administration (NASA) hosted the Artemis and Ethics workshop at NASA headquarters, inviting 55 participants from a wide range of scholarly disciplines to participate in a dialogue on ethical considerations for Artemis and the Moon to Mars initiative. At this event, participants identified a set of challenges in engaging the ethical and social implications of these missions. This paper seeks to further explore those concepts from the workshop report and provide insights on how to discuss the design implications of engineering leadership decisions and to elicit meaningful engagement on these topics. This analysis can inform future research and educational approaches and help ethics and social science researchers to engage engineering and project leaders in constructive dialogue.

1. Introduction

The engineering education research community has developed a broad swathe of case studies, methodologies, and frameworks for thinking about how to teach engineers about the nature of their work[1]. The American Society for Engineering Education has a separate Engineering Ethics Division that has also tackled broader topics on how engineers should consider the ethical and societal implications of what they do. Our research paper here seeks to build bridges to some of that engineering education and ethics research by reflecting on recent efforts that have been performed from within a government agency, the National Aeronautics and Space Administration (NASA), to reflect on the implications on the work of engineers. This event was called the Artemis and Ethics workshop, and it focused on bringing in social science and humanities scholars into conversation with NASA engineers, scientists, and managers, to discuss the long term ethical and societal implications of NASA's human space exploration efforts from the Moon to Mars. Whereas some ASEE ethics division research focuses on the impact of educational discussions on students, ours involved practicing engineers as well as managers and policy analysts who shape the future of major engineering endeavors. While we will describe this case study in subsequent sections, we will point out some specific points of content in the report now, that may best serve as bridges for engaging in the engineering education literature.

This paper seeks to further explore the concepts described in the workshop report, particularly as they relate to collaboration with engineers and engineering leaders and the design implications of engineering leadership decisions. In this paper, we concentrate specifically on the content in

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[1] Johri, A. and Olds, B.M. eds., 2014. Cambridge handbook of engineering education research. Cambridge University Press.

Appendices E and F of the workshop report, which captures notes from brainstorming sessions and dialogues during the workshop. Our analysis focuses on supporting and sustaining engineering ethics dialogue and the challenges therein. While not a direct goal of the workshop, this analysis begins a bridge to support a longer-term dialogue with a broader community, centered around engineering leadership and ethics and practical application.

One finding from the workshop indicates that engineering leaders and social science and humanities scholars can benefit from dialogues like this one. Engineering leaders grapple with ethical quandaries at all stages of their career: depending on their level of authority and responsibility, they may be willing to engage differently with ethical concepts and the implications of ethical decision-making. Social scientists and humanities scholars can learn directly from the lived experience of engineers and project managers and better understand the rationale for their decisions when in direct conversation. The interest in engaging on these topics, and deeper study on the ways in which practicing engineers engage on these topics, may be a valuable point of study for future engineering education and ethics research.

2. Background on the NASA Artemis and Ethics Workshop

We will now provide background on the Artemis and Ethics workshop, which is the basis of deeper analysis in subsequent sections of the paper. In April 2023, NASA hosted the Artemis and Ethics workshop at NASA Headquarters in Washington, DC, inviting 55 participants from a wide range of scholarly disciplines to participate in a dialogue on ethical considerations for Artemis and the Moon to Mars initiative[2]. Taking place over two and a half days from April 12 to 14, the workshop, sponsored by NASA's Office of Technology, Policy, and Strategy (OTPS), sought insights on two study questions: 1) How should NASA consider the ethical, legal, and societal implications (ELSI) of the Artemis and Moon to Mars efforts?; and 2) What are the key ethical and societal implications that need consideration? Participants with backgrounds in law, social science, the humanities, public policy, science, and engineering were given an introduction to NASA's Artemis mission objectives and overall design and invited to present their research and engage in dialogue with NASA personnel with policy, project management, and engineering experience. During the workshop, the researchers and NASA personnel collaborated to address the study questions, and in doing so, identified ways to consider the ethical and social implications of these missions. NASA reported on the views expressed by participants at the event in a synthesis report, noting that views represented were those of participants and did not necessarily reflect the views of NASA. Key themes raised at the workshop included:

