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

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Abstract

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 particular classical approaches such as principalism and stakeholder analysis, students are given a theoretical framework for analysis of the case, as a way to find answers to 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.

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.

Dr. Daniel Raviv, the engineer who developed the Eight Dimensional Methodology, and paper co-author, technology ethicist Dr. 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. 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. The LBT project will soon mark the erection of the worlds' 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.

The Apache leaders have been outspoken about their protest over the project, and clear that the project threatens the sanctity of their sacred rituals and worship. The Apache leaders have pleaded to have the project abandoned. As presented, the case features the University of Virginia, and its challenges in consideration of the whether and how to join the LBT project consortium. The University of Virginia wishes to secure its position as a world-class astronomy research partner, and feels it needs to join the LBT project consortium in order to do so.

Analysis of the case offers to decision makers the use of the Eight 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.

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 particular classical approaches such as principalism and stakeholder analysis, students are given a theoretical framework for analysis of the case, as a way to find answers to 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.

This paper introduces the Eight Dimensional Methodology for Innovative Thinking (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 students who are learning how to address everyday problems faced in the workplace, by helping them to see otherwise obscure alternatives and solutions.

The second co-author, the professor who developed the Eight Dimensional Methodology, and technology ethicist (first co-author), suggest that this tool can be especially useful in teaching students how to identify solutions and alternatives for particular problems of engineering, and for the ethical challenges which arise with them. First, the Eight Dimensional methodology helps to generate many out of the box, innovative solutions, in a short period of time. In addition, it offers to the engineering student a methodology for penetrating and seeing new dimensions of those problems.

To demonstrate the effectiveness of Eight Dimensional Methodology as an analytical tool, and then for thinking about ethical challenges to engineering, this paper presents the case of the construction of the Large Binocular Telescope (LBT) on Mount Graham in Arizona. 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 of land. The 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 department of Astronomy, the site was selected from a survey of 280 potential mountain sites because of its high 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.

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. The LBT project will soon mark the erection of the worlds' 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.

The University news officials report that in the mid 1980's 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' Methodology (See appendix and references 6 & 7 for full explanation.)

Here is how it works:

The user explores solutions in eight different thinking directions, one at a time. In each direction ("dimension") the user is guided through multiple questions or suggestions that stimulate his/her mind in sub-spaces in which solutions may be found. These thinking dimensions are: Uniqueness,
Dimensionality, Directionality, Consolidation, Segmentation, Modification, Similarity, and Experimentation. The user may choose to use them at a very high level by asking only eight different questions, or at deeper, more detailed levels of specific sub-strategies.

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 ideas, which broaden and expand the possibilities. The purpose is to generate as many ideas as possible all kind of ideas, in a short period of time. In doing so, we open to a new set of solutions which otherwise might never have been thought of.

The Eight Dimensions' questions

The user may choose to explore solutions at a non-detailed, high level, by asking the following eight questions:

1.) Uniqueness:

What is unique about the processes, objects, features or situations? Could these observations be used to find solutions?

2.) Dimensionality:
What could be done with space, time, cost, color, temperature, or any other dimension?

3.) Directionality:
Could things be done from different directions or points of view?

4.) Consolidation:
Would it be helpful to consolidate objects, concepts, or processes?

5.) Segmentation:_
How could segmentation of solutions, concepts, processes, resources, objects, or dimensions help?

6.) Modification
What if modifications to the existing situation are introduced?

7.) Similarity_
Why not look at similar concepts, problems, principles, solutions, patterns, and processes?

8.) Experimentation_
Could estimating, guessing, simulating, or experimenting help?

The ideas generated for this particular analysis, as highlighted in this paper, took one half hour over the telephone, in a conversation between the two authors; one who is unfamiliar with Eight Dimensional Analysis, and other, its creator. It is a very efficient and accessible method for generating ideas. We also used the Eight Dimension sub strategies as detailed in Appendix A.

