SAND2007-3905C

Unique NAVIS-based Strategy for Framing Dialog Regarding Complex, High-Consequence Systems

Jeffrey D. Brewer[1], Ph.D.; Sandia National Laboratories[2]; Albuquerque, New Mexico, USA

Keywords: decision making, public communication, risk analysis, nuclear energy

Abstract

Debate concerning the introduction or expansion of complex, high-consequence systems can quickly deteriorate into heated exchanges between supporters and detractors. The general public may then forgo benefits and/or incur costs due to distorted perceptions of these systems. This paper describes a strategy for framing communication aimed at mitigating "unhelpful biases" that hinder proper interpretation of available data, especially in domains where previous events and/or communication have led to entrenched opposition among particular stakeholders. The basic strategy involves a "risk comparability" or "first do no harm" approach in which debate begins with a "maximally practicable failsafe design" (i.e., 5–10 times the monetary costs envisioned by supporters). Less expensive, "riskier" system designs are then considered using an environmental impact statement (EIS) analogous approach. The strategy fosters trust among stakeholders by including them in cost versus benefit design decisions–beyond a simple acceptance or rejection of one design. Implementation details for the basic strategy are distilled from the recently developed NAVIS-based decision making method, consisting of a taxonomy of biases (partitioned into **n**ormative, **av**ailability, and **i**ndividual **s**pecific categories), a list of critical thinking skills, and a structured decision making process. Specific system examples touch upon: nuclear energy, carbon sequestration, and hydrogen-powered vehicle refueling.

Introduction

As the economic, environmental impact and energy security arguments strengthen for the expanded use of nuclear energy for electricity generation, sequestration of carbon emissions from fossil fuel plants, and eventual use of hydrogen as a "zero emission" energy carrier for transport vehicles, it becomes increasingly important to improve methods of communication *within* and *between* groups of stakeholders/decision makers about the cost and benefits of such complex, high-consequence systems. The types of stakeholder groups of interest here range from loosely bound members of the general public to so-called advocacy coalitions comprised of elected officials, policy analysts, and/or various other members of public and/or private organizations sharing common beliefs and policy objectives with respect to a given complex system (ref. 1, 2). It is argued that greater understanding and application of knowledge regarding human biases, critical thinking skills, and individual specific characteristics is needed to improve the quality of decisions and communication strategies which emerge during debates concerning the particular complex system(s) to pursue, the pace of implementation, specific sites for facilities, transport routes for fuel and waste products, etc. This need for understanding, especially what are termed "unhelpful biases" (i.e., biases hindering proper interpretation of available data) is particularly critical in domains where previous events and/or communication have led to entrenched opposition among particular stakeholders. It is recognized that groups polarized against one another typically descend into the "spiral of stereotypes," that is, they stop talking to one another, but not about one another such that rumor and a priori beliefs take on more credibility than dialogue intended to promote mutual understandings between the camps (ref. 3). Similarly, a "dialog of the deaf" may ensue where opposing groups simply talk right past one another (ref. 1). In addition, it is also recognized that advocacy coalitions with strong scientific/engineering technical membership have also been known to spawn distrust and opposition among "non-technically knowledgeable" stakeholders (e.g., the general public) by inappropriately characterizing arbitrary decisions as "scientific" decisions. This phenomenon, noted by Freudenburg (ref. 3), creates "...a self-fulfilling prophecy–accusing a wide range of people of being anti-science, and then ultimately creating just that result" (p. 125).

This paper presents a communication approach that is proposed to enhance meaningful dialog (with respect to costs and benefits) pertaining to a complex, high-consequence system. It aims to facilitate agreement on decisions for

[1] Author, point of contact, and presenter.

[2] Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000.

action between groups with moderate levels of conflict between core beliefs and secondary goals.[3] It is further (and more tenuously) proposed that the communication approach may even help "build bridges" or repair trust among groups with historical polarization (e.g., environmental groups, or their sympathizers in the general public and nuclear power utilities). Additionally, the NAVIS-based decision making method underlying the communication approach is proposed to be highly beneficial for mitigating unhelpful bias processes, promoting genuine knowledge increase, modifying belief systems, and strengthening consensus about costs, benefits, and actions to take regarding a complex, high-consequence system *within* any group of stakeholders, "honest broker" entities, or among policy brokers. The communication strategy begins stakeholder dialog on a complex, high-consequence system with a "maximally practicable failsafe design" (MPFD) that represents the system with an addition of safety features and conservative defense-in-depth measures which increases system cost 5–10 times above the version believed to be "cost effective" by system supporters/developers. The specific details of this MPFD are arrived at following a NAVIS-based assessment of various stakeholder groups (e.g., polling data, focus groups, interviews, etc.). The dialog continues among many stakeholders, within a *quasi-professional forum* (i.e., to ensure at least semi-professional rules of conduct and communication; see reference 2 for details), by discussing less expensive, "riskier" system designs using an EIS analogous approach. It is argued that this strategy fosters trust among stakeholders by including them in cost versus benefit design decisions–beyond a simple acceptance or rejection of one design option. Specific examples of the concept involve the expansion of nuclear power, carbon sequestration, and hydrogen-powered personal vehicle refueling.