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[2] Z. Pirtle, K. McBrayer, and A. Beauchemin, "Artemis, Ethics, and Society: Synthesis from a Workshop," NASA Report ID: 20230012799, 21 September 2023. Available: https://www.nasa.gov/wp-content/uploads/2023/09/otps-artemis-ethics-and-society-report-final-9-21-02023-tagged.pdf

- Cross-cutting ethical questions such as how humanity benefits from space activities, the nature of lunar sustainability, and the values brought to space exploration
- There can be practical and cultural challenges for identifying ethical and societal implications in Moon to Mars activities;
- A community of researchers working on ELSI is interested in ongoing engagement with NASA and the space community;
- A range of options exist by which space organizations like NASA can consider ethical and societal topics[3].

In many ways, the Artemis and Ethics Workshop represents a differentiated engagement with stakeholders for NASA and explores ways in which both engineering leaders and working-level engineers might engage on these broader topics. Although a few discrete activities have considered questions of ethics, including recent astrobiology studies as well as those conducted during the Apollo era, most discussions on these topics have been limited to historical research and discussion. Further, the workshop provided an opportunity for the agency to gather insights from experts in an array of fields, and it also challenged NASA participants to consider how they might introduce the ideas shared to colleagues who could benefit from and apply these insights directly. Some of these challenges have been long discussed by the engineering ethics community: at what level are engineers responsible for their products? How can project managers and engineers effectively integrate societal considerations in workaday efforts? Others were more unique to the Artemis mission, including space sustainability, balancing access to locations on the moon, and sharing the benefits of space activities.

3. Workshop Concepts in Dialogue with Engineering Education and Ethics Research

As stated, we seek to connect ideas discussed by participants in the NASA Artemis and Ethics Workshop with related research on engineering ethics and engineering education. It places these concepts in a dialogue to suggest ways to build continuity and stability into the bridges that connect related disciplines. We will here discuss the content that was discussed at the workshop, highlighting themes that might be of deepest resonance to the engineering education and ethics communities.

The workshop participants' presentations and discussions are summarized in Appendices C, D, and E of the workshop report[3]. Topics covered included observations on history, sustainability and stewardship, inclusion, legal issues, coloniality, economics, and space agency engagement with ELSI. These comments represented the views of participants, and not necessarily of

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[3] See Pirtle et al cited earlier.

NASA[4], and they do not provide a comprehensive picture of all issues that NASA or other large scientific organizations might face. However, they present a sketch of how some sorts of informed participant knowledge may support a broader dialogue about the ethical aspects of NASA's exploration activities. The issues raised represented the expertise and knowledge of invited participants: given the diversity of potential topics for discussion, other participants may have raised other issues for consideration.

The report categorizes methods suggested by participants about how NASA could consider addressing the ethical challenges and potential solutions proposed by the workshop participants into five thematic areas: policy, management, research, conversations, and education[5]. In this paper, we delve deeper into the education theme, using some threads provided by workshop participants and incorporating additional pedagogical considerations. Our focus here is on professional learning and development for members of the engineering workforce, which represents a more ecosystem-based approach than structured learning in an educational environment[6].

Workshop participants suggested education options including early career education, social science training for engineers, engineering training for ethicists, and supporting a common language[7]. The knowledge gap between ELSI experts and non-experts - what would be needed to equip others with appropriate knowledge to anticipate and resolve ethical challenges[8] - was not characterized with any consensus by the participants but is necessary to explore in order to determine the feasibility and value of educating the workforce and inviting further dialogue.

