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Speaking Tech to Power:
Moral Reasoning for the Engineer's Role in Public Policy

The policy role of the engineer must grow as our nation and the world increasingly turn to technology to solve societal problems. To be sure, the capacity to create innovative technical solutions remains essential. But for those engineers who seek to contribute fully to the common wealth, technical problem-solving alone is no longer enough. In addition, they must engage with the policy process to ensure that the ethical considerations surrounding any technology reinforce rather than diminish its potential for good. The history of technologies ranging from nuclear power to genetically modified crops demonstrate the perils of neglect.

Public involvement, however, adds ethical and value judgments to engineering design in stronger measure than would derive from technical and economic considerations alone. And so, by introducing ethical decision-making into the engineering curriculum, we educators can better prepare our students to serve as "public citizens." In particular, I suggest that three perspectives can serve as a framework for moral reasoning in decisions regarding design or technology:

- a rule-based reasoning process, termed *deontological*;
- an outcomes based process, termed *consequentialist*; and,
- an *aspirational* frame, where ethical judgment springs from the kind of human being the decision maker seeks to become.

These have been proposed for other professions,[1] both to teach moral reasoning and for career-long application. They could serve engineers equally well.

Ethical Values in Engineering[i]

The engineering profession has done well in creating the tools of a modern society. The instruments of our material prosperity—computers, airplanes, dental procedures, power plants, and the like—function reasonably well despite our occasional grumblings, and only the most ardent lunatic would really wish to have, say, his dentistry done with the methods of the 19th Century.

But the public interest also brings with it performance requirements that reach beyond the functional and into the domain of ethics. A simple thought-experiment can illuminate this. Imagine a society in which human life holds no value. Even in such a world, cars would have brakes. Drivers that cared neither for their own lives nor for the lives of others would still find it inconvenient to stop by running into trees. However, a society that held life to be precious and implemented that view in its public policies would

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[i] This paper focuses on the content to be taught, leaving plans for integration into the engineering curriculum for separate discussion.

require very different brakes on its vehicles than one that did not. Thus understanding the ethical foundations of policy leads to better engineering.

In our more complex society, we ask more complex questions in setting the societal expectations for government policies to implement. For example:

- Is the technology "fair" in the balance of risk and reward that its use imposes? For example, critics note that the tall stacks that carry pollutants away from a power plant simply deposit those pollutants on a different set of "victims."
- Does the technology promote a just society? For example, the arguments for "soft path" technologies advanced by Amory Lovins and others in the 1970s criticized the centralization of authority that nuclear power would require. In contrast, early proponents like Alvin Weinberg saw no difficulties with the rise of an elite nuclear "priesthood" to manage the technology.
- Is the technology inherently and uncontrollably dangerous? Opponents of genetically modified foods have made these arguments, and the opponents of nano-scale technology—for example, Michael Creighton with *Prey*—are beginning to do so.
- Are the risks of the technology being managed in a way that properly considers the values and ethics of the society in which it is embedded? Arrogant bureaucracies can kill a technology, as the case of the R-101 (below) shows.

Such ethical dimensions create the foundation for public intervention in the course of new technology, both to promote some technologies—solar power, for example—and to regulate others—nuclear power, for example. To participate most effectively in these public processes, engineers must assume ethical duties and develop skills in ethical reasoning as the engineering profession becomes increasingly accountable for public welfare.

Toward a Framework for Ethical Reasoning

The full concept of *ethical reasoning* reaches well beyond the bland admonishment to "be nice." (To be sure, none of us knows what "nice" really means—unless, of course, the concept applies to ourselves, in which case the meaning can become quite specific.)

More fundamentally, however, the ethical choice is unlikely to please all parties, and often requires the decision maker to be un-nice to someone. This poses difficult choices, and a more formal framework can sometimes help. Such a framework for ethical reasoning would include two basic elements: the analytical and the judgmental.[2] First, I will speak to the analytical component—presumably the sweet spot for the engineering mind—and later address the judgmental component.