Perceptions and Communication Regarding the Siting of Complex, High-Consequence Systems

The achievements of science and technology have been important, impressive, and have helped to provide unprecedented physical safety and material wealth. Yet this has been done at the cost of substantially increasing individuals' vulnerability to risks associated with interdependence (refs. 3, 4). These dramatic technological advancements have brought with them tremendous complexity and greatly increasing pressures for specialization which virtually eliminate the ability of most members of society to obtain more than a superficial understanding of the myriad of tools and technologies on which they depend for survival (refs. 1, 3). Thus, the exponential rise in knowledge requirements and associated reliance on highly specialized experts necessary for making complex, high-consequence systems succeed (in a safe manner) greatly amplifies the need for *trust* between technology experts, high-level decision makers, members of the general public, and various other interest groups/advocacy coalitions. Those who assume leadership positions in communications relating to the implementation of such systems must be mindful of these ever increasing needs for trust and consider seriously and respectfully the perceptions of risk and uncertainty of all stakeholder groups. It has been shown that trust in program officials affects public response to hazardous facilities proposed for their "backyard" (refs. 5, 6). Additional variables influencing the acceptability of a high-consequence facility include (1) its perceived risk to the health and safety of nearby residents, (2) the perceived need for the facility, and (3) the level of trust in public officials charged with management and oversight functions (refs. 7, 8).

In a survey of perceived risk and uncertainty regarding the management of nuclear waste, Jenkins-Smith and Bassett (ref. 9) found that among scientists, business people, and environmentalists (living in Colorado and New Mexico), the scientists perceived the least risk, followed closely by business people, while environmentalists perceived much greater risk. When asked about uncertainty, the environmentalists were more certain of their perception of risk than were scientists and business people, respectively. Fortunately, this study also found that when provided with new information stating that risks were either lower or higher than previously supposed, each group showed a willingness to adjust their risk perceptions in concert with lowered or raised risk information. However, environmentalists showed a stronger propensity to revise their position toward greater perceived risk when told of "increased risks" than to perceive less risk when told of "decreased risks." In another study, including 1,234 randomly selected U.S. resident respondents, safety measures and compensation tools that could be used for siting potentially hazardous facilities were investigated. The facilities included a prison, landfill, a hazardous waste incinerator, and radioactive waste disposal plant. The prison and landfill were to be located 1 or 10 miles from the respondent; the hazardous waste incinerator and radioactive waste disposal plant were to be located 10 or 50 miles from the respondent. The following results were obtained (ref. 8): (1) all of the facilities were viewed more positively when a benefits/safety package was provided; (2) four in ten would accept a prison, but less than one in ten would initially accept a nuclear

[3] See reference 2 for an excellent discussion of advocacy coalition belief systems and secondary goals as well as examples of the interplay between such groups on specific political issues related to energy policy in the United States.

waste repository (with the other two options between this range); (3) perceived *risk* was the largest factor determining facility acceptability, but perceived *trust* of an independent inspection agency hired by local officials and perceived *need* for the facility were also important; (4) large portions of respondents were either hard-core opponents or supporters of a facility; the percentages willing to change their acceptance opinions when offered benefits/safety packages were: 69% (prison), 73% (landfill), 66% (incinerator), and 56% (repository); (5) the final percentage of supporters for a landfill, incinerator, or repository was at least 10% higher when economic benefits were offered *before* additional safety measures (i.e., when monetary benefits are offered after additional safety measures it may be perceived by some as a bribe for accepting the facility); (6) monetary payments paid directly to residents (e.g., tax rebates) were seen as least appropriate while payments to those adversely affected economically (property value guarantees) or physically (medical costs) were seen as most appropriate; (7) with respect to additional safety benefits including: independent inspections by an agency approved by local officials, approval of the facility design by local elected officials, and facility shutdown authority by local officials; it was revealed that having local officials provide design approval *negatively* impacted facility acceptance.

The study authors offered two possible explanations for the finding that having local officials provide design approval negatively impacted facility acceptance. One explanation proposed that local officials are trusted to express resident interests, but not seen as competent to oversee a complex hazardous material management program. The second explanation proposed that local officials were perceived to be more susceptible to the influence of the facility operator/owner than state or federal officials. Taken together, the results from the studies mentioned above indicate that perceptions regarding complex, high-consequence systems can be changed, and the concept of negotiating additional safety measures can increase system acceptability. Therefore, so long as local officials are not given the responsibility for final, "detailed system design approval" (e.g., in the case of a commercial nuclear power plant this would rest with the Nuclear Regulatory Commission) then the MPFD concept is not unreasonable.

The NAVIS-based Taxonomy of Biases

The unique, recently developed NAVIS-based decision making method includes a framework for understanding key aspects of risk perception and decision making and provides a systematic technique for making improved decisions regarding complex, high-consequence systems (refs. 4, 10). The method is not designed to be an Orwellian[4]-type of decision making "wisdom" that enables manipulation by an elite group with a specific agenda. It is a method aimed at generating comprehensive analyses (within limits of relevant knowledge bases) among representatives of relevant stakeholder groups, in a professional forum, that strategically facilitates navigation away from "unhelpful biases" or "decision making traps" which often ensnare the unwary. The components of the method include the NAVIS taxonomy of twenty-seven recognized bias processes; a list of ten specific, carefully defined critical thinking skills[5]; and an iterative, team-based, strategic decision making approach. The method is purposefully designed to be a very comprehensive, normative tool; although its components are amenable to various types of stand-alone applications for specific analyses/decisions. The entire decision making method is not detailed in this paper; however, in order to build an appropriate context for the MPFD communication strategy, partial exposition of the NAVIS taxonomy is provided (see reference 4 for details and the body of evidence supporting the entire decision making method).