While engineering ethics research was only occasionally discussed at the workshop, participants noted that engineering ethics has evolved over the past few decades[9] into a required topic for undergraduate or graduate engineering students at some engineering schools along with other

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[4] To re-iterate, NASA's report was clear that the experts cited in the report represented their personal views, and claims about particular ethical challenges do not necessarily mean that NASA or the United States government view these issues to be problematic. This was clarified in the report and should be interpreted as part of the context about our discussion here about ethical challenges that emerged.

[5] Ibid, 11-13

[6] W.C. Lee, "Pipelines, Pathways, and Ecosystems: An Argument for Participation Paradigms," Journal of Engineering Education, vol. 108, no. 1, pp. 8-12, 2019. https://doi.org/10.1002/jee.20241

[7] Workshop report pages 15-16

[8] While not focused on an ELSI expert to non-expert divide, a classic summary on such a division is: B. Wynne, "May the sheep safely graze? A reflexive view of the expert-lay knowledge divide," in Risk, Environment and Modernity: Towards a New Ecology, vol. 40, p. 44, 1996.

[9] G.L. Downey, "What is engineering studies for? Dominant practices and scalable scholarship," Engineering Studies, vol. 1, no. 1, pp. 55-76, 2009. DOI: 10.1080/19378620902786499

humanities elements[10]. This complements the ABET requirement for undergraduate student outcomes that include "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"[11]. However, generational diversity in the engineering workforce means that many engineering professionals, such as those at this workshop, may not have been exposed to these concepts in their early career[12]. In the course of daily work, however, engineering professionals encounter ethical conundrums that can provide important opportunities for learning and dialogue[13]. The results of the Artemis and Ethics workshop suggest ways we might further foster and promote this dialogue, within NASA and in other forums.

4. Infrastructure for Dialogue at the Workshop and Beyond

The workshop represents an attempt to bring social science and humanities expertise to bear in shaping and developing a significant NASA mission. NASA has explored public collaboration in a range of other programs[14]. Most of these programs are defined by NASA, and participation is

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[10] K.C. D'Alessandro, M.K. Swenty, and W.N. Collins, "Integrating History into Engineering Curriculum," in Proceedings of the 2014 ASEE Southeast Section Conference, American Society for Engineering Education, 2014. [Online]. Available: http://se.asee.org/proceedings/ASEE2014/Papers2014/4/72.pdf.

[11] ABET, "Criteria for Accrediting Engineering Programs, 2024 – 2025." https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2024-2025/

[12] The workshop organizers did solicit perspectives from the NASA attendees and did seek out a handful of early career researchers to be part of the 20 NASA attendees. Based on anecdotal reports, there did not seem to be a significant difference in how older and younger attendees reacted to the workshop. The report describes attendees here: "Given past challenges to infusing ethical and societal impacts research into practice, we invited 20 civil servants from a variety of roles inside of NASA, asking them to engage from their personal perspectives. These included early-career staff as well as representatives from key Mission Directorates at NASA Headquarters, notably the Exploration Systems Development Mission Directorate (ESDMD), Space Technology Mission Directorate (STMD), and Science Mission Directorate (SMD). The rationale was that this would help identify new viewpoints or possible actions that could be considered by NASA" (report, p. 26)

[13] D. Kim, S.J. Howland, and B.K. Jesiek, "Encountering Engineering Ethics in the Workplace: Stories from the Trenches," in Proceedings of the 2021 American Society of Engineering Education Virtual Annual Conference. [Online]. Available: https://par.nsf.gov/biblio/10291937.

