Eight-Dimensional Methodology for Innovative Thinking about the Case and Ethics of the Mount Graham, Large Binocular Telescope Project*

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ABSTRACT: *This paper introduces the Eight Dimensional Methodology for Innovative Thinking (the Eight Dimensional Methodology), for innovative problem solving, as a unified approach to case analysis that builds on comprehensive problem solving knowledge from industry, business, marketing, math, science, engineering, technology, arts, and daily life. It is designed to stimulate innovation by quickly generating unique "out of the box" unexpected and high quality solutions. It gives new insights and thinking strategies to solve everyday problems faced in the workplace, by helping decision makers to see otherwise obscure alternatives and solutions.*

Daniel Raviv, the engineer who developed the Eight Dimensional Methodology, and paper co-author, technology ethicist Rosalyn Berne, suggest that this tool can be especially useful in identifying solutions and alternatives for particular problems of engineering, and for the ethical challenges which arise with them. First, the Eight Dimensional Methodology helps to elucidate how what may appear to be a basic engineering problem also has ethical dimensions. In addition, it offers to the engineer a methodology for penetrating and seeing new dimensions of those problems.

To demonstrate the effectiveness of the Eight Dimensional Methodology as an analytical tool for thinking about ethical challenges to engineering, the paper presents the case of the construction of the Large Binocular Telescope (LBT) on Mount Graham in Arizona. Analysis of the case offers to decision makers the use of the Eight

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Dimensional Methodology in considering alternative solutions for how they can proceed in their goals of exploring space. It then follows that same process through the second stage of exploring the ethics of each of those different solutions.

The LBT project pools resources from an international partnership of universities and research institutes for the construction and maintenance of a highly sophisticated, powerful new telescope. It will soon mark the erection of the world's largest and most powerful optical telescope, designed to see fine detail otherwise visible only from space. It also represents a controversial engineering project that is being undertaken on land considered to be sacred by the local, native Apache people. As presented, the case features the University of Virginia, and its challenges in consideration of whether and how to join the LBT project consortium.

Introduction

Case analysis is a common method for teaching engineering ethics. In this process, students are presented with the details of an engineering ethics problem, which was faced by particular individuals in a given situation while working for a particular organization. Students read the details of the case, and then use that case as the basis for discussion about how the ethical dimensions of the case might be addressed. With the use of varied approaches such as principalism and stakeholder analysis, students are given a theoretical framework for analysis of the case as a way to answer the question, "What ought to be done?" Active discussion about the details of the case usually brings to light some of the complex questions of duty, responsibility, maximizing benefits and minimizing harm, which are common features of ethical dilemmas in the professions of modern engineering.

Mt. Graham is a large mountain on public land in southeastern Arizona. It has public uses, is part of the Coronado National Forest, and covers about 200,000 acres.

The Large Binocular Telescope (LBT) itself will occupy 1.2 acres, and the total present area for the Mt. Graham International Observatory is 8.6 acres. Currently, Mt. Graham has over 40 miles of roads, recreational lakes, a Bible camp, a commercial apple orchard, and about 100 residences. It has about 280,000 recreational visitor days of use per year. According to the University of Virginia (UVA) Astronomy Department, the site was selected from a survey of 280 potential mountain sites because of its altitude, low light pollution, low atmospheric water vapor, and ease of access. Mt. Graham is considered to be the best practical site remaining in the continental U.S. for large telescopes. A 16-story enclosure has recently been constructed for what is to be the world's most powerful optical telescope, the Large Binocular Telescope. Telescope assembly began in June 2002. It is scheduled to be in operation in 2005.

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The University news officials report that in the mid 1980s the Forest Service carried out cultural surveys on Mt. Graham. Two shrines were located on Hawk and High Peaks. Additional surveys were carried out on Emerald and Plainview Peaks, and nineteen local tribes were contacted to see if they had concerns. Four tribes, the Ak-Chin, Hopi, Zuni, and the San Carlos Apache responded but raised no objections to the proposed plans for the telescopes. The shrines were protected and the telescopes were located near Emerald Peak on a site with no known adverse cultural impact. In 1990, two years after the completion of the final environmental impact statement, some members of the San Carlos Apache tribe raised objections to the use of the site.

Apache leaders have been outspoken in their protest over the project and insistent that the project threatens the sanctity of their sacred rituals and worship. They have pleaded with the University of Virginia to have the project abandoned. The University of Virginia has decided to proceed. It feels it needs to join the LBT project consortium in order to secure its position as a world-class astronomy research partner.

