Musings on Engineering Ethics at the US National Science Foundation (NSF) and the National Academy of Engineering (NAE)

In the second decade of the 21st Century, engineering ethics is becoming a recognized academic specialty as well as a recognized component in good engineering practice and research and in engineering education. This chapter takes a thematic and chronological approach to its evolution, with information about the history of its support from the NSF. NSF is a federal agency with a yearly budget appropriation from the US Congress. Its mission is to support STEM (science, technology, engineering and mathematics) research infrastructure and projects, and science and engineering education, throughout the country.

In 1975 I was hired to assist the NSF in initiating its programs focused on ethics and STEM. I retired from NSF in 2005. In 2007, I was hired part-time at the National Academy of Engineering (NAE) to develop new ethics programs at the NAE Center for Engineering Ethics and Society (CEES): NAE is part of the National Academies of Sciences, Engineering, and Medicine (NASEM). I retired from this position in 2017. The NASEM is a federally chartered non-profit honorary membership organization of scientists and engineers who provide advice to federal agencies, other organizations, and the public about technical dimensions within policy-related issues. This chapter will also provide some information about the development of ethics activity at NAE.

At the National Science Foundation

As an independent (non-cabinet) agency of the Federal government, NSF receives its appropriation each year through legislation from the US Congress signed into law by the President. Its appropriation in fiscal year (FY) 2017 was about $7.5 billion – about the same as it was in 2010. The National Institutes of Health (NIH) budget for FY2017 was about $30 billion, of which perhaps half is for the category of basic research (Mervis, 2018). The difference in these numbers indicates the higher priority medical research has in our nation than do all other civilian branches of sciences and engineering research and education. The National Human Genome Research program at the NIH began in 1989 and soon thereafter established an ethics activity with considerable funding available in that area of biomedical ethics (Hollander, Under Review).

When NSF took its place among the Federal agencies in 1950, engineering was part of the division of Mathematical, Physical and Engineering Sciences (MPE). Including social science among the sciences NSF would support was a contentious item, and the language of the agency's 1950 Charter indicates the compromise that the support of basic scientific research can include "mathematical, physical, medical, biological, engineering, and other sciences." Social science is thus allowable but not mandatory. In 1954, MPE supported two projects in History and Philosophy of Science (Overman, 1990).

When then NSF director Guy Stever reorganized the agency into seven directorates in 1976, engineering remained part of what was renamed the Mathematical, Physical Sciences, and Engineering Directorate (MPE). The Directorate for Biological, Behavioral, and Social Sciences

(BBS) was established. In 1981 engineering gained directorate status; the Directorate for Social, Behavioral, and Economic Sciences (SBE) split from BBS in 1991 (Overman, 1990).

NSF interest in supporting projects in science and engineering ethics became evident in the early 1970s, developing independently of the bureaucratic changes outlined above. However, these changes gave both engineering and the social sciences a seat at the table with the other Directorate heads. The ethics efforts would need to meet evidentiary standards including those from the social and behavioral sciences if they were to survive at the agency, and they would need to find a compatible home in one or another Directorate. The ethics activities bounced between directorates until finding a home in a group in SBE including history and philosophy of science and science and technology studies, named Science, Technology, and Society (Hollander, 2015).

In the early 1970s NSF program officers in the biological sciences recognized the potential for new developments in those sciences to raise societal questions and encouraged the agency to consider how it might support study of these questions. In association with the National Endowment for the Humanities (NEH), which supported humanities research, the NSF organized an advisory group to examine the matter. It recommended that NSF establish a distinct program with its own review procedures; NEH could cooperate where it saw relevance to its mission (Hollander, 2015).

Around this same time, philosopher Robert Baum came to work at the NSF, on the new ethics and science program activity. Dr. Baum specialized in research and education on ethics and technology and came from a university known for educating engineers, Rensselaer Polytechnic Institute. RPI also housed one of the first Science and Technologies Studies (STS) departments in the US. Baum was looking for an assistant, and as I worked on my dissertation, he hired me (Hollander, 2020).