[14] A. Kaminski, L. Buquo, M.C. Roman, B. Beck, and M. Thaller, "NASA's public participation universe: Why and how the US space agency is democratizing its approaches to innovation," in *AIAA SPACE 2016*, p. 5466, 2016. D. Tomblin, Z. Pirtle, M. Farooque, D. Sittenfeld, E. Mahoney, R. Worthington, G. Gano, M. Gates, I. Bennett, J. Kessler, and A. Kaminski, "Integrating public deliberation into engineering systems: Participatory technology assessment of

typically limited to providing contributory data based on personal interest, often by hobbyists and students. One criticism of this participation model is that it does not provide opportunities for concerned partners to advocate effectively for changes to scope and does not allow for emerging relationships and knowledge development among scientists and non-scientists as equals in dialogue[15]. That is, when participation is scripted by the scientist or other authority organization as a transactional interchange, results are limited to the prescribed scope of inquiry[16].

The design of the Artemis and Ethics workshop instead sought to achieve something closer to the transdisciplinary deliberative model proposed by Suryanarayanan and Kleinman, wherein objects of shared concern, varieties of scientific expertise, and varieties of non-scientific expertise are placed in dialogue through collective deliberation and experimentation[17]. The experimentation itself at the Artemis and Ethics workshop, however, was focused more on policy ideas than scientific discoveries.

Many elements are at play in supporting effective citizen dialogues, and decisions on participants, logistics, and substantive content will have consequences for the outcome[18]. Star's framework of infrastructure elements[19] is here adapted to describe arrangements made in support of the Artemis and Ethics Workshop, which may provide useful considerations for further dialogues:

NASA's Asteroid Redirect Mission," *Astropolitics*, vol. 15, no. 2, pp. 141-166, 2017.There are also specific citizen science elements: https://science.nasa.gov/citizen-science/.

[15] J. Chilvers and M. Kearnes, "Remaking Participation in Science and Democracy," Science, Technology, & Human Values, vol. 45, no. 3, pp. 347-380, 2020. https://doi.org/10.1177/0162243919850885

[16] G. Ottinger, Refining Expertise: How Responsible Engineers Subvert Environmental Justice Challenges. New York: New York University Press, 2013.

[17] S. Suryanarayanan, D.L. Kleinman, C. Gratton, A. Toth, C. Guédot, R. Groves, J. Piechowski et al., "Collaboration Matters: Honey Bee Health as a Transdisciplinary Model for Understanding Real-World Complexity," *BioScience*, vol. 68, no. 12, pp. 990-995, 2018. [Online]. Available: https://www.jstor.org/stable/90026611.

[18]D.L. Kleinman, M. Powell, J. Grice, J. Adrian, and C. Lobes, "A Toolkit for Democratizing Science and Technology Policy: The Practical Mechanics of Organizing a Consensus Conference," Bulletin of Science, Technology & Society, vol. 27, no. 2, pp. 154-169, 2007.

[19] S.L. Star, "The Ethnography of Infrastructure," American Behavioral Scientist, vol. 43, no. 3, pp. 377-391, 1999.

Element	**Workshop Approach**	**Description and Comment on Possible Alternative Infrastructures to Be Explored**
Location	Washington, DC, NASA Headquarters	Physical location enabled greater access and engagement for NASA workforce participants but may have limited participation for distant groups. Embeddedness[20] of NASA Headquarters may also have suppressed some critiques of NASA practices, as invited participants may have perceived themselves as guests
Participants	Invited expert participants and invited NASA workforce participants	The workshop limited invitations to encourage more free-flowing conversations among participants, but broader participation would be valuable to ensure diverse perspectives are heard and recognized
Disciplines	ELSI expert disciplines, including social sciences, law, and the humanities	Areas of study were selected to provide a broad survey of perspectives. A larger capacity meeting might include multiple perspectives from people with the same or similar discipline backgrounds.
Agenda	Two and a half days, varied presentations, breakout groups, and large discussions	Offering a variety of ways to engage encouraged participation in different formats. Including more asynchronous communication could support longer-term dialogues.
Transparency	Workshop was not recorded but a report was produced to summarize proceedings	Informing participants about the intent and degree of transparency helped them to aware of and make decisions regarding their level of comfort with information being shared, but clearer guidelines could be presented.
Insider knowledge	Participants were invited to a preliminary session to hear about NASA's activities and intent	Providing a preliminary session for participants helped to provide knowledge of NASA as an organization and the design of its projects, which facilitated discussion and contributed to a consistent baseline among external experts; but more work than a single session could be done.