Analysis of this particular case offers to decision makers the use of Eight Dimensional Methodology in considering alternative solutions for how they might have proceeded in their goals of exploring space. It then follows that same process through the second stage of exploring the ethics of considering those different solutions.

The Eight Dimensions

This technique guides the student through the exploration of solutions in eight different thinking directions, one at a time. In each direction ("dimension") multiple questions or suggestions are posed to stimulate the thinker's mind in sub-spaces in which solutions may be found. Some of the solutions, which come from this process of ideation, may not be practical, feasible, or make sense given our current knowledge and abilities. They may be too expensive, and may even challenge basic beliefs and facts of scientific understanding. Nevertheless, the process serves to generate as many ideas as possible, which broaden and expand the possibilities, in a short period of time. In doing so, we open to a new set of solutions which otherwise might never have been considered.

The Eight Dimensions questions

- *Uniqueness*:
  What is unique about the processes, objects, features or situations? Could these observations be used to find solutions?
- *Dimensionality:*
  What could be done with space, time, cost, color, temperature or any other dimension?
- *Directionality:*
  Could things be done from different directions or points of view?

- *Consolidation:*
  Would it be helpful to consolidate objects, concepts or processes?
- *Segmentation:*
  How could segmentation of solutions, concepts, processes, resources, objects or dimensions help?
- *Modification*
  What if modifications to the existing situation are introduced?
- *Similarity*
  Why not look at similar concepts, problems, principles, solutions, patterns and processes?
- *Experimentation*
  Could estimating, guessing, simulating or experimenting help?

Using Eight Dimensional Methodology, a number and variety of solutions can be generated for the Case of the Large Telescope at Mount Graham. One may then consider which solutions make the most sense and are most feasible. And most importantly, which offer answers that address the ethical questions of minimizing harm, enhancing good, and addressing respect for persons?

A group called The Mount Graham Coalition formed to stop construction of the LBT. This group included the Apache Survival Coalition and a few small environmental groups. The group had been particularly anxious to stop the University of Virginia's involvement in the project. According to the UVA Astronomy Department, "UVA's withdrawal from the LBT consortium would do enormous damage to the Astronomy, which is the highest ranked science department in the school of Arts & Sciences, and would do irreparable harm to the University's stated goals of increasing the quality and reputation of its science departments."[a]

In October 2002 the local *Daily Progress* newspaper reported a follow up to the story. It's opening line reads, *Over the objections of many American Indian groups, the University of Virginia announced Thursday that it will invest $4 million in a consortium that will operate three telescopes on an Arizona mountain considered sacred by Western Apaches.* That article placed the University in a dim light, with Apache's calling UVA lack of support "absolutely abominable" and UVA representatives quoted as being "very pleased" with their own efforts. And, it communicated to the larger community and general public just how unresolved the issue continues to be.

In the end, only one party was satisfied. The others were offended and disappointed. The ethical issues are apparent. First, we must ask what moral obligations, if any, do the University of Virginia and their project managers have to those who oppose the project? In this case, a stakeholder approach to engineering ethics suggests that there is always present the moral obligation to consider each stakeholder, even those with limited power or influence, or those who represent no

a. Swenson, Eric, "UVA will invest in controversial telescope project," *The Daily Progress*, Wednesday Dec 18, 2002.

apparent interest to the project. On the other hand, there are those critics who would discount the Apache coalition, accusing them of using UVA's role in the telescope project as a means to wield power, gain influence, and create new access to potential resources, especially since with or without the University of Virginia, the project will proceed. To disregard the Apaches may seem helpful to the project, especially from the perspective of those Astronomy Department members who have a stake in their own scholarship and prestige. But such disregard comes with moral responsibilities of judging the values and integrity of other human beings. It also begs the question of the moral obligation any party has to another whose views conflict due to cultural or social disparities.

In this case, we must also ask whether the stated harms are true harms, relative to the goals and aspirations of the project itself. A utilitarian approach to engineering ethics would ask which of the scenarios considered represents the greatest good for the most. In sheer numbers, it is difficult to measure the weight of the benefit of joining a coalition against the native peoples of an ancient land. The obligations and commitments of one interested party clashed with ideologies, beliefs and sensitivities of another. But many different scenarios emerged in the Eight Dimensional analysis, and each one can now be considered in light of utilitarian ethics.