Before I dive further into this chronology, a word or two about the development of the field in the context of the broader area of STEM ethics and ethics education might be helpful. Since its inception, but becoming more evident from the 1980s, with increasing public attention to issues of research integrity, there have been two focal strands in STEM ethics projects – those that focus on ethics of STEM in society and those focusing on ethics in the practice of STEM (Hollander, 2020 and 2015). Another way to characterize these themes for engineering, particularly in the US where the view of engineering as a profession is strong, would distinguish between engineering as a profession (the practice) and engineering as an agent of change or innovation (engineering in society). In the context of profession, the concern for ethics is on the implications of the ethical issues for individual practitioners and professional societies. When considering engineered innovations, the concerns are for the ethical issues raised in their development, implementation, assessment, modification, etc. and for the responsibilities of all parties engaged and affected. If these issues are to be addressed, parties engaged and affected must “own” the activities and actions and their responsibilities for them. Engineers have a major role in identifying and assessing these phenomena, but they are not alone.

Institutionally, the second decade of the 21st Century has seen the development of departments of engineering education in US colleges and universities, mainly in colleges and universities with strong engineering programs. Recent years have also seen more attention to engineering ethics from such gatekeepers as professional engineering societies (especially including the engineering accreditation body called ABET) and the NAE. The colleges and universities provide homes in which issues of engineering ethics can be incorporated into the educational programs, and as this happens the intentions of engineers and their associations to engage with and take charge of these matters will become clear. This has both positive and negative implications. Positively, having these parties assume responsibility is essential to address issues and train next generations. Negatively, this control may push aside attention to important issues and sideline important perspectives particularly concerning redress of social inequities.

The first awards in the new ethics program at NSF were made in 1976; in one form or other STEM ethics activities and awards have continued from then until now. The remainder of this chapter focuses on ethics activities in or related substantially to the field of engineering ethics until my retirement from the NAE in 2017.

In an article in *Science, Technology & Human Values*, Nicholas Steneck and I identified 172 projects funded by the NSF ethics program from 1976-1987 (Hollander and Steneck, 1990). The appendix contained a list of 44 awards cited in the article. Many of the principal investigators on those awards will be familiar to people who work in engineering ethics and some would be counted as founders of the field: Albert Flores, Deborah Johnson, Stephen Unger, Vivian Weil, and Caroline Whitbeck. Steneck and I grouped these 172 projects into topical areas; several besides that of engineering ethics (in which we classified 15 awards) are relevant to it: most clearly germane are risk/benefit analysis (9), computers (9), environmental Issues (15), hazards (25), university-industrial relations (5), and energy (4). Among the larger list are awardees Robert Anderson, Mark Frankel, Roger Kasperson, Douglas MacLean, Dorothy Nelkin, Kristin Shrader-Frechette, and Judith Swazey. Michael Davis, Joseph Herkert, Michael Loui, Taft Broome, and Aarne Vesilind are not named in this article, but they also received awards from the program and I would count them among founders of the field too.

Professional development awards in the new ethics program were intended to allow scientists and engineers and humanities scholars to develop cross-disciplinary expertise; engineers were among the earliest to participate. Aarne Vesilind studied with philosopher Bernard Gert with one of these awards, and Taft Broome was among the earliest engineers to study ethics and philosophy at RPI with this award. Michael Davis began to recruit interdisciplinary faculty pairs to develop new science and engineering ethics offerings for undergraduate curricula through several ethics projects. Early grants also supported several workshops in engineering ethics that were structured to foster collaborative research and educational relationships between philosophers and engineers. Vivian Weil and Al Flores ran several of these workshops. These early efforts resulted in such partnerships as that between Mike Martin and Roland Schinzinger, whose book *Ethics in Engineering* was in its fourth edition in 2018; informal introductions resulted in the collaboration between philosophers C.E. Harris, Michael Pritchard, and engineer

Michael Rabins on the text *Engineering Ethics: Concepts and Cases*. This book was in its sixth edition in 2018 and included additional authors Ray James and Elaine Englehardt.