The core objectives of the workshop were the research questions noted above, mainly focused on ways that NASA should consider the ethical and societal implications of its Moon to Mars work. NASA described its approach for identifying workshop attendees as follows: "For speakers and

[20] Ibid

discussion participants, we solicited different views and rationales that we deemed relevant for thinking through the ethics of Moon to Mars. OTPS focused the content on Artemis and Moon to Mars, and as such excluded from analysis broader issues facing NASA" (report p. 24). Identifying a broad segment of disciplines across the social sciences and humanities was also important to achieve the research goals. NASA's report describes using brainstorming sessions as a way to get more structured dialog across the participants and other attendees. NASA also prepared for the workshop by providing background information to the speakers about the nature of NASA's Moon to Mars plans, helping to make discussion of the workshop - be it critical or not - was connected to NASA's current thinking and plans.

5. Concept Interpretations at the Boundary

The first element that this paper seeks to explore is the variety of interpretations when engineering professionals encounter concepts from the social sciences and humanities, and especially when those engineers are considering the broader ethical and societal impacts of their work. The concept of boundary objects and boundary organizations are well-established in the literature[21]. They effectively note how different groups can refer to the same words, artifacts, or organizations, but interpret their meaning in separate ways, each looking at the words through their own lenses. Studies of how to navigate these boundaries can involve efforts to align groups across goals, common language, and in how communication occurs.

Mixed interpretations across disciplines are manifest in some of the Workshop report results, in which approximately 4% of the condensed list of ethical ideas submitted at the workshop related to "Defining Ambiguous Terms" and 8% related to "Reflective Capacity by Practitioners"[22]. When these topics are combined, we gain a picture of where a bridge may be helpful. One engineer attendee at the workshop did ask that social science and humanities scholars please develop their own common language, to make it easier for NASA staff to be able to understand and follow the competing dialog at the workshop. Others discussed how they had to develop their own capability to understand and reflect on these issues over the course of the workshop.

Other examples of ambiguous terms described in the workshop report are "due regard", "accessibility" (in reference to access to space), "harm", and "sustainable", all of which are grouped in the "Theoretical" theme for purposes of the study [1, page 45]. Definitions of each of

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[21] S.L. Star and J.R. Griesemer, "Institutional ecology, 'translations' and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39," Social Studies of Science, vol. 19, no. 3, pp. 387-420, 1989. H.I. Hanson, B. Wickenberg, and J.A. Olsson, "Working on the boundaries—How do science use and interpret the nature-based solution concept?," Land Use Policy, vol. 90, p. 104302, 2020. D.H. Guston, "Stabilizing the boundary between US politics and science: The role of the Office of Technology Transfer as a boundary organization," Social Studies of Science, vol. 29, no. 1, pp. 87-111, 1999.

[22] Workshop report page 8.

these concepts have been debated in academic and popular contexts. Debated concepts of "harm", for example, is a fundamental issue for the study of torts in the United States. There is virtue, however, in more clearly defining these and other terms for the purposes of a shared conversation across discipline boundaries.

One challenge in facilitating dialogue is that ethics for government employees tend to be closely associated conceptually with legal constraints, such as conflicts of interest or procurement, and employees are expected to participate in these topics by means of compliance rather than dialogue. Ethics in this context is a highly regulated concept, governed by statutes that define ethical responsibilities across the U.S. government, such as the Ethics in Government Act of 1978; criminal statutes that define the ethical rules and penalties for misuse of government office; and multiple sections of the U.S. Code of Federal Regulations that provide the parameters in which government officials may operate and procure goods and services[23]. The U.S. Office of Government Ethics, a division of the federal government's Office of Personnel Management, was established in 1978 to provide standards for ethics policies across the Federal Government and provide the infrastructure for senior officials' financial disclosures, which is intended to reduce the potential for conflicts of interest[24]. These are narrow interpretations of the concept of ethics, yet the responsibility to abide by this guidance is so important and pervasive across government that they tend to preclude other interpretations of the concept of "ethics".