Finally, can questions of maximizing good and minimizing harm be addressed in the project specifications, before the decision is finalized and as a step in the original conceptualization and project design? In other words, why can't a stakeholder analysis, which uses a thinking tool such as the Eight Dimensional Methodology, become an integral part of any engineering design? The moral duties to respect others, to minimize known harm, and to maximize the good were challenged by the University's ambitions for technological development and scientific superiority. Might a deeper method of analysis such as Eight Dimensional Methodology have helped to identify possibilities that could minimize the harms? Were these alternatives neglected or even dismissed due to ambition and the enthusiasm to move forward? Or were they simply not considered? Is there a reason, in terms of ethical responsibility, to even find and consider alternatives, despite the sacrifice of time that process may involve? Or, should the ambitions of technological progress be viewed as more worthy and fruitful than listening to and adjusting to the voices of a few, seemingly disgruntled Native Americans?

The eight dimensions are designed to stimulate creative thought and new possibilities, ideally before, but also after the fact. But sometimes, those new possibilities must be cast out due to ethical complications. Consider, for example, what may occur if the large telescope were designed to appear mysterious and odd, beyond human comprehension (like the pyramids) such as was suggested in the dimension, which makes the familiar strange. This may offer a solution to devise a mystique that would keep people at bay, and give the project protection from the expressed fears and practical concerns of ordinary, lay people. On the other hand, that particular solution presents alarming moral problems. Deception always carries a moral burden. Nevertheless, as an element of Eight Dimensional Methodology, that one new solution itself opens up ideas for other solutions. And that is exactly the point: the process asks

the thinker to abandon all judgment of what is right or wrong, affordable, feasible and practical, even moral, in order to create a process where ideas flow freely and unencumbered. As for the end result of the Mount Graham Large telescope Project, it is not our place to judge whether the decision of the University of Virginia was ethical or not. We do suggest, however, that the Mount Graham project may be proceeding with less perceived harm had its decision makers been taught to use such a process.

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APPENDIX A — The Eight Dimensional Methodology

Unifies existing problem-solving knowledge, techniques and solutions from different disciplines Engineering and technology, Inventions, Business and Marketing, Industry, Math and Science, Art, and Daily life. Well-known methods like Analogy, TRIZ (A Russian Acronym for Theory, Solution, Innovation, Problem), SCAMPER (Substitute, Combine, Adapt, Modify, Put to other Uses, Eliminate), Lateral Thinking, are part of it.

It is discipline independent. The nature of its construction implies that it can be used to generate ideas for problems from Engineering to Business to daily life.

- Comprehensive and systematic thus allows anyone to be creative in the idea generation process, a key step in innovation.
- Stimulates thinking by focusing on eight different problem-solving strategies… one at a time.
- Generates many out-of-the-box & high quality ideas in a short period of time
- May be used by individuals/teams anytime. It is in particular useful in increasing efficiency in both quality and quantity of brainstorming and similar team setting methods.
  In addition, it allows individuals to generate ideas even when their minds are "too tired to think."
- Reduces and even eliminates psychological inertia. It reduces the well-known scenario of dominant "bully" individuals that control brain storming sessions and shut off any creativity attempt by other participants. Unexpected and "crazy" ideas may be awarded or blamed on the method. No finger pointing.
- Easy to learn and to use. After all who wants to learn or use a complicated method?
- It should be emphasized again that the methodology focuses ONLY on the process of idea generation step of the problem solving process.
  In addition, it is important to clarify that it is **not** a problem-solving cookbook.

The Eight-strategies

The strategies for inventive and innovative problem solving are pictorially illustrated next. They can be used in any order to solve problems. They provide directions for thinking, thus allowing the use the left and right modes of the brain. The related sub-strategies are listed next.