Many other very significant contributors to the field received awards from the NSF, reviewed proposals individually or on panels and contributed to the Online Ethics Center (OEC). I add a few names here: Heinz Luegenbiehl, Rosalyn Pinkus, Donna Riley, Larry Shuman, Dan Vallero. Other names appear below, and some go unnamed simply because I haven't done a systematic search. I apologize for these shortcomings, but I am proud to be able to show that much important work came from NSF support. Deputy Division Director Susan Kemnitzer in the Division of Engineering Education and Centers (EEC) encouraged program officers in the division to cooperate in consideration of engineering ethics proposals, thus strengthening the relevance of the effort. Several engineering program officers in that division came to their positions with considerable expertise in the field.

As support for ethics research and educational activities at NSF continued, the program developed a new outreach effort to all NSF science and engineering programs via the Research Experiences for Undergraduates (REU) sites projects in the early 1990s. All the research directorates were supporting these summer programs of research offerings for undergraduate science and engineering majors. Adding ethics to these efforts began with a successful pilot in chemistry in 1992. The other NSF directorates signed on in 1993 and the program continued to make small amounts of funding for ethics available through 2006. The funds gave the scientists and engineers who led these programs an incentive that more than a few accepted. Engineering was actively engaged in this effort and ethics became a standard part of the engineering REU submissions throughout this period. Since it turned out that all the REU applications to engineering included ethics components, engineering supported many of the successful applications without asking the ethics program for financial help.

Another successful collaboration between NSF ethics activities and engineering resulted from the interest of engineering program officers – particularly Mihail Roco - in the ethical and social implications of nanoscience, engineering, and technology. The swirl of public interest about potential safety issues surrounding the development of this technology also bolstered NSF interest in responding to that concern. A special competition resulted in support for several centers focusing on nanotechnology in society that began in 2005. The funds for centers headquartered at Arizona State University and University of California Santa Barbara came from those allocated for a special nanoscience and engineering initiative and provided support to historians and philosophers of science, engineering, and technology as well as STS scholars interested in studying connections between emerging technologies, ethics, and society. This support fostered collaborations with nanoscience and technology researchers, and gave these scholars critical funding for research (NSF 2018a). Numbers of NSF programs made ethics a component of their solicitations, including the flagship program for interdisciplinary graduate science and engineering education, which began in 1998 (Hollander, 2020; TERC, 2018).

Public and Congressional interest in issues of research integrity strengthened support for ethics activity in NSF. In 2005 three NSF directorates – Education and Human Resources, Engineering, and the Social Behavioral and Economic Sciences – took the lead in developing a new foundation wide program called Ethics Education in Science and Engineering (EESE). EESE made 89 awards from 2007 through 2013 for projects to improve STEM graduate student ethics education. The results from these projects, which provide materials and approaches for student and faculty use in classrooms and workshops, are available in several on-line resources such as onlineethics.org and the Ethics Education Library of the Illinois Institute of Technology. EESE ended when a new NSF effort that focuses explicitly on changing academic institutions to foster ethics in STEM began (Layne, 2015). In all of these programs engineers and engineering were and are well represented.

Support for ethics research at NSF continued in the program called CCE-STEM or Cultivating Cultures for Ethical STEM. Its emphases on scientific and engineering practice and on empirical research activity are easier fits with a scientific research agency, but challenge philosophers to strengthen connections to empirical work (Hollander, 2020). In this incarnation, the CCE-STEM priorities might emphasize issues of academic and research ethics rather than more general issues about the ethical implications of scientific and technological trajectories and their effects (NSF 2018). Although that orientation might advantage research ethics over engineering ethics, inspection of the award abstracts I believe would show engineering still well represented. Perhaps more than the natural and physical sciences, engineering fields are used to the tension that exists between wealth-generating and equity-generating activities where these broader questions are posed. Additionally, the NSF Science, Technology, and Society (STS) program literature continued to identify ethics explicitly as part of its priorities with a strong emphasis on science and technology in society (NSF 2015).

At the National Academy of Engineering (NAE)

Before turning to the activities at the NAE another large influence on the development of engineering ethics education needs acknowledgment – ABET. ABET is the accreditation body for engineering programs in the US and, to an increasing extent, abroad. A federation of 34 engineering societies who establish criteria for accreditation, ABET established a new set of outcomes-based criteria in 2000 that included professional and ethical responsibility. Information is available at http://www.abet.org/accreditation/.