The taxonomy of biases begins with the categories of *normative knowledge*, *availability*, and *individual specific* attributes into which the many biases/tendencies are grouped (see fig. 1). Normative knowledge involves a person's skills in combinatorics,[6] probability theory, and statistics. Research has shown that training and experience in these quantitative fields can improve one's ability to accurately determine event likelihoods. The availability category of biases includes those which result from the structure of human cognitive machinery. Individual specific biases include a particular person's values, beliefs, personality, interest, group identity, and substantive knowledge (i.e., specific domain knowledge both in general and that related to the decision to be made). This unique framework represents the author's attempt at arranging risk perception and decision making biases/tendencies into categories that are somewhat orthogonal in two major respects. First, they are proposed to be different with regard to how easily one may improve their capacities for decision making in those areas (i.e., through training and experience). Second, the first two categories (i.e., normative knowledge and availability) comprise biases that are relatively easy

---

[4] In reference to George Orwell's (1945) allegorical tale *Animal Farm* in which a minority of power seekers succeeds in dominating the majority and imposing political and social tyranny (ref. 11).

[5] The critical thinking skills are taken from the excellent compilation developed by Arnold B. Arons (ref. 12).

[6] Combinatorics is the branch of mathematics concerned with counting, arranging, and ordering (ref. 13).

to "depersonalize" from a given person. That is, different individuals have varying capacities for success on normative tasks due to specific training and experience histories. Availability biases result from the fact that the decision makers of interest here are all human beings. Only the individual specific biases are intimately connected to each person's unique identity and personality (i.e., the core of the individual). Listed below are the three main categories of the NAVIS taxonomy with brief descriptions of the associated biases.

Normative Knowledge: These are the biases related to one's skill in combinatorics, probability theory, and statistics.

- *Insensitivity to Sample Size*–People often do not associate confidence in statistics with the size of the sample from which they are gathered (ref. 14).
- *Means and Medians Estimated Well*–People are relatively good at guessing values of central tendency (refs. 15, 16).
- *Coefficient of Variation is Noticed*–People tend to think in terms of the standard deviation divided by the mean (refs. 15, 16).
- *Variance Largely Ignored*–People do not display skill at guessing variance, or standard deviation as distinct metrics (refs. 15, 16).
- *Gambler's Fallacy*–Chance is often viewed as a self-correcting process in which a deviation in one direction induces a deviation in the opposite direction to restore a hypothesized equilibrium. In fact, deviations are not "corrected" as chance processes unfold, they are merely diluted (ref. 17).
- *Small Probabilities Overestimated*–This appears to occur at probabilities below approximately 0.1 (refs. 16, 18-19).
- *Large Probabilities Underestimated*–This appears to occur at probabilities above approximately 0.1 with an upper bound near 0.95 (refs. 16, 18-19).
- *Regression to the Mean*–This phenomenon involves many data generating processes both natural (e.g., heights of offspring, diameter of peas, etc.) and those related to human performance (e.g., cognitive and motor skill tests) such that measurable variables oscillate about a stable mean (or one that moves very slowly over time). First articulated by Francis Galton in the 1870s, regression to the mean is the insight that many processes do follow symmetric, generally normal distributions which oscillate about an "average ancestral type" (ref. 17). One example of this phenomenon noted by Tversky and Kahneman (ref. 14) comes from a discussion with experienced flight instructors who commented that praise for an exceptionally smooth landing is typically followed by a poorer landing on the subsequent try, while harsh criticism after a poor landing is usually followed by an improvement on the next try. The instructors inferred that verbal rewards are detrimental to learning, while verbal punishments are beneficial, in opposition to accepted psychological doctrine. This conclusion is patently unwarranted in light of regression to the mean. Failure to understand this phenomenon leads to overestimating the effectiveness of punishment and to underestimate the effects of reward. Consequently, one is most often rewarded for punishing others and most often punished for rewarding them (ref. 14).
- *Changing the Number of Options, Leads to Dramatic Changes in Probability Assignments*–Provide people with two options and probabilities may be split 50/50. Add one additional option and the breakdown of percentages for options A, B, and C will likely be closer to 10/15/75 (ref. 20).
- *Probability of Conjunctive Events is Overestimated*–These events involve series combinations and the overestimation results from anchoring toward simple individual probabilities (refs. 14, 18).
- *Probability of Disjunctive Events is Underestimated*–These events involve parallel combinations (refs. 14, 18).

Availability: These biases relate to the human cognitive machinery that enables perception, learning, remembering, and communication.

- *Anchoring Effect*–People are biased toward the first option or value they see or the first judgment they make (ref. 14).
- *Illusory Correlation*–This involves associating two things together without proper reflection on how weak that connection is or should be. It appears when multiple items that are easily recalled together (e.g., they may have been encoded into memory at nearly equivalent points in time) may be perceived as having a causal relationship (refs. 16, 21).
- *Recency*–Recent events are typically easier to recall (ref. 22).
- *Imaginability*–People tend to generate several instances of events from memory and evaluate the frequency of occurrence based on the ease with which these events can be constructed (refs. 14, 22).