We see potential entry points for engineering education and ethics research in some of NASA's approaches for training and developing engineers. NASA's competency models for program and project managers and systems engineers include ethics and define the concept as "Demonstrating integrity, ethical conduct, and acceptable behavior in all project activities in line with federal government principles"[25]. Proficiency requires fundamental knowledge of the program on which the engineer or project manager is working, federal government regulations, as well as "political, economic, and other factors that influence project goals", which could well incorporate ELSI concepts described at the Artemis workshop. Expectations rise for engineers as they move through the ranks in the competency model, with the most senior personnel being responsible for creating a culture of integrity and ethical performance[26].

Some data from the workshop does bely the potential value for considering engineering education and ethics research more deeply among practitioners. Many workshop participants were not well acquainted with scholarly frameworks for other disciplines[27]. Providing concept

[23] https://www.nasa.gov/organizations/ethics-rules/
[24] https://www.oge.gov/web/oge.nsf/about_our-history
[25] https://appel.nasa.gov/career-development/competency-models/c-4-0-professional-leadership-development/#c4.4
[26] Ibid
[27] Workshop report page 4

clarity and identifying resources to support that clarity could assist both engineering professionals and social science and humanities scholars in building more effective scaffolding.

6. Value Alignment Across Institutions of Engineers

The second element is to demonstrate how engineering ethics can be aligned to organizational values to support engagement, which was a topic of discussion at the workshop, especially based on the work of Janet Vertesi[28]. At NASA, values are readily present and reinforced across all levels of the workforce. NASA's core values are "safety, integrity, teamwork, excellence, [and] inclusion"[29]. These guide workforce conversations during leadership and regular staff meetings, safety briefings, and other conversations. They are reinforced through communications and culture and engraved into buildings.

We believe that exploration of these values is part of being a responsible public servant and is tied to support for NASA's mission. The degree to which each individual is directly responsible, however, varies[30]. One potential educational objective is to ensure that the workforce is capable of dealing with ethical questions at an appropriate level, in the same way that they are asked to demonstrate their skills in communication, teamwork, or, for that matter, requirements management. If necessary, members of the workforce should be able to surface ELSI concepts and frame them as requirements or work with the appropriate policy professionals to do so.

The workshop discussions did explore questions about how to align values of institutions like NASA to their ultimate societal impact. An example of this type of dialogue and an outcome was provided by one workshop participant. The participant described a situation in which a proposed space mission patch had colonialist overtones that were overlooked by the designers and mission managers[31]. By providing frameworks and lenses for members of the engineering workforce, the group might have anticipated the issue and alleviated the need to redesign the patch and/or taken advantage of the opportunity to reconsider the metaphors that the mission invoked[32].

As engineering organizations develop partnerships with other groups, particularly in multidisciplinary or transdisciplinary approaches, participants tend to become more reflexive in

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[28] J. Vertesi, Shaping Science: Organizations, Decisions, and Culture on NASA's Teams. University of Chicago Press, 2020.
[29] https://www.nasa.gov/careers/life-at-nasa/
[30] A. McAninch, "Go Big or Go Home? A New Case for Integrating Micro-ethics and Macro-ethics in Engineering Ethics Education," Sci Eng Ethics, vol. 29, 20, 2023. https://doi.org/10.1007/s11948-023-00441-5
[31] Workshop report page 14
[32] G. Lakoff and M. Johnson, Metaphors We Live By. Chicago: University of Chicago Press, 2003.

their considerations and decision-making[33]. Additionally, there is evidence that introducing science policy and ethical concepts to graduate engineering students can improve understanding of the complex interrelations and value systems at work in engineering projects[34]. Members of the NASA workforce may consider how their values - and their organization's values - are aligned with partners, and how those partners align their own values with larger societal issues. Providing opportunities to reflect on these areas in advance of direct collaboration could streamline discussions and improve the likelihood of successful collaboration.