The ABET criterion gave many engineering departments and programs the impetus to find colleagues able to help establish and teach ethics in and for their curricula. While there is considerable controversy over the efficacy of the ethics education in undergraduate engineering education, certainly this requirement has gained the attention of engineering leaders and faculty. Engineering departments and engineering education departments are well aware of the importance of ABET accreditation to the profession and its continuing social status. Ethics assessment is a weak point for programs in the ABET accreditation process; perhaps increased integration of ethics into educational programs can improve this situation.

Public and scholarly and professional attention to socio-technological developments and social controversies probably all played a role in the ethics initiatives at the National Academy of

Engineering, but the influence and support of NAE president William A. Wulf (1996-2007) is well recognized. In his tenure as president, computer scientist and engineer Bill Wulf sponsored a large conference in 2004 on issues of ethics and emerging technologies, and a presidential advisory group that focused on how to initiate an ethics program at NAE. He believed that engineering should and would have to grapple with the macro-ethical problems that complex, uncertain systems presented to our planet. He worked with Caroline Whitbeck to transfer her on-line ethics (OEC) resource (onlinethics.org) to the NAE. Wulf also assisted in raising support from NAE members, both financial and intellectual, for the ethics programs.

Managed by CEES before its transfer, the OEC is among the earliest and longest-lived of on-line resources devoted to STEM ethics. From 2014-2019 it received an award from NSF to develop and expand its offerings to include sciences as well as engineering. The advisory group for this project includecd co-chairs John Ahearne and W. Carl Lineberger, as well as Stephanie Bird, Derrick Cogburn, Felice Levine, Michael Loui, Carl Mitcham, Robert Nerem, and Victoria Stodden. It received its second NSF award, starting in 2019, to strengthen development of widely accessible on-line resources and outreach to particular audiences.

NAE structures require that advisory committees whose chairs are members of the NAE oversee all NAE efforts. John Ahearne, former president of Sigma Xi and an NAE member, was first chair of the advisory group for the NAE CEES. Ahearne's specialties included research integrity, and nuclear policy. Other members of the group and of the OEC advisory group well known for scholarship in engineering ethics included Stephanie Bird, Michael Loui, Indira Nair, and Carl Mitcham. Group members with significant influence on initial CEES projects were Juan Lucena and Clark Miller. All of these persons are well-known contributors to the field.

Ron Kline points out that the values of concern in engineering ethics and research ethics are often the same, but the priorities are different. In his reckoning, the order of attention to issues in research ethics puts research integrity first and social implications of research fifth, while that for engineering ethics puts public health, safety, welfare and the environment first and integrity of reports fifth (Kline, 2013). This order of attention was true for the priorities of the CEES advisory group, which was most enthusiastic to promote CEES attention to issues of social justice and sustainability; climate change, engineered systems, and society; and of energy ethics (CEES 2018).

The workshop on "Engineering, Social Justice, and Sustainable Community Development" held in early October of 2008 in the historic National Academy of Sciences building in Washington DC was the first activity that CEES developed. It attracted a large number of participants and an audience that included many engineers. The impetus for the event came from Juan Lucena and other members of the advisory group who raised questions about how to reconcile disparate goals for engineering projects, particularly those in areas of poverty or crisis. Three goals besides or beyond those of economic benefit stood out: environmental sustainability, social justice, and human welfare may conflict with each other as well as with economic progress. Chapter 6 in the resulting report contains summaries of small group discussions at the meeting that provide perspectives on how to address the questions (NAE 2010).

These CEES projects promoted attention to issues of collective responsibility – that is, those issues that need organizational and social changes to occur in order for ethical problems to be resolved. Complexity and uncertainty, as Bill Wulf noted, are hallmarks of these issues. So the focus required inter-disciplinary efforts as well as perspectives from public and private sector organizations to be addressed. The climate change and energy ethics projects grew from insights of Clark Miller and other advisory group members concerning the neglected importance of engineered systems in promoting or interfering with sustainability and social justice. Information from both the energy ethics and the climate change projects is available on the OEC (OEC 2018a, OEC 2018b). OEC features include two videos from the climate change project, and the project report is available through the National Academies Press (NAE, 2014).