A Framework for Ethical Reasoning: the Analytical Component

In an ideal world, the engineer—here presumed to be the one making or advising the decision—would understand all the options and the consequences of each. To the extent that such understanding cannot be achieved, the foundation for ethical choice must change because the decision maker cannot see the full implications of choosing one option over another. It serves better, however to start with a simpler case, one in which the analysis yields straightforward results. The story of the R-101, a needless and preventable airship disaster, illustrates this well.

Foresight and Disaster: The Case of the R-101

Engineers can influence the success of public policies by their assertiveness and skill in ensuring that technical judgment receives due weight in the implementing decisions. Yet as a practical matter, meaningful risks to employment, career, and reputation attend this assertiveness, and the question of when an engineer has done his or her duty ranks high among the ethical considerations of the profession.

Consider the case of the R-101, the air disaster that effectively ended Great Britain's participation in lighter-than-air transport. On a rainy Autumn morning in 1930, the R-101 nosed into the ground on a ridge in France. The crash itself occurred at low speed and so appeared relatively benign; but the hydrogen gas ignited, and 48 of the 54 persons aboard perished, including many of the design team.[3] The way that this happened illustrates a crucial intersection between policy and professional ethics.

The British airship program was born of three policy imperatives: (1) developing the military potential of airships; (2) using air transport to knit together a fraying global empire; and (3) competing with rival Germany in the commercial air business. To achieve these ends, the Labor government of Ramsay MacDonald developed the "Imperial Airship Scheme" in 1924. As a part of this policy design, the government sought to establish air service between England and India. Airplanes, however, were generally incapable of extended flights, and so the airship became the only option that could deliver immediate results. To implement this policy, the government chose a contest in which one airship would be developed by the Air Ministry, and another by private enterprise. The winner would be awarded the air route to India.

The private competitor, the R-100, would be built by the Airship Guarantee Company, a special-purpose subsidiary of Vickers, Ltd. The public entry, the R-101, would be supervised by the Air Ministry and constructed at the Royal Airship Works at Cardington.

When the initial flight trials were conducted in 1929-30, neither ship performed as well as had been expected, though the R-100 appeared slightly superior. On August 1, 1930, the R-100 completed its maiden trans-Atlantic voyage from England to Montreal, Canada, arriving 78 hours after departure. (Canada was chosen as the initial destination for the R-100 because the engines were gasoline fueled, which was thought at the time less adaptable than diesel fuel for tropical use.) The return flight was completed in an astonishing (for the 1930s) 58 hours.

In the meantime, the publicly-funded competitor, the R-101, had endured a series of technical setbacks. Most importantly, the R-101 lacked “disposable lift,” the ability to carry more than its own weight—the design had contemplated a disposable lift of 50 tons, but only 35 tons was actually achieved. In part, this derived from a design choice: the use of diesel engines, which offered a flabby weight to power ratio and proved unreliable in operation. To add lift, a new 35-foot section was inserted, making the total length an awkward 777 feet. In addition, stability problems plagued the R-101, a consequence of its lack of lift and the insufficient reach of its fins into the airstream. The airship suffered a propensity for uncontrolled dives, nearly plunging to the ground during its flight at the Hendon air show in 1930. Its hydrogen gas bags also developed numerous leaks, perhaps attributable to defective valves, and thus the airship tended to lose lift in flight. And finally, the rubberized compound used to treat the fabric covering the airship appeared to degrade the underlying material—even in the mild summer weather of 1930, the skin of the airship developed chronic rips. The implications of these defects for a craft about to undertake a transcontinental flight were ominous.