In accordance with federal government training guidance[35], any learning and development investment must be aligned to the agency's mission and objectives and further agency goals. Following this model, learning and dialogue on ELSI concepts could support the NASA mission by reducing conflict with stakeholder groups and ensuring expenditures align to societal values. The measurement of adherence to these principles was not discussed in any depth by participants. What threads might prove most beneficial to meet mission needs? Might adherence to other competencies, such as organizational awareness, team communication, or similar areas, result in projects that are better aligned from an ethical perspective? One area that was not directly explored in the Artemis and Ethics workshop was matters of care, which may provide fundamental support for introducing these concepts.

7. Opportunities from Considering Research on Design for Care

There has been an upsurge in research about 'design for care', which seems like a relevant way to capture and summarize some themes from the workshop. We will describe how concepts of care can be applied to support engagement with engineering professionals. While ethics are often treated as matters of concern, elevating ethical concepts to matters of care reinforces the human dimension and human implications of engineering decisions. Lessons on these concepts have been learned and relearned through tragedy, but they can also be reinforced by identifying design elements that support the engineer's role as caretaker instead of purely as creator.

Underlying many of the workshop discussions was a sense from some participants that NASA's interest in ELSI in the context of the Moon to Mars missions could be new, promising, or a

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[33] M. Gibbons, C. Limoges, H. Nowotny, S. Schwartzman, P. Scott, and M. Trow, The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies. SAGE Publications Ltd, 2010. https://doi.org/10.4135/9781446221853
[34] M.J. Bernstein, K. Reifschneider, I. Bennett et al., "Science Outside the Lab: Helping Graduate Students in Science and Engineering Understand the Complexities of Science Policy," Sci Eng Ethics, vol. 23, pp. 861-882, 2017. https://doi.org/10.1007/s11948-016-9818-6
[35] Office of Personnel Management, "Training Evaluation Field Guide," 2011. [Online]. Available:
https://www.opm.gov/WIKI/uploads/docs/Wiki/OPM/training/Field%20Guide%20to%20Training%20Evaluation_6-8-2011-FINAL.pdf.

source of hope for participants. Speakers described their history of engagement with the topic with deep emotion. Many who had dedicated themselves to advocacy for these issues credited Linda Billings for leading the way, based on her foundational work in communications and inclusive participatory assessment of space missions. In her presentation, Billings noted concerns with human spaceflight, particularly when considering the tradeoffs implicit in these investments and the opportunity costs of human exploration[36]. These concerns may be characterized as concerns about misdirected or misaligned care.

Care is also invoked in two proposed educational policy options suggested by participants, "Use case studies to educate and invoke emotional reasons to care about ethics (Study what is so well done in the Normalization of Deviance/Columbia Accident trainings - these are very impactful on NASA employees)"[37] and "Make training resources via SATERN emotionally engaging, like the Challenger or Institutional Silence programs"[38]. Both of these suggestions reference internal training modules or workshops provided to NASA employees, some of which are required for all personnel or new personnel. The purpose of these trainings varies depending on context, but they are generally provided to reinforce elements of NASA's safety culture, promote a common understanding of behaviors like organizational silence that can detract from the mission, or provide opportunities for shared reflection and commemoration of tragic accidents.

These trainings may be especially memorable because of the care with which they are designed and deployed by staff, with an explicit goal to encourage emotional reflection. For instance, training and agency town hall meetings are delivered in proximity to NASA's annual Day of Remembrance, which occurs near the time of year of the Challenger and Columbia accidents. By relating the delivery of behavioral guidance to preventing similar tragedies, the training is given emotional weight and key messages are absorbed and shared among the workforce.