1. Uniqueness
1.1 Discover what does not change
1.2 Compare characteristics/features
1.3 Look for unique and ideal solutions

2. Dimensionality
2.1 Start with less
2.2 Start with more
2.3 Manipulate time/space/cost dimensions and structure/topology/state
2.4 Reduce details
2.5 Duplicate it/ Repeat it

3. Directionality
3.1 Take it the other way around
3.2 Direct it
3.3 Change your point of view

4. Consolidation
4.1 Combine
4.2 Make it multi-purpose
4.3 Use multi-meaning/ ambiguity

5. Segmentation
5.1 Learn to share and manage resources
5.2 Segment/cut (in space/time)
5.3 Separate

6. Modification
6.1 Rearrange
6.2 Extract/pull6.3 Substitute/exchange
6.4 Add/ Subtract
6.5 Change
6.6 Self Modification
6.7 Add something in between
6.8 Localize
6.9 Take partial or overdone action
6.10 Automate It
6.11 Purify / mix
6.12 Make it more personal

7. Similarity
7.1 Look for Pattern/Rule
7.2 Look for and use analogy
7.3 Make it similar

8. Experimentation
8.1 Work it out
8.2 Estimate/Guess
8.3 Be prepared for serendipity

APPENDIX B — Full Text **—** "UVA will Invest in Controversial Telescope Project," by Eric Swensen, *The Daily Progress*, December 12, 2003 *(Reprinted with permission).*

Over the objections of many American Indian groups, the University of Virginia announced Thursday that it will invest $4 million in a consortium that will operate three telescopes on an Arizona mountain considered sacred by Western Apaches.

The planned creation of an American Indian advisory council to help guide future development of Mount Graham and UVa's pledge to provide more educational and employment opportunities for American Indians did not satisfy opponents of the project, one of whom called UVa's decision "absolutely abominable."

"I'm very pleased," said Robert T. Rood, chairman of UVa's Astronomy Department. "It's something a lot of us have put a lot of effort into, checking out and trying to set up the arrangements".

The decision caps an eight-month public debate over whether UVa should invest in the telescope consortium that pitted American Indian and environmental groups opposed to the telescopes against proponents in the university's Astronomy Department.

Citing Mount Graham's key role in their religious and cultural life along with environmental objections, Apache tribal leaders and activists have urged UVa not to invest in the consortium. In May, nine environmental groups led by the Sierra Club sent a letter to UVa President John T. Casteen III asking the school not to pump money into the project.

Rood has countered that the environmental objections are overblown and that the telescopes on Mount Graham take up a small portion of the mountain, adding that access to a large telescope is needed to make UVa's Astronomy Aone of the nation's elite.

Late this summer, Block appointed a five-member faculty panel to examine the issue and make a recommendation, which UVa administrators followed closely in making their decision.

The committee included an astronomy professor supported the project. It also included the chairwoman of UVa's Anthropology Department, who had said earlier in the year after visiting Mount Graham as part of a UVa delegation that she could not support the project unless the University of Arizona, which leads the consortium, gave Apaches greater say in the future of the mountain's development. The University of Arizona has had a long-running battle with Apache tribes and activists over the Mount Graham telescopes.

In a report dated Sept. 12, the committee found that the telescope project "is of vital importance to the University of Virginia astronomy program."

"An exhaustive review of opportunities to take part in the programs for other large telescope projects reveals no opportunity combining the [Large Binocular Telescope's] capabilities generally and the match of its specific instrumentation to the research interests of the faculty," the report said.

The report also noted the "variety of serious objections" to the Large Binocular Telescope made by opponents of the project and that the decision "presents serious, and not easily negotiated, issues of competing values based, often, on different cultural assumptions."

"At the same time, we emphasize that a withdrawal by the University of Virginia at this late stage in the project would be entirely symbolic," the committee said. "The telescope will remain on the mountain; another university or research consortium will claim the brief time-share our astronomers are seeking."

The committee concluded that withdrawing from the project would be devastating to the Astronomy Department. The symbolic benefits of withdrawing would be difficult to determine, meanwhile, "not least because there is already some evidence that the universities concerned have begun to change for the better their relations with Native American communities."

So the committee recommended approving UVa's investment in the consortium, conditioned on the creation of an advisory committee to give American Indians a greater say in Mount Graham's future development.

Also included were recommendations that UVa aggressively recruit American Indian faculty and students and work to set up cultural and educational exchanges with Apache tribes...

Unsurprisingly, telescope opponents were dissatisfied with UVa's decision.

Robert Witzeman, a member of the Mount Graham Coalition, derided the importance of the advisory committee.

"An advisory committee could be anything," he said. "It would have no significance under law."

"There's nothing short of removal," Witzeman added, that would satisfy the Apaches.

Michael Nixon, an attorney who represents the Apache Survival Coalition, angrily denounced the decision.

"The University of Virginia should be ashamed of being so selfish," he said. "I have serious doubts whether this decision would be supported by the Board of Visitors or the people of Virginia, who are well known throughout the world for their respect for religious beliefs."