At the same time that technical difficulties mounted for the R-101, the urgency of the competition drove the government team. The Labor government saw the R-101 as a demonstration of the superiority of publicly-developed technology, and thought themselves engaged in "...a great experiment of national importance, too great to be entrusted to commercial interests."[4] Thus, the flight schedule for the R-101 was to be maintained despite its technical problems, which were swallowed up in the “can-do” attitude of its designers.[5]

The only dissenting voice came from an F. McWade, chief inspector for the Aeronautical Inspection Directorate, which held the authority to grant the R-101’s certificate of airworthiness. Apparently appalled at the condition of the airship, McWade wrote directly to the Air Ministry Office in London, pointing out the seriousness of the situation. However, his supervisor did not pass the memo to the secretary of the Air Ministry, but rather sent it to the director of development at the Royal Airship Works, one R. B. Gilmore. Thus, the first formal sounding of alarm was sent to the party charged with keeping the R-101 on schedule. In response, Gilmore returned a soothing memo claiming the problems well in hand, and McWade’s warning never reached the Air Ministry. McWade’s supervisor counseled that he should pay attention only to the execution of the plans then in place, which advice McWade apparently took. Content that his duty had been fulfilled, McWade dropped the matter.[6]

With the clarity of hindsight, we can see the ethical failings of this process—willful failure to follow the technical evidence where it led, a contentment to let others assume the risks of flight in an airship that could not receive an ordinary airworthiness certificate, and the use of rank to overrule legitimate technical concerns. And so the R-101 did indeed depart England on schedule, and its crash ended the British lighter-than-air program. After the official inquiry into the R-101 disaster, the entire program was cancelled, the Royal Airship Works closed, and the more promising R-100 broken up for scrap.

In the case of the R-101, the evidence was clear and available at the time to anyone who cared to look. But in many other instances, the analysis is not so straightforward, and engineers must build their conclusions on a more subjective basis—indeed, on a foundation that blends with the judgmental component of ethical reasoning, which I will address subsequently.

<u>The Conclusiveness Problem: Allowing for Uncertainty, Ambiguity, and Ignorance</u>

When the evidence and analysis lead to clear conclusions, as with the R-101, the chief ethical questions concern the duty of the technology expert to ensure the implications of his analysis weighed sufficiently in the decision at hand. But in other cases, the technical evidence remains mixed, and no amount of research is likely to clarify it before a decision must be made.

Consider the current debate over anthropogenic causes of global warming, for example. Time and research will indeed provide the clarity needed, but only at the risk of accumulating damage while the problem is being assessed. In the meantime, the nature and extent of this damage cannot be demonstrated convincingly, and so a general policy problem arises—appropriate actions must be taken before research and analysis can show that they really are appropriate.

This policy problem springs from events outside the range of historical experience and unknowable at the time that a decision must be made. Neither the probabilities nor the outcomes of these events can be understood in advance, and so the concepts we know as "risk" fail to guide decision making.

The structure of this "conclusiveness" problem was captured in a recent analysis of risk by Dr. Shimon Awerbuch and colleagues. I will use the case of global climate change to illustrate how four monsters under the policy bed sharply limit the possibility of analytical conclusiveness:[7]

- *Risk,* where analytical conclusions are not determinate, but must be based on a probability distribution;
- *Uncertainty*, where reliable estimates cannot be made for the likelihood of the outcomes identified;
- *Ambiguity*, where the outcomes cannot be closely characterized, in some cases because we cannot imagine them and in others because such characterization depends upon the perspective of the observer, perhaps a consequence of differing institutional interests or cultural values; and,
- *Ignorance*, where neither likelihood estimates nor well-characterized outcomes enjoy sufficient credibility to guide analysis of ethical consequences.

These components of what is commonly (but misleadingly) called "risk" can be organized as shown in Figure 1 into a *full-spectrum risk space*.[8] We can illustrate the implications for conclusiveness by sorting some typical components of the larger energy/climate issue into the categories of Figure 1. Four examples—safety in power plants, oil peaking, terrorist attack, and climate change—show how this can be done and suggest the implications for ethical reasoning.