Throughout this time, STEM ethics education was not neglected however, and several CEES projects focused on engineering ethics education. One supported by the NSF Engineering Directorate, 2014-2016, invited faculty and administrators at US colleges and universities to submit materials about their engineering ethics activities to CEES for consideration for special acknowledgment. The CEES project directors were Frazier Benya and Simil Raghavan; the NSF program officer who made this award was Donna Riley. The call resulted in 44 submissions. The publication that resulted acknowledges all of the submissions and describes 25 exemplary activities and programs (National Academy of Engineering, 2016).

During this time, the CEES advisory group that had overall responsibility for CEES projects consisted of chair Gerald Galloway, and members Paul Boulos, Thomas Budinger, Ed Carr, Glen Daigger, Joe Herkert, Sharon Jones, William Kelly, Felice Levine, Indira Nair, Sarah Pfatteicher, Chris Schairbaum, Jen Schneider, and Paul Thompson. A selection committee reviewed the submissions; its members included Stephanie Bird, Gerry Galloway, Joseph Herkert, Indira Nair, and Chris Schairbaum from the CEES Advisory Group and two additional members: Andrene Bresnan and Sharon Kenny.

Besides the ongoing efforts in CEES, the NAE and NASEM hosted numerous ethics and STEM activities; here are just two of those addressing engineering ethics. In 2017, NAE, IEEE, and AAES held a joint event that examined ethical issues for artificial intelligence, particularly focused on autonomous transportation (NAE Website 2017). NASEM worked with counterpart organizations in other countries to develop a publication focused internationally on ethics in graduate education (IAP 2016).

Conclusion

In brief, public and professional interest indicates that the field of engineering ethics and its role in engineering education will continue and evolve. The field has expanded the notion of what engineering is and how ethical responsibility factors into it. Engineers and their organizations are assuming increasing responsibility to address ethical questions. Certainly, a great deal has been accomplished, and I am very happy to have played a part in it.

Nonetheless, a great deal of work remains to develop a coherent agenda for engineering ethics and engineering ethics education. In particular strengthening the engagement of philosophical expertise with that from the field of science and technology studies (STS) might create a useful connection between normative and empirical analysis. Philosophical examination can assess assumptions and procedures that might otherwise be uncritically accepted as ethical. The conceptual foundations and empirical approaches in STS can also raise these questions as well as provide empirical evidence to challenge or support them. Another factor that could strengthen the contributions of engineering ethics to engineering would be the development of ways to expand the perspectives in the classroom by promoting representation from views traditionally not present – those from environmental groups and underserved communities, for instance. Promoting gender and racial equity in the profession is another route. We can await with interest how the field evolves further.

Finally, placing the development of engineering ethics into the more general context of support from the federal government for research and innovation may be useful. The impetus for this support has been the generation of wealth, not equity, for the nation. Difficulty in persuading powerful actors to support ethics programs goes with the perception that such efforts will slow the pace of wealth generation. This tension will continue, and organizations supporting ethics activities can expect to face it when conflicts arise. The roles of transparency and public engagement can mitigate and overcome some of these problems, and academic and professional organizations can both support and gain from successful efforts, particularly those that can reconcile these disparate objectives.

References

ABET. 2018. Accreditation: http://www.abet.org/accreditation/.

Center for Engineering Ethics and Society. (CEES). 2018. The CEES home page at the NAE identified current ethics efforts at https://www.nae.edu/26187.aspx, Information about the energy ethics and climate change projects was found at https://www.nae.edu/Activities/Projects/CEES/57196/EnergyEthics.aspx and https://www.nae.edu/Activities/Projects/CEES/57196/35146.aspx. Since ethics activities at NASEM have been redistributed throughout the organization, information about them is available through particular reports or topical searches.