<u>Uniqueness</u>

Our analysis looks specifically at the problem: what may have been the University's alternatives for locating an optical device to be used for space exploration? One reason for pursuing alternatives is that the currently planned location, considered to be sacred by the local, native Apache people, challenges the engineering ethics decree to increase good while minimizing known harms. The process of generating ideas, which will lead to varied other solutions, begins, then, with the question of uniqueness. One sub-strategy of uniqueness is, "what does not change?" No matter where they put the telescope, it does not affect the dimensionality of what is being measured. This means that theoretically the new optical device can be put anywhere (taking into account some obvious constraints). _

Two details of considering uniqueness are to compare characteristics and features, and to look for and use unique and distinguishing features. Since the suggested site is considered to be sacred by the local group of people, one may consider alternative locations. For example, can the optical device be constructed at a different elevation? How about at a different place on earth? As it stands, the project is part of an established collaboration, and is likely to happen with or without the University of Virginia.
Since the suggested site is considered sacred by the local native features, this is unique

about this particular location. It should be used in the ideation process.

Another element of the uniqueness dimension is to magnify the difference, in this case, to look at the differences between the suggested site and other sites. Can the goals and ambitions of the project be accomplished differently, without compromise? Perhaps other locations fail to offer the comparable clarity of resolution, ability to take pictures as regularly, and the accessibility of this one. Therefore, it may have clear and strong advantages over other sites. But if we look at alternatives, perhaps there are other sites still that offer these and more advantages.

Ultimately, the uniqueness dimension prompts looking for unique and ideal solutions. An ideal solution should take no space, will have no cost, and will be achieved in no time. To achieve a solution, which will be as close as possible to the ideal one, one may ask: Can we avoid the whole project and achieve the desired results using existing devices? For example, can existing stationary telescopes (located on earth) be used, and/or can we use existing or a modified space telescope, or use existing (or new) satellites to mount the device, or place an optical device on the moon, a shuttle, or on the surface of the ocean? These solutions may solve the problem, and could be close to ideal. If we had a chance to start all over again, how would we approach it, what would we do? How do we explore space without offending the native people who are physically and spiritually connected to the land? Each of these questions and ideas come under "Uniqueness," the first of the Eight Dimensions.

Dimensionality

In considering the problem from the element of dimensionality, the second dimension, the basic question is 'what can we do with dimensions?' What could be done with space, time, cost, color, temperature, or any other dimension? First, we can start with less. Can we do something on a smaller scale, not as rigorous? Or, is there a way to focus on solving a special case, or several special cases? So, rather than having a telescope which can do everything, can we focus our efforts on a few particular features to be measured? Such as brightness of stars, the relative angle between two stars, orbits or distances from the earth.

New and novel alternatives may arise if we explore or partition objectively, another feature of dimensionality. Maybe we can have several different small telescopes instead of one big one. We can partition the major tasks of astronomical observation into several small subtasks, each taking care of a portion of the larger research questions, such as segments of space, or particular solar systems, individual star clusters, particular planets, etc.

We can also consider what is possible if we start with more, looking at the global picture. It means, do we have a direction in which to look globally, instead of at details? Can we achieve the same goals by looking globally? Sometimes observations of the overall, and larger picture, can achieve the same or better results as looking at the details. A global view may open new understandings not originally thought of.

Perhaps there are multiple solutions yet to be considered: many more devices, many different mountains, a series of many telescopes stretched from the North to the South Pacific? And what happens to our thinking about alternatives when we expand consideration to beyond those disciplines most obviously connected to astronomy? Perhaps if the project were to include astrologers, life scientists, anthropologists, and cosmologists, new solutions to the project's problem would emerge. Or, if project members were to reconsider what it would mean to team-up with others, new thinking could be included. The team function is already a feature of this project, but with a twist, it may also be a solution to be considered. Perhaps there are interested other institutes or tribes, or universities. Any group, any configuration may be possible.