Risk: Analysis of Power Plant Safety

A modern electric generating station brings together highly energetic materials, pressurized gasses, high heat loads, and high-voltage electric energy. Neither its construction nor its operation are without risk, both to those employed there and to the general public—and for that reason, issues of safety help determine what gets built.

Power plant designers and operators have accumulated a large corpus of experience over the years. As a result, the likelihood of accident can be expressed in probabilistic terms, and the techniques of probabilistic risk analysis offer confidence that risk can be managed, even though not eliminated. Therefore, this example from the larger energy/climate problem falls within the "Risk" quadrant of Figure 1. Here, the limits of conclusiveness are set by the probability distribution, and the engineer can estimate with reasonable confidence the range of consequences of, for example, changes in design or operating practices.

In contrast, other elements of the energy/climate debate are not so conveniently characterized. Either the consequences of alternative actions are poorly understood or the likelihood of game-changing events cannot be estimated—or both. We must now turn to those quadrants of Figure 1.

Uncertainty: Oil Disruption as an Example

The world's largest oil processing facility, Saudi Arabia's Abqaiq complex, sits about 24 miles north of the Gulf of Bahrain. The entire petroleum output from the southern oil fields in Saudi Arabia, around 7 million barrels per day, flows through this facility and thence to the loading terminals at Ju'aymah and Ras Tanura. The flow of petroleum through Abqaiq is comparable to the entire United States production in 2004 of around 8 million barrels per day.

Thus, the consequences of a successful terrorist attack on any of these facilities can be understood with grim certitude. The likelihood of such an attack, however, remains obscure. Better intelligence would help, but past surprises ranging from the attack on Pearl Harbor to the destruction caused by Hurricane Katrina suggest that ample information is often available before the disaster—the difficulty lies in its interpretation and acceptance.

Thus, issues like the threat of oil disruption reside in the *Uncertainty* quadrant of Figure 1, and present the analyst with a significant conclusiveness problem. One solution is to disregard likelihood entirely and assume the worst case prevails. This often proves successful for advocates of one cause or another, especially those seeking to block new facilities or technologies—wind farms off coastal Cape Cod and nano-scale technology come readily to mind.

Though tactically advantageous for advocacy groups, a worst-case approach offers little help in analyzing the ethical consequences of a decision or issue. This is true because the sum of a society's resources will still prove inadequate to remedy all of the worst-case possibilities. Therefore, policy must select which to address and which to defer; and there is little basis for that choice in the absence of likelihood estimates.

Ambiguity: the Problem of Peak Oil Production

Ambiguity characterizes the Northeast quadrant of the risk space shown in Figure 1. Here, one can find sufficient evidence for most observers to estimate the likelihood of events, but estimates of their consequences diverge wildly.

Consider the peaking of conventional world oil production. About 72 million barrels per day (mmbd) of conventional oil were pumped out of the ground in 2004, according to the U.S. Energy Information Administration.[9] Most analysts now foresee world production capacity in the range of 100 mmbd to 120 mmbd, achievable with investments coming on-stream in the next few years. Beyond that, a decline in production seems inevitable. The current excess of price (around $60 per barrel as of this writing) over marginal cost offers evidence that world markets are anticipating this peak in conventional oil production.

Even though some disagreement remains concerning the timing of the transition from increasing to declining oil production, most geologists seem to have reached consensus that a peaking point exists. Further, reasonably available signposts—discovery rates for new fields, or projections of petroleum demand, and the like—can guide the astute observer in estimating a probability distribution for the onset of production decline.

In contrast, the possible <u>consequences</u> of a downturn in conventional production vary sharply with the perspective of the observer. On the one hand, geologists and those holding a science-based perspective tend to view the coming peak as catastrophic.[10] They warn that the downturn will be steep and that unconventional production of liquid fuels could arrive too late to make a difference. This school of thought foresees sharply curtailed economic activity arising first in transportation. Some analysts of more apocalyptic persuasion imagine worldwide economic collapse.