- *Salience*–This is associated with the level of stimulation of the senses and how strong sensory input demands attention resources (ref. 23).
- *Retrievability*–The ease with which an item can be brought out of memory, or constructed using memory-type mental processes (refs. 14, 22).
- *Representativeness*–People will associate the probability of A belonging to class B, or of A being from process B by the degree of similarity between A and B (ref. 14).
- *Explicitness*–One who is able to imagine an event in detail will tend to attach greater weight to that event. Highly explicit descriptions in spoken, written, or visual form will enhance the intensity of the experience of that description, i.e., occupy more attention resources, and encourage cognitive "replaying" of the description many times; this strengthens the coding of that explicit description in long-term memory (ref. 22).
- *Framing Effect*–This phenomenon, regardless of unvarnished facts, means that word choices, image choices, and all aspects of presentation greatly influence resulting interpretations (ref. 24).

<u>Individual Specific:</u> These biases are shaped by a particular person's values, personality, interests, group identity, and substantive knowledge (i.e., specific domain knowledge, both in general and that related to the decision to be made).

- *Loss Aversion*–Many people are not highly risk-averse, they are perfectly willing to choose a gamble when they feel it is appropriate; people are loss averse. The key is how different individuals mentally account for the concept of loss (refs. 17, 25). This concept also includes the widely discussed *dread* factor (refs. 26, 27).
- *Law of Effect*–The tendency for people to strongly avoid negative stimuli (i.e., pain, discomfort, embarrassment) and seek to increase positive stimuli, i.e., pleasure (refs. 22, 28).
- *Constantly Requiring More*–In 1738, Daniel Bernoulli offered his definition of utility; he claimed that different people will pay different amounts for desirable things, and as one accumulates more of that thing, the less they will pay to acquire more (ref. 29). People routinely violate this definition of utility by demonstrating various tendencies toward insatiable acquisition. Recall the phrase, "keeping up with the Joneses" (ref. 17).
- *Locus of Control*–Defined by Rotter (ref. 30) as a person's perception of the control they have over job performance and work-related rewards such as pay and promotion. People identified as having an internal locus of control believe that such things are under their control. Those identified as having an external locus of control believe such things are the result of luck, chance, or whether the boss likes them–i.e., not within their control. In the NAVIS taxonomy, locus of control is generally used to refer to one's perception of control in choices involving a risk-related object.
- *Ambiguity Aversion*–People will wager on vague probabilities when they feel knowledgeable, but prefer to wager on chance when they do not feel competent in the specific decision domain (refs. 17, 31).
- *Confirmation Bias*–People tend to seek out evidence which confirms their current position and to disregard evidence that conflicts with their current position (ref. 32). In fact, several studies have specifically shown that preliminary hypotheses based on early, relatively impoverished data interfere with later interpretations of better, more abundant data (refs. 33-35).
- *Hindsight Bias*–This is the bias in which a person recalls having greater confidence in an outcome's occurrence or lack of occurrence than they had before the resulting events were known (ref. 36).

<u>Communication Examples Using NAVIS-based Strategy</u>

The NAVIS-based communication strategy proposed here is a method for engaging a range of stakeholders in meaningful and productive dialog regarding complex, high-consequence systems. The strategy may be initiated and sustained by any stakeholder with the requisite resources and will. However, it is assumed that the initiating stakeholder group having such resources and motivation will be one that supports the implementation of the system.