Manipulation of time/space/cost dimensions and structure/topology/state provides yet another perspective from which to consider alternatives to the problem. We have assumed the optical device should be on a remote mountaintop, when maybe it could be in the Grand Canyon! Or, in a desert! Taking it to the extreme stimulates new ideas. And changing the temporal dimension asks new questions of what may be possible. Perhaps instead of a permanent structure, they could build a device, which is used only one time, or is disposable. What about if it is longer a stationary device, but rather something that moves from one location to another. We don't know the specifics, but maybe there is some way for the telescope in question to be a mobile device. No longer would its use be limited to a particular mountain, but then it would be able to be moved from one location to another, and get different points of view. The mountain will not be there to be used forever.

Adding a dimension is interesting. What if they could add a feature, which allows it to leave the ground, and fly? Or, suppose it would be possible to make it invisible, either through a material that is barely perceptible, or a color, or surround it with greenery, such as trees, which hide it totally from external view? If a dimension were to be eliminated, what would be possible then? Making it stationary eliminates the motion and time dimensions. Then you can explore one dimensional image array instead of a two dimensional image. Moves from two dimensions to one can focus on a very narrow point in space.

Reducing the details offers yet another way to consider dimensionality. For example, momentum can make a difference, so; perhaps the optical device can be placed on a satellite that takes photographs at accelerated speeds, which may give photographs with very high resolution. This would be similar to techniques used in image processing. Also to be considered is the possibility of continuing with useful actions. If some telescopes somewhere are going to be dismantled or are considered to be obsolete, maybe they can be retrofitted with new elements and reused in their current locations. That way, features of existing telescopes on established land could be used to address the goals of the new project, implemented in different locations.

Directionality

In thinking about directionality, maybe it is possible to find a new way to get the same results. Telescopes are usually based on visual information, what you see is what you get. But there are ways to use indirect measurements to gather astronomical information. Maybe for space exploration, we can use the measurement of wavelengths in the spectrum, or vibrations to find and measure patterns in space. Using the eight dimensional analysis does not tell us exactly which ways are the best, but the point is to ask, are there ways to achieve the same thing, perhaps using non-visual information?

One way to approach that question is by taking it the other way around. Suppose you want to measure the volume of a bead, but you don't have a measurement device to do so. You can, however, put the bead into a cup of water and measure the amount of displaced water. Then, you can determine its volume. In the case of the Mount Graham, Large Binocular Telescope, an alternative solution can arise from a similar approach. How about using a mirror to provide new points of view? They could use a mirror to look at reflections of space objects, looking at the mirror rather than directly with an optical device. Similarly, new ideas arise when one changes one's point of view. Instead of the focus of research being on what's out there in space, perhaps the focus could instead be to look at the effects of the stars and the moon and their positions on the tides of the ocean, rivers and on the wind currents across the deserts. Perhaps the point of view can be shifted from outer space, to looking back onto the earth itself, and its relationship with what there is in space.

A complete change of point of view, or consideration of others points of views, can be particularly effective in generating new ideas for alternatives in such as problems as the Mount Graham project. One could add in to the possible solutions consideration of other stakeholders, such as the local Apache people, the community at large, state and local government, area children, other religious organizations, special interests groups such as environmentalists, all kinds of lobbyists.

Consolidation

Consolidation, the 4th dimension posed in the Eight Dimensional Methodology asks 'would it be helpful to consolidate objects, concepts, or processes?' Maybe the Mount Graham site can be designed as a temple for worship, or given an enhanced environmental feature. Maybe it can be designed to be a sign of a particular religious icon, or mythical figure, significant to the Apaches. Maybe it can contain a lodge for ceremony that also connects with the Apaches beliefs about the stars and celestial bodies. Maybe it could be an educational facility for local tribe members and their children. Maybe the new device becomes a tourist attraction, with profits being donated to the preservation of Apache traditions, or to purchase and preserve the future use of the land for the Apache people.