Herkert, Joseph. 2004. Chapter 9: Microethics, macroethics, and professional engineering societies. *Emerging Technologies and Ethical Issues in Engineering.* National Academy of Engineering. Washington, DC: National Academies Press. https://www.nap.edu/read/11083/chapter/9

Hollander, Rachelle D. 2020. Chapter 13 in A Guide to Field Philosophy: Case Studies and Practical Strategies. Edited by Evelyn Brister and Robert Frodeman, New York: Routledge, 2020.

Hollander, R. D. 2015. National Science Foundation. *Encyclopedia of Science, Technology and*

Ethics. 2nd Edition. Cengage Learning. 458-464.

[redacted]. Professional responsibilities in scientific and engineering research. In *Science, Technology and Society*. Edited by S. Restivo. New York: Oxford University Press, pp. 414-420.

IAP (InterAcademy Partnership). 2016. *Doing Global Science: A Guide to Responsible Conduct in the Global Research Enterprise.* Princeton: Princeton University Press. http://interacademycouncil.net/File.aspx?id=29431

Kline, Ronald R. 2013. Balancing priorities: Social responsibility in teaching responsible conduct of research. Frazier F. Benya, Cameron H. Fletcher, and Rachelle D. Hollander, Editors*; Practical Guidance on Science and Engineering Ethics Education for Instructors and Administrators.* Washington, DC: National Academies Press.

Layne, Linda L. 2015. Ethics and the National Science Foundation. *Encyclopedia of Public Administration and Public Policy, Third Edition.* Taylor & Francis. DOI: 10. 1081/E-EPAP3-120053328.

Mervis, J. 2018. “Congress gives science a record funding boost,” *Science.* 359: 1447-1448. 30 March.

National Academy of Engineering. 2004. *Emerging Technologies and Ethical Issues in Engineering*. Washington, DC: National Academies Press.

National Academy of Engineering. 2010. *Engineering, Social Justice, and Sustainable Community Development: Summary of a Workshop*. Washington, DC: National Academies Press.

National Academy of Engineering. 2014. *The Climate Change Educational Partnership: Climate Change, Engineered Systems, and Society: A Report of Three Workshops.* Washington: National Academies Press.

National Academy of Engineering. 2016. *Infusing Ethics into the Development of Engineers: Exemplary Education Activities and Programs.* Washington: National Academies Press.

NAE Website 2017. “Session Two: Ethics and Autonomous Vehicles” Webcast 4-24-2017. 2017 NAE-AAES Convocation of the Professional Engineering Societies. https://www.nae.edu/168699.aspx

National Academy of Sciences, National Academy of Engineering, and Instutute of Medicine (NAS, NAE, IOM). 2011. *Examining Core Elements of International Research Collaboration: Summary of a Workshop.* Washington, DC: The National Academies Press.

National Research Council (NRC). 2014. *Culture Matters: International Research Collaboration in* *a Changing World (Summary of a Workshop).* Washington DC: The National Academies Press.

National Science Foundation (NSF). 2018. *Cultivating Cultures for Ethical STEM (CCE-STEM)* NSF 18-532. Replaces Document(s): NSF 15-528. https://www.nsf.gov/pubs/2018/nsf18532/nsf18532.htm

National Science Foundation (NSF). 2018a. National Nanotechnology Initiative. https://www.nsf.gov/crssprgm/nano/.

National Science Foundation (NSF). 2015. *Science, Technology, and Society (STS)* Program Solicitation
NSF 15-506 Replaces Document(s): NSF 12-509
https://www.nsf.gov/pubs/2015/nsf15506/nsf15506.htm

Online Ethics Center (OEC). 2018a. "Featured Videos" Climate Change and Infrastructure I, Climate Change and Infrastructure II, accessed from the OEC home page: https://onlineethics.org/cases/climate-and-infrastructure-i-why-does-it-matter May 4, 2024.

Online Ethics Center (OEC). 2018b. Results from this project are available at https://onlineethics.org/collection-detail/Energy%20Ethics

Overman, Ronald. 1990. Internal Document prepared on the history of support for social sciences at NSF prior to establishment of the Directorate for Social, Behavioral, and Economic Sciences and available to NSF staff.

TERC. 2018. *About IGERT.* http://www.igert.org/public/about.html.