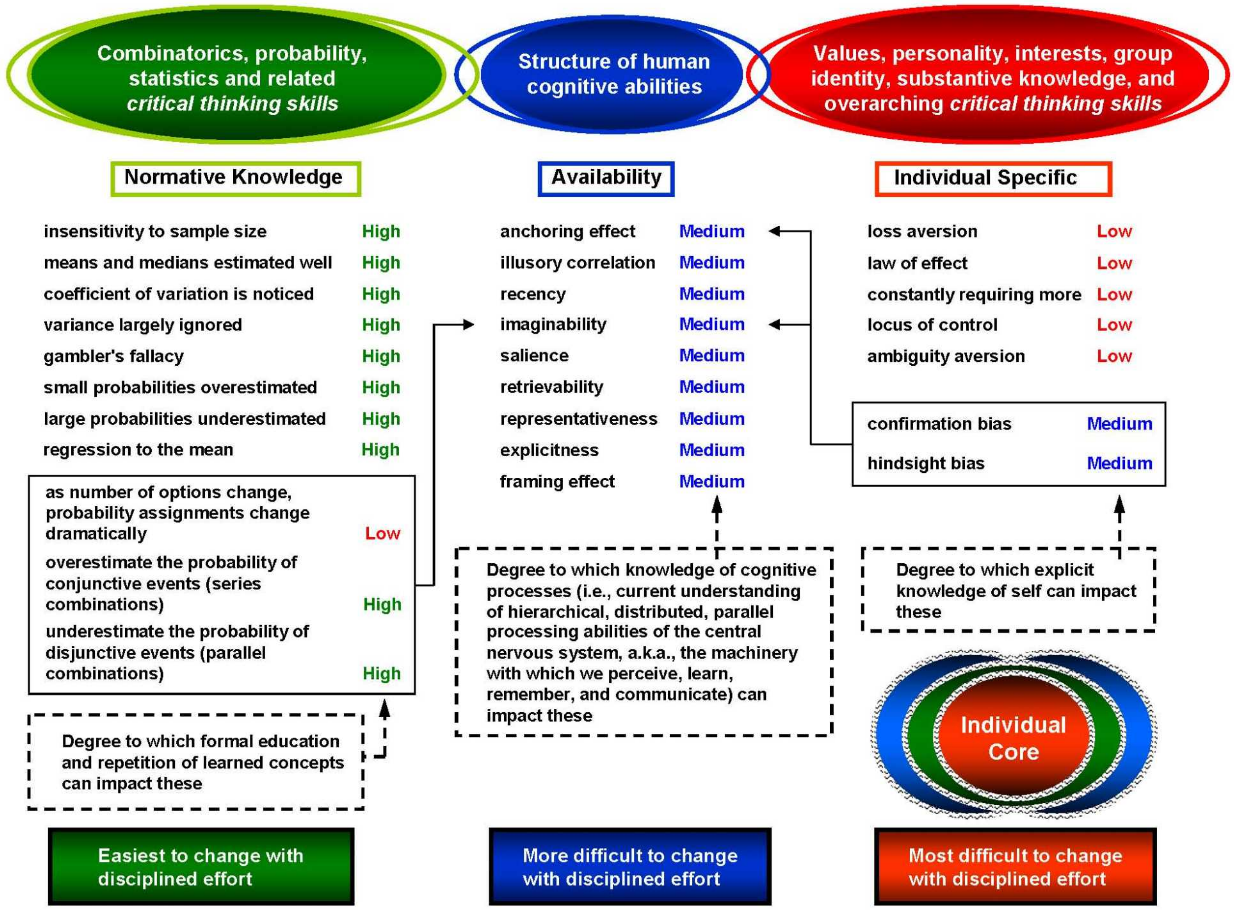

Figure 1 – The unique NAVIS-based framework in which one may understand decision making biases/tendencies that researchers have identified. The unique aspects *introduced by the author*, following an extensive review of relevant data, include: (1) the three categories into which previously investigated biases are ordered, (2) strong interdependencies hypothesized between biases as indicated by solid lines with arrows, and (3) the degree to which biases may be mitigated via disciplined efforts by a specific decision maker as indicated by dashed lines with arrows; high, medium, and low ratings[7]; and the green, blue, and red boxed items. Note also the prominence of critical thinking skills (discussed in ref. 4) in the normative knowledge and individual specific category descriptions. The nested ellipses in the lower right corner represent the way in which, over time, normative and availability biases are important filters that mediate what becomes part of an individual's core values, beliefs, etc.

The basic steps of the strategy involve: (1) perform a NAVIS-based self-inventory of the stakeholder team members leading the implementation–this serves to increase explicit clarification of one's starting point for advocating (for or against) a complex system (see ref. 4 for details on this process); (2) perform a diligent review[8] of the knowledge bases relating to the complex system–this is akin to "doing one's homework" on a system's technical basis as well as acknowledging knowledge limitations (i.e., research *known knowns* and *known unknowns*, and keep in mind the existence of *unknown unknowns* and potential "game changers"); (3) develop an initial MPFD concept–begin to clarify the dimensions along which the complex system could be elevated to an near-indisputable "failsafe" system

[7] The high, medium, and low ratings should be interpreted as comparative measurements on an *ordinal scale*, i.e., these are high-to-low assessments without specific delineation of the separating intervals. Further research is required to locate the biases on an *interval* or *ratio scale*. See Stevens (ref. 37) and Conover (ref. 38) for a thorough discussion of scales of measurement.

[8] This critical step is meant to shore up a stakeholder's internal (i.e., to self and fellow team members) and external (i.e., to those outside this particular stakeholder's "vantage point") claims to being an "honest broker" with respect to the important technical questions relating to a particular complex, high-consequence system. In cases where the initiating stakeholder is a prospective system developer, then it may be prudent to actually commission a semi-independent third party to perform the MPFD communication role.

given current system understandings (e.g., tremendous defense-in-depth measures); (4) perform a NAVIS-based assessment of various stakeholder groups (via polling data, focus groups, individual interviews, etc.)–this promotes mutual respect among other stakeholder groups and provides information to further refine specific aspects of the MPFD concept (i.e., ensure that adjustable dimensions or design options are intelligible and appropriate for the desired communication); (5) refine the MPFD concept and prepare initial communication materials and arrange multiple professional (e.g., invitation only meetings facilitated/moderated by a neutral, respected moderator) and quasi-professional (e.g., town hall meetings facilitated/moderated by respected local officials) fora or venues for discussion (ref. 2); (6) widely publicize the MPFD process and encourage participation by all relevant stakeholder groups; and (7) iteratively discuss the MPFD and "riskier" system designs (which are less expensive to initially build) in both the professional and quasi-professional settings so that many stakeholders have some ability to provide input to the cost versus benefit design decision–beyond a simple acceptance or rejection of one design option. It is important to mention that in step (5), the MPFD is refined and fully articulated in terms of progressive design options starting with an acceptable "cost versus benefit" design put forth by prospective system supporters/developers. Along with each design option should be a simplified EIS-type analysis/statement (e.g., an extended fact sheet) which includes considerations of environmental impacts, adverse environmental effects which cannot be avoided, alternatives to the proposed action, the relationship between local short-term uses of the human environment and maintenance and enhancement of long-term productivity, and any irreversible and irretrievable commitment of resources which would be involved (ref. 39). The following three brief examples illustrate aspects of the proposed NAVIS-based communication approach.