In consolidation, new combinations of solutions are made to open up alternatives. For example, as mentioned earlier, many of the same optical devices can be used in multiple locations. Or, use can be made of many different types of devices in multiple and distinctive locations.

Some words in English may have ambiguous meaning, when written in particular ways in a sentence. In a similar way, consolidation can be used to make particular solutions ambiguous, giving multiple meanings and multi-meaning enhancing ambiguity for the sake of generating new ideas. In other words, when meaning or particular language is changed, or used in new and novel contexts, original meanings are removed, allowing for new understandings, attitudes and perceptions to emerge. So, if the Mount Graham Large Telescope project is renamed, or redefined not as university collaboration for space observation, but as a community based education facility, or a religious temple for space exploration, or a wilderness space center, or a human-heaven connector, then the possible ways of perceiving the project also change.

<u>Segmentation</u>

The questions of segmentation involve the use of existing resources, objects, materials, energy sources, functions, information, space, time, and budgets. It has to do with whether we can use what we have already to solve the problem. In this case, can the moon, space stations, satellites, other telescopes, be used for the same purpose? Or, might there be a way to share space and time? The facility might be made available to the local people, for example, on Tuesday, Thursday and Saturday, for use as a shrine. On Monday, Wednesday and Friday, it is run as a telescope for scientific investigation. On Sunday, it becomes a nature preserve, with educational tours of habitat and wildlife.

As the current solution stands, parties involved are losing. The University is losing good will. The Apache people believe they are losing their sacred land. Sharing space and time opens ideas for solutions where both parties have gained something over their current position. Segmentation provides a similar alternative. For example, past couches were standard in length and shape. Then, L or U shaped and segmented couches were introduced. Today, one can have a loveseat, full sofas, and modular matching chairs, allowing you to rearrange the set as desired. Or, you can buy a sofa that comes apart into sections. Both possibilities expand what can be done with cleaning, and rearranging for particular functions. Perhaps rather than building the telescope as designed to be one device, it can be built in segments, or built to be separated and used as smaller parts.

<u>Modification</u>

What, if any, modifications to the existing situation might be introduced? Maybe rearrangement of the existing structure would help. Currently on the mountain, there do exist research structures that have been used for observations. Maybe before this newest, larger device is installed, the current devices might be rearranged. Or, if the project is overly ambitious, and trying to achieve that which is not needed, then they can extract what is not necessary, unnecessary elements or disturbing parts.

Another alternative to consider is a substitute or exchange. Instead of an optical device, perhaps they might exchange it for something else. Maybe something like a flying device, which shoots up from underground, goes out into the sky, takes millions of photos, and then returns to its underground station. While this may seem like a wildly outrageous idea, it may lead to alternatives in terms of the design of the structure, building and device, as well as to the way things are being measured.

It is also important to ask questions about how known harms might be converted into benefits. For example, one of the best ways to deal with the potential harms of fire is to use fire. Before the big forest fire comes, use of a controlled fire can assure that when the real fire comes, it will not burn out of control, because space has been created where there were once trees. This converts potential harm in to benefit. In the case of this large telescope project, the question of conversion of harm into benefit asks, 'how does the fact that we are building something that is harmful, can be used as a benefit to the Apache? Making the site into a temple, or classroom, or lodge may offer a benefit. Maybe the place will not even have to be occupied, which may address some of the concerns of the Apache. Or, how about if something is added in between? For example, if you have two people standing next to each other who want to be one millimeter apart without touching each other, how can they do it? They can put a newspaper in between them. In this case, we can put something between the actual sacred, mountain land, and the telescope itself. Such as a pocket of air, tress, water, or other another layer of land. Alternatively, they could take partial or overdone action. Maybe rather than a collaboration, more can be done with other universities elsewhere. Or, fewer can be involved in this particular project. Automation offers another alternative. If they eliminate the need for people from the whole process, so the whole telescope can operate by itself, it may be a good solution for some.