On the other hand, the economists' perspective contemplates a smoother transition as higher fuel prices motivate unconventional sources of hydrocarbons—coal, shale, and tar sands—to replace the conventional. At worst, this would mitigate the decline of conventional oil production; and at best it might provide for continued growth in liquid fuels consumption. This cheerful view, however, requires of the economist two implied assumptions:

- that the massive amounts carbon that would be released from unconventional feedstocks remain unconstrained, either because an acceptable way can be found to sequester them or because carbon release proves not to be a public concern; and

- that sufficient and timely investment in unconventional hydrocarbon sources will be forthcoming in response to the price signals.

Thus, the estimated consequences of the inevitable peak in production of conventional oil depend closely on the intellectual point of departure of the observer—and perhaps the institutional affiliation as well. Those seeking to analyze the consequences of events or decisions that fall within the *Ambiguity* quadrant of Figure 1 therefore face an even greater challenge than under *Uncertainty*.

Ignorance: the Issue of Rapid and Irreversible Climate Change

The prospect of climate change that occurs too rapidly for effective adjustment has long concerned thoughtful observers. To be sure, such an event would create winners as well as losers. But the latter would probably outnumber the former and would include the poorest around the globe, always the most vulnerable to environmental catastrophe.

This gloomy prospect, however, has not yet motivated effective policies in response. Critics stress that the certain costs of action today outweigh the more speculative benefits derived from protecting against a poorly specified disaster far in the future.[11] Lacking a clear and demonstrable danger, political institutions have been reluctant to take effective action.

The *Ignorance* quadrant of the larger risk space tends to dominate much of the debate over energy/climate policy. The most obvious response would be to improve our knowledge, and accelerated research on climate change becomes the beginning of policy wisdom. But learning accumulates at a slower pace that decisions, which still must be made—or not made, which also amounts to a decision. Power plants will be built—or not built. Synthetic fuel investments made—or not made...and so forth. And so decisions falling into the *Ignorance* quadrant provide the greatest challenge for the analyst seeking to discern the ethical implications of alternative courses of action.

The quality of ethical decision making for issues in which ignorance dominates the risk space can be improved with two planning tools commonly employed by strategic and financial analysts in private companies—scenario planning and real options analysis. Scenario planning does not attempt to forecast an unknowable future, but rather builds views of plausible alternative futures. Thus it provides the analyst with an intellectual platform from which to ask the question, “What would we do if this came to pass?” The methods of scenario analysis are well described elsewhere[12] and need not be summarized here. Real options analysis (as distinct from financial options analysis) complements scenario methods by enabling the engineer to place a value on alternative courses of action.[13] Both these methods warrant consideration for inclusion an ethics-based engineering curriculum.

Analytic Foundations for Ethical Reasoning in Summary

Despite the difficulties outlined above (and at the risk of some hubris), let us assume that we educators can do a reasonably good job of preparing our students for the analytical component of ethical decision making. The more difficult issues concern preparing them for the judgmental, to which we now turn.

A Framework for Ethical Reasoning: Judgment

With regard to the judgmental element of ethical reasoning, Dr. Daniel Wueste, Director of the Rutland Center for Ethics at Clemson University, recommends a framework built around three questions:[14]

- How do basic ethical principles, the Golden Rule and so forth, inform the decision?
- What would be the consequences of alternative courses of action?
- What would a wise and benevolent decision maker do in these circumstances?

These questions are stated formally as three principal types of ethical theories. The first is termed *deontological*, and under this theory ethical conclusions would be rule-based, derived from first principles. Examples include the Ten Commandments, the Golden Rule, and so forth. Actions taken pursuant to this view would spring from a primary duty to follow the rules wherever they lead independent of the consequences. Rigid adherence to the deontological principle, however, begs some obvious questions:

- Whose rules are to be followed?
- Must these rules be followed in all circumstances?
- If not universal, when does one get a pass?