<u>Expansion of Nuclear Power for Electricity Production:</u> This example, based upon notional ideas from reference 40, hypothesizes the application of the 7-step NAVIS-based communication strategy to the topic of building new nuclear power plants.[9] It is assumed that the overarching objective of the stakeholder spearheading this process (i.e., an electric utility company) is to build a new nuclear power plant on a virgin site (i.e., not at an existing power plant site) to better serve the needs and concerns of its customers. The stakeholder initially perceives a key near-term *need* of those customers as including increased generating capacity to meet rapidly increasing demand and key *concerns* as including a desire for decreased air pollution and decreased greenhouse gas emissions. The MPFD resulting from steps 1–5 of the strategy included a nuclear power reactor design with a double-domed containment structure, incorporating numerous additional safety features above and beyond the baseline "cost-effective" design, and sited over 80 miles from the nearest population center. The "cost-effective" design was envisioned with a single rectangular containment structure. Three variations ranging from MPFD to "cost-effective" were prepared to initiate the iterative communication process. A notional graphic illustrating the basic design options is shown in figure 2.

<u>Underground Carbon Sequestration Facility/Reservoir:</u> The design and construction of facilities used in underground sequestration of carbon dioxide emissions from fossil fuel plants is seen by many as an important method for reducing human-generated driving forces that may contribute to an undesirable level of global warming (ref. 41). In a hypothesized application of the NAVIS-based communication strategy, it was discovered that there are both analyzed and perceived concerns related to large-scale leakage of sequestered carbon dioxide from this type of complex system (i.e., immediate human dangers near ground-level and climate change effects at high-altitude). In response to these concerns, the MPFD developed for communication with stakeholder groups included extensive containment, monitoring, siting, and emergency response components.

<u>Hydrogen-powered Personal Vehicle Refueling Station:</u> One option for transitioning to "clean" hydrogen powered vehicles involves producing hydrogen in mass at large power/thermochemical plants, which is then distributed to high-pressure storage tanks at refueling stations where individual consumers fill high-pressure (e.g., 5,000 pounds per square inch) hydrogen tanks in their cars (ref. 42). In a hypothesized application of the NAVIS-based communication strategy to this complex system, it was discovered that safety concerns over high-pressure vessel failure are critical. The MPFD developed for initial communication with stakeholders directly addressed these concerns by proposing several new protective features to both the pressure vessels and refueling equipment.

---

[9] It should be noted that the use of this example is not intended to suggest that there are any essential deficiencies with the current process of designing, siting, or licensing nuclear power plants in the United States. In fact, in the author's personal opinion, the United States' model for nuclear power regulation and involvement of relevant stakeholders is excellent. Recall that a key motivation behind the development of the NAVIS-based strategy for framing dialog regarding complex, high-consequence systems is aimed at "bridge building" and "nurturing trust" among groups with varying levels of historical opposition; while simultaneously elevating the "honest broker" credibility for system supporters/developers among groups with less initial opposition to the proposed system.