The intent of these two suggestions seems to be to highlight the value of incorporating emotion into instruction. The NASA workforce's responsibility to all ELSI concerns is more diffuse than the workforce's accountability to prevent another Apollo, Challenger, or Columbia tragedy, but the ethical concepts can still invoke an emotional response, especially around concepts of sustainability, public benefit, and differing cultural values. Emotional responses can be culturally suppressed in engineering work, as was seen in what Cech researched with engineering undergraduate changes over their curriculum[39]; however, emotion and empathy are also

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[36] Report page 37
[37] Report page 40
[38] Report page 41
[39] E.A. Cech, "Culture of disengagement in engineering education?," *Science, Technology, & Human Values*, vol. 39, no. 1, pp. 42-72, 2014.

recognized as necessary by practicing engineers[40] . Following Puig de la Bellacasa's concept of "re-affecting objectified worlds"[41], how might the process of bringing affect and emotion more readily to bear in assessing technological decisions or determining requirements change outcomes?

Another possibility is suggested by Frigo, Milchram, and Hillerbrand's "Designing for Care (D4C)" approach, which frames caring practices within the project management and system design process through four different means of caring: attentiveness, responsibility, competence, and responsiveness[42]. These four practices may be loosely overlayed with the four themes derived from the Artemis and Ethics workshop potential recommendations: decision process, theoretical, forecasting, and substantive issues (specific examples)[43] The decision process options focus on who is involved in decisions and how decisions are made, demonstrating responsibility or "care for" practices. The theoretical options describe the challenges of definitions and lack of parity, which might be reframed as responsiveness or "care-receiving" practices. The forecasting options anticipate future concerns and future needs, in a way similar to attentiveness or "care about" practices. Finally, the substantive issues options correspond most closely to competence or "care-giving" practices, in which personnel would be "integrating care within their professional skills"[44]. Recognizing care practices as a skill set that complements or is incorporated within expected project management and engineering competencies, such as ethics, communications, organizational awareness, or other facets, would support impactful learning and development opportunities like the ones cited as most impactful in the proposed options.

8. Concluding Thoughts and Bridges Yet to Be Built

This is a preliminary analysis meant to connect an important space policy event - the Artemis and Ethics workshop - to research in engineering education and ethics research. This was a novel effort to have practicing engineers engage in a broader dialog. Not all of it was perfect, as the discussion about bridging boundary concepts and enabling care above indicate. This is another strong example of how practicing mid- and late-career engineers could be valuable infusion points for research from engineering education and ethics work that ASEE performs.

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[40] J.L. Hess, J. Strobel, R. Pan, and C.A. Wachter Morris, "Practicing engineers' perceptions of empathy and care: Derived exploratory factor structure from a 37-item survey," in Proceedings of the American Society for Engineering Education Annual Conference, Indianapolis, IN, 2014.
[41] M. Puig de la Bellacasa, "Matters of Care in Technoscience: Assembling Neglected Things," Social Studies of Science, vol. 41, no. 1, pp. 85-106, 2011.
[42] G. Frigo, C. Milchram, and R. Hillerbrand, "Designing for Care," Sci Eng Ethics, vol. 29, 16, 2023. https://doi.org/10.1007/s11948-023-00434-4
[43] Report page 8-9
[44] Frigo, Milchram, and Hillerbrand page 16.

Engineering education should continue to not solely focus on undergraduate and graduate education but should look at the full life cycle of an engineer's career. The Artemis and Ethics workshop might offer reasons why such later career reflection needs to also consider broader issues of policy and institutional reflection.

Additional research and analysis should inform future research and educational approaches and help ethics and social science researchers to engage engineering and project leaders in constructive dialogue. What correlations might exist in workforce education for efforts like this one?

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