To illustrate these difficulties, consider the following thought-experiment:

> You are determined to be truthful in all circumstances. Late one evening as you are dozing in your easy chair over *Principles of Thermodynamics*, a madman bursts through the door brandishing a machine gun and machete. He screams that he hates children. He asks where yours are. They are asleep upstairs. Do you tell him that?

The formal statement of Wueste's second question is called the *consequentialist* theory. Here, decisions are based strictly on outcomes, independent of any first principles. Utility theory, seeking the greatest good for the greatest number, provides the intellectual and ethical foundation. Consequentialist reasoning, however, also raises some difficult questions:

- Who decides what is good?
- How does one choose among competing priorities?
- How does one address second-order and third-order consequences?

To illustrate how a consequentialist approach might be applied, reconsider the plight of inspector McWade in the R-101 case. McWade might have reasoned that the immediate consequence of any further actions on his part would be his dismissal; and once he was gone, higher management could do as it pleased. And so, nothing he could do would save the R-101. Indeed much history supports the view that large, public institutions, especially those that have enjoyed success, respond poorly to information that contradicts their well-established policies. Consider the case of General Eric Shinseki, former Chief of Staff of the U. S. Army.

In early 2003, shortly before the launch of hostilities in the Iraq War, General Shinseki testified before the Congress that a force of several hundred thousand would be needed to stabilize the country. However prescient that might have been, Shinseki's view contradicted the Secretary of Defense, and so was dismissed by Deputy Secretary Wolfowitz as "wildly inaccurate." Shinseki's replacement as Chief of Staff was announced shortly afterward—and over a year in advance of his planned retirement, an act of reprisal that effectively neuters one as an effective player in the Pentagon's bureaucratic wars.[15] And so the Iraq War was launched with minimum force following the Secretary of Defense doctrine.

Shinseki's integrity contrasts sharply with the conduct of the Joint Chiefs of Staff in the early 1960s. Despite their best professional judgment to the contrary, the Joint Chiefs agreed to and enabled the domestic political machinations of the Kennedy and Johnson Administrations that led the nation into the Viet Nam War.[16] Inspector McWade would have recognized the problem—the consequences of ethical decisions are personal as well as professional.

The formal statement of Wueste's third question concerns being rather than doing. It asks what actions that the kind of person the engineer aspires to become would take, and hence is termed the *aspirational.* This perspective offers greatest value in addressing policy problems for which conclusiveness poses a major challenge. Reconsider the choice made by General Shinseki. His Congressional testimony drew upon professional judgment and could not be proven prior to experiencing the circumstances on the ground. Rather than hide within this admitted uncertainty, he chose to make this judgment available to the Administration and the Congress, an action one would expect from a highly principled leader.

And where benevolent circumstance provides a stronger analytical basis for decision making, it tends to force a choice illuminated by the *aspirational* framework—does our ethical engineer wish to remain a problem-solving cipher or risk his or her paycheck to pursue an unpopular inquiry?

Convergence and Limits in Decision Making

When the answers to all three questions converge in support of an ethical conclusion, the decision maker can have greater confidence that justice has been well served. But alas, that is too often not the case. Consider the following parable, adapted from one used by a medical doctor, Charles Bryan.[17]

> Hiking in the Andes, you round a bend in the trail and enter a clearing where 30 terrified villagers are being held at gunpoint by a band of drug runners. Identifying the leader of the thugs, you ask what is going on. He declares his intent to execute the villagers in reprisal for information he believes they have provided to narcotics agents. Stunned, you babble in broken Spanish about human rights to the increasingly bemused leader. “Okay,” offers the head thug, “I’ll make you a deal. If you kill one of these villagers yourself, I will let the others go free.” He loads one bullet into the chamber of an assault rifle and hands it to you. What do you do?