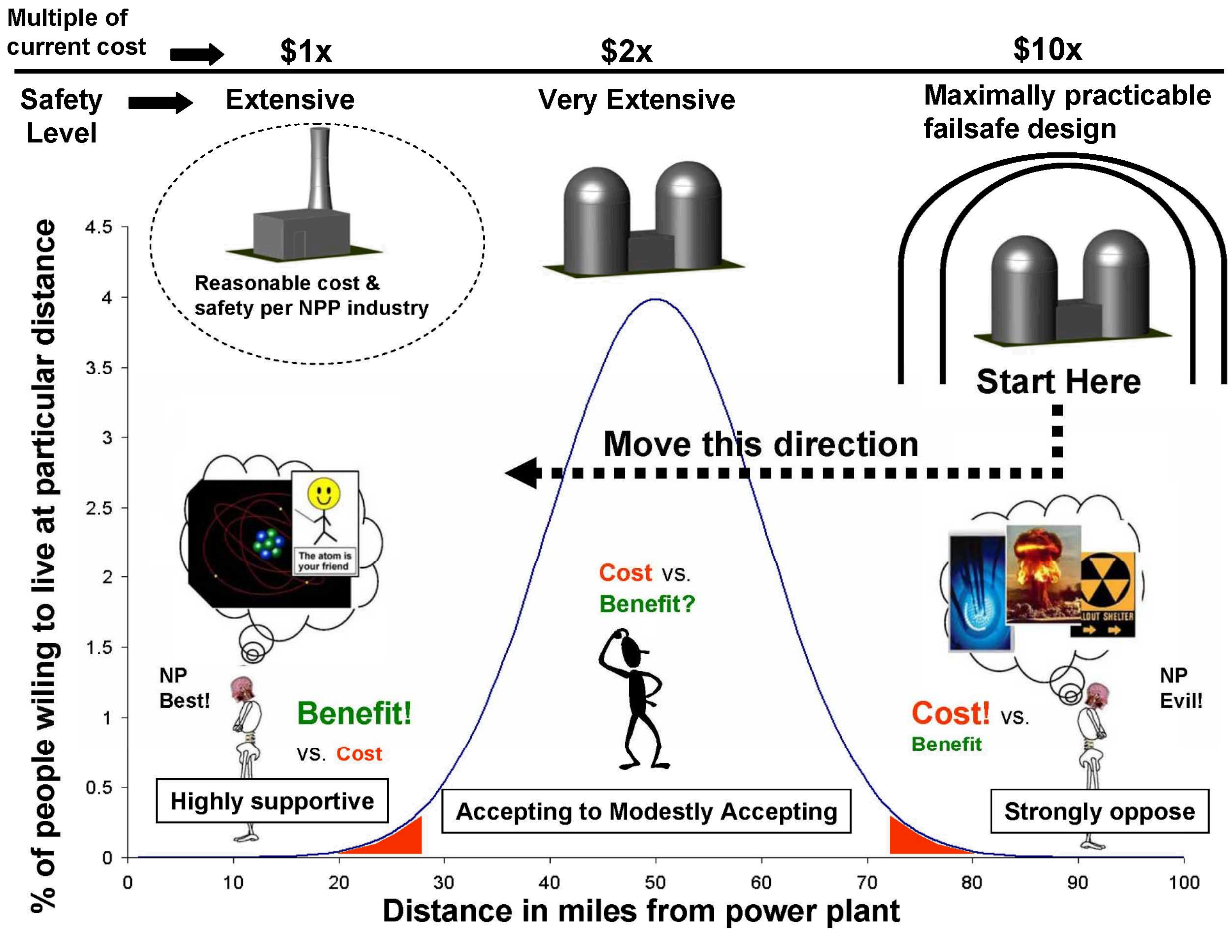

Figure 2 – Notional illustration showing a hypothesized MPFD for use in NAVIS-based discussion for siting and building a new nuclear power plant. The illustration shows design features that emerged from hypothetical focus group discussions with three stakeholders representing initial acceptance perspectives that were highly supportive, modestly accepting, and strongly opposed to the basic idea of locating this particular complex, high-consequence system in or near "their backyard."

Discussion

The NAVIS-based strategy is proposed to be an effective method for mitigating unhelpful biases while simultaneously establishing or rebuilding trust among groups with historically opposing views. The strategy leverages extensive research into decision making bias processes, critical thinking processes, and energy policy making dynamics. Previous studies lend support for the basic strategy; however, there are also indications that over emphasis upon "safety-related costs" versus "benefits" when discussing complex, high-consequence systems can be problematic (refs. 43, 44). This implies a need for carefully considered use of the MPFD concept. While the strategy may be intuitively appealing, research is needed to verify and validate its underlying basis.

Conclusion

This paper has introduced a novel strategy for framing dialog regarding complex, high-consequence systems which is based upon the unique, recently developed NAVIS-based decision making method. The basic strategy begins debate with a "maximally practicable failsafe design" and progresses toward "riskier" system designs using an EIS analogous approach. Specific system examples touched upon include nuclear power, carbon sequestration, and hydrogen-powered vehicle refueling.

References

1. Sabatier, P.A. “An advocacy coalition framework of policy change and the role of policy-oriented learning therein.” Policy Sciences 21 (1988): 129-168.
2. Jenkins-Smith, H.C. “Analytical debates and policy learning: analysis and change in the federal bureaucracy.” Policy Sciences 21 (1988): 169-211.
3. Freudenburg, W.R. “Risky thinking: facts, values and blind spots in societal decisions about risks.” Reliability Engineering and System Safety 72 (2001): 125-130.
4. Brewer, J.D. Risk perception & strategic decision making: general insights, a new framework, and specific application to electricity generation using nuclear energy (SAND 2005-5730). Albuquerque, NM: Sandia National Laboratories, 2005.
5. Flynn, J., W. Burns, C. K. Mertz, and P. Slovic. “Trust as a determinant of opposition to a high-level radioactive waste repository: Analysis of s structural model.” Risk Analysis 12 (1992): 417-430.
6. Williams, B., S. Brown, and M. Greenburg. “Determinants of trust perceptions among residents surrounding the Savannah River nuclear weapons site.” Environment and Behavior 31 (1999): 354-371.
7. Kunreuther, H., K. Fitzgerald, and T.D. Aarts. “Siting noxious facilities: a test of the facility siting credo.” Risk Analysis 13 (1993): 301-318.
8. Jenkins-Smith, H.C. and H. Kunreuther. “Mitigation and benefits measures as policy tools for siting potentially hazardous facilities: determinants of effectiveness and appropriateness.” Risk Analysis 21 (2001): 371-382.
9. Jenkins-Smith, H.C. and J. G. W. Bassett. “Perceived risk and uncertainty of nuclear waste: differences among science, business, and environmental group members.” Risk Analysis 14 (1994): 851-856.
10. Brewer, J.D. “Risk perception and strategic decision making: a new framework for understanding and mitigating biases with examples tailored to the nuclear power industry” (paper presented at the Eighth International Conference on Probabilistic Safety Assessment and Management, New Orleans, LA, May 14–18 , 2006).
11. Orwell, G. Animal Farm. New York: Everyman's Library, 1993.
12. Arons, A.B. A Guide to Introductory Physics Teaching. New York: John Wiley & Sons, 1990.
13. Larsen, R.J. and M.L. Marx. An Introduction to Mathematical Statistics and Its Applications, 3rd ed. Upper Saddle River, NJ: Prentice Hall, 2001.
14. Tversky, A. and D. Kahneman. “Judgment under uncertainty: Heuristics and Biases.” Science 185 (1974): 1124-1131.
15. Peterson, C.R. and L.R. Beach. “Man as an intuitive statistician.” Psychological Bulletin 68 (1967): 29-46.
16. Hogarth, R.M. “Cognitive process and the assessment of subjective probability distributions.” Journal of the American Statistical Association 70 (1975): 271-289.
17. Bernstein, P.L. Against the Gods: The Remarkable Story of Risk. New York, NY: John Wiley & Sons, 1998.
18. Hillel, M.B. “On the subjective probability of compound events.” Organizational Behavior and Human Performance 9 (1973): 396-406.
19. Kahneman, D. and A. Tversky. “Choices, Values, and Frames.” American Psychologist 39 (1984): 341-350.
20. Redelmeier, D.A. and E. Shafir. “Medical decision making in situations that offer multiple alternatives.” Journal of the Amercian Medical Association 273 (1995): 302-305.
21. Tverskey, A. and D. Kahneman. “Availability, a heuristic for judging frequency and probability.” Cognitive Psychology 5 (1973): 207-232.
22. Kandel, E.R., I. Kupfermann, and S. Iverson. “Learning and memory.” In Principles of Neural Science, edited by E.R. Kandel, J.H. Schwartz, and T.M. Jessell, 1227-1246. New York: McGraw-Hill, 2000.
23. Wickens, C.D. and J. Hollands. Engineering psychology and human performance, 3rd ed. Upper Saddle River, NJ: Prentice Hall, 2000.
24. Tversky, A. and D. Kahneman. “The framing of decisions and the psychology of choice.” Science 211 (1981): 453-458.
25. Kahneman, D. and A. Tversky. “Prospect Theory: An analysis of decision under risk.” Econometrica 47 (1979): 263-291.
26. Slovic, P. The Perception of Risk. Sterling, VA: Earthscan, 2000.
27. Slovic, P., B. Fischhoff, and S. Lichtenstein. “Perceived Risk: Psychological Factors and Social Implications.” Proceedings of the Royal Society of London A 376 (1981): 17-34.
28. Miller, G.A. Psychology: The Science of Mental Life. New York: Harper & Row, 1962.
29. Bernoulli, D. “Specimen Theoriae Novae de Mensura Sortis (Exposition of a New Theory on the Measurement of Risk).” Econometrica 22 (1954): 23-36.
30. Rotter, J.B. “Generalized expectancies for internal versus external control of reinforcement.” Psychological Monographs 80 (1966): 1-27.