Making the design of the project more personal offers solutions for others. Increased communication between the different parties, with say, regular meetings during the design phase, which include the individual members of the local community, personalizes and makes the whole thing more accessible.

Similarity

Similarity, the 7th dimension leads to the alternative of finding other science projects where native peoples have objected, and learning from those cases. Can something similar, a similar case, for example, of conflicting interests of stakeholders help the University to learn and think of new ways to solve the problem? Recalling the same or similar problem/goal; recalling a concept or a path of thought and adapting it; recalling and combining two or more other relevant ideas; are among the ways to approach similarity, in searching for alternative solutions to this and other engineering problems.

One obvious but shunned alternative is to temporarily skip the problem. What happens if they put the project on hold, for now? Or, totally ignore the problem, and proceed. Or, how about making the strange, familiar? This particular technology may be strange to the local people. One solution is to educate them to its purpose and values. Conversely, it may solve the problem to make the familiar, strange.

Experimentation

Finally, Eight Dimensional Methodology looks to questions of experimentation. How can the problem be worked it out? Can the large telescope be tried on a smaller scale, to see what happens before going all out with the large-scale project? Can it be given a year, and then reconsidered as to whether it should go forward. Can a simulation be run, with input gathered from many, in order to learn what people say? Estimates and guesses can be used to gage the results and effects of the project. What if they were to put together different scenarios and guess at what would happen with each? This is the place in Eight Dimensional Methodology where we try to anticipate potential problems and avoid them by estimating, simulating, guessing, etc.

Of course, sometimes things happen by themselves. Perhaps if nothing is done, someone else will do it. And, serendipity also has its place. But we must be prepared for it, and observe for it.

Using Eight Dimensional Methodology, a number and variety of solutions have been generated for the Case of the Large Telescope at Mount Graham. Perhaps many of these solutions were being considered in the process of making a decision. Now its time to ask, 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 has been formed to attempt to stop construction of the LBT. This group includes 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 Department of 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."[1]

In October of 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 an dim light, with Apache's calling UVA lack of support "absolutely abominable" and UVA representatives quoted as being "very pleased" with their own efforts. (See appendix for full text of article). And, it communicated to the larger community and general public just how very 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 whose who oppose the project?

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[1] Swenson, Eric, "UVA will invest in controversial telescope project," The Daily Progress, Wednesday Dec 18, 2002.

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 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 them over this claim may seem prudent 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, as be asked and addressed in the engineering science, before the decision process itself begins, 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, under 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. Never the less, 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.

Conclusions and Next Steps

Thinking creatively through possible solutions to cases such as the Mount Graham project is critical in the process of engineering education. We suggest that the Eight Dimensional Methodology offers to both students and professional engineers a deepening process to approach such cases, by bringing to light alternatives either never considered, or otherwise unimaginable, or prejudged as too outlandish to ever be considered.

Engineering students are regularly presented with problems requiring technical solutions Creative problem solving, either individually or in teams, usually leads to a number of possibilities that might be pursued through actual design and implementation. But the student's ability to think broadly and creatively in that initial imaginative process is sometimes limited and hampered by the self-imposed or external factors. The Eight Dimensional Methodology for problem solving offers to the student and instructor a tool for looking at many different solutions to be considered, before placing limitations or restrictions on the creative process itself. For example, the Eight Dimensional Methodology could be incorporated into Capstone projects in the proposal stages of development. Obviously, not all solutions that are thought of as a result will be feasible, affordable, efficient, or even materially possible. That is not the point. The goal is to mentally stretch and stimulate the engineering student towards thinking creatively about problems, towards realizing the vast possibilities of many diverse and otherwise unconsidered solutions.

We encourage faculty members to consider adoption of this process in technical courses, where students are challenged to think about solving problems. And, that in addition to the technical considerations, which are inherent in any engineering solution, those educators ask of students how each solution imagined might help to elucidate or speak to ethical problems, which can sometimes be encumbrances in sound engineering design.

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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, SCAMPER, 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.

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 *department one 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 who 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."