Here, the rule-based perspective and the outcome-based perspective differ sharply. A principled person holding dear the sanctity of life might refuse the offer. One seeking the greatest good for the greatest number might accept it, albeit with great sorrow. (The aspirational perspective might seek new options, but those are assumed to be unachievable here.)

Thus, ethical frameworks can never provide deterministic answers. However, a three-perspective approach can stimulate students’ awareness of the ethical dimensions of decisions that engineers must increasingly make. Taken together, these three perspectives have provided an effective framework for ethics analysis in the medical profession. They can do so for engineering as well, especially when supplemented by instruction in methods for analysis across the full spectrum of risk—scenario planning and real options analysis.

Conclusion: Ethics in the Engineering Curriculum

As engineers assume greater responsibilities for advising and guiding the policy process, in effect speaking tech to power, they will need greater capacity for addressing the ethical issues that dominate the public square. This brief essay has focused on the intellectual content—the material that could help develop the moral reasoning capacity of our engineering students. Plainly much remains to be resolved regarding the integration of this content into the curriculum and into the engineering profession at large. Hence, this paper might serve as the beginning rather than the end of the debate.

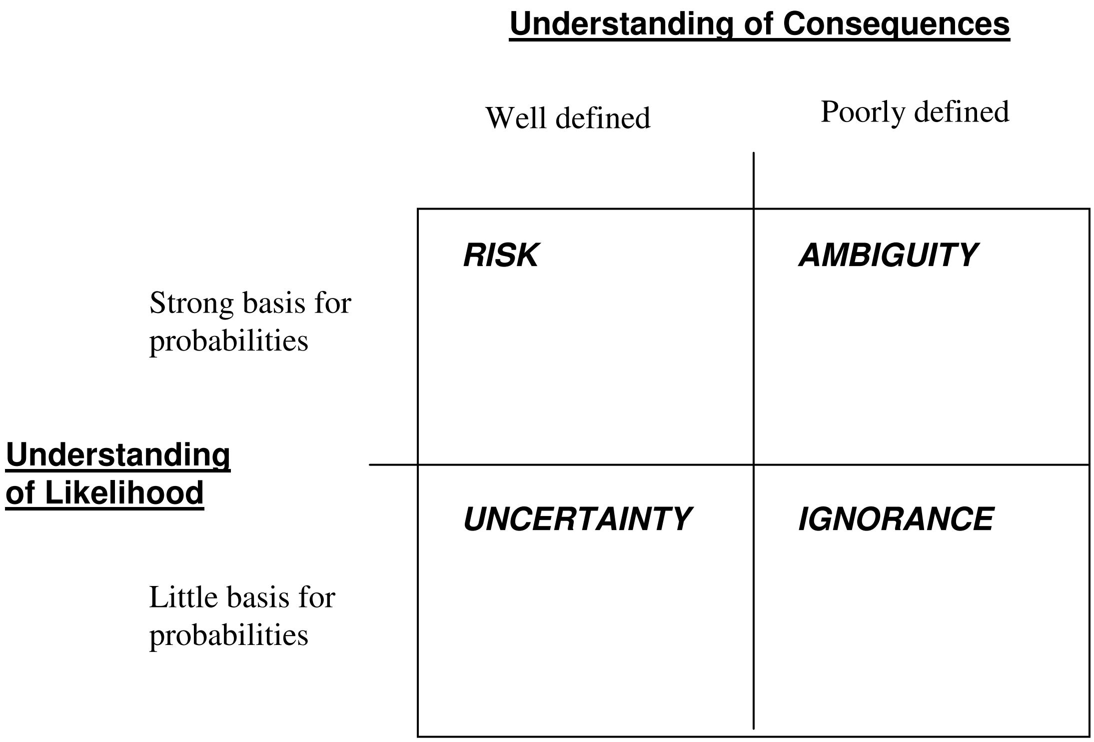

Figure 1
Full Spectrum Risk Space
Adapted from Awerbuch et. al., 2006

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