31. Fox, C.R. and A. Tversky. "Ambiguity aversion and comparative ignorance." Quarterly Journal of Economics CX (1995): 585-603.
32. Einhorn, H.J. and R.M. Hogarth. "Behavioral decision theory: Processes of judgment and choice." Annual Review of Psychology 32 (1978): 53-88.
33. Greenwald, A.G., A. R. Pratkanis, M. R. Leippe, and M. H. Baumgardner. "Under what conditions does theory obstruct research progress?" Psychological Review 93 (1986): 216-229.
34. Reason, J. Human Error. Cambridge, UK: Cambridge University Press, 1990.
35. Anderson, N.H. and A. Jacobson. "Effect of stimulus inconsistency and discounting instructions in personality impression formation." Journal of Personality and Social Psychology 2 (1965): 531-539.
36. Fischoff, B. "Hindsight = foresight: The effect of outcome knowledge on judgment under uncertainty." Journal of Experimental Psychology: Human Perception and Performance 1 (1975): 288-299.
37. Stevens, S.S. "On the theory of scales of measurement." Science 103 (1946): 677-680.
38. Conover, W.J. Practical Nonparametric Statistics, 3 ed. New York: John Wiley & Sons, 1999.
39. Knief, R.A. Nuclear Engineering: Theory and Technology of Commercial Nuclear Power. Washington, DC: Taylor & Francis, 1992.
40. Brewer, J.D., R. Cox, and C. Mendez. "Unique NAVIS-based approach for framing dialog regarding nuclear power expansion." Transactions of the American Nuclear Society 95 (2006): 963-964.
41. Hoffert, M.I., K. Caldeira, G. Benford, D. R. Criswell, C. Green, H. Herzog, A. K. Jain, H. S. Kheshgi, K. S. Lackner, J. S. Lewis, H. D. Lightfoot, W. Manheimer, J. C. Mankins, M. E. Mauel, L. J. Perkins, M. E. Schlesinger, T. Volk, and T. M. L. Wigley. "Advanced technology paths to global climate stability: Energy for a greenhouse planet." Science 298 (2002): 981-987.
42. Ogden, J.M. "Prospects for building a hydrogen energy infrastructure." Annual Review of the Energy Environment 24 (1999): 227-279.
43. Jenkins-Smith, H.C. "Reactions to risks associated with nuclear power plants" (invited presentation at the Center 6700 Distinguished Speaker Series; Energy, Resources & Nonproliferation Unit; Sandia National Laboratories, Albuquerque, NM. February 26, 2007).
44. Kunsman, D.M. On the Public Perception of the Risks from Nuclear Weapons: Would Oralloy Be More Acceptable Than Plutonium? (SAND93-0318). Albuquerque, NM: Sandia National Laboratories, 1993.

Biography

Jeffrey D. Brewer, Ph.D., Principal Member of the Technical Staff, Sandia National Laboratories, P.O. Box 5800, MS 0748, Albuquerque, NM 87185-0748, USA, telephone – (505) 845-0494, facsimile – (505) 844-2829, e-mail – jdbrewe@sandia.gov.

Dr. Brewer is a risk analyst in the Energy, Resources, and Nonproliferation (ER&N) Unit at Sandia National Laboratories. His expertise includes systems analysis, human factors and human reliability analysis across multiple military and commercial systems.