MAKING SUSTAINABLE DECISIONS USING THE *K*ON*V*E*R*GENCE FRAMEWORK

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ABSTRACT

Hundreds of contaminated facilities and sites must be cleaned up. "Cleanup" includes decommissioning, environmental restoration, and waste management. Cleanup can be complex, expensive, risky, and time-consuming. Decisions are often controversial, can stall or be blocked, and are sometimes re-done - some before implementation, some decades later. Making and keeping decisions with long time horizons involves special difficulties and requires new approaches, including:

- New ways (**mental model**) to analyze and visualize the problem,
- Awareness of the option to shift **strategy** or reframe from a single decision to an adaptable network of decisions, and
- Improved **tactical processes** that account for several challenges. These include the following:
  - Stakeholder values are a more fundamental basis for decision making and keeping than "meeting regulations."
  - Late-entry players and future generations will question decisions.
  - People may resist making "irreversible" decisions.
  - People need "compelling reasons" to take action in the face of uncertainties.

Our project goal is to make cleanup decisions easier to make, implement, keep, and sustain. By sustainability, we mean decisions that work better over the entire time-period—from when a decision is made, through implementation, to its end point. That is, alternatives that can be kept "as is" or adapted as circumstances change. Increased attention to sustainability and adaptability may decrease resistance to making and implementing decisions.

Our *K*ON*V*E*R*GENCE framework addresses these challenges. The framework is based on a **mental model** that states: where ***Knowledge***, ***Values***, and ***Resources*** converge (the K, V, R in *K*ON*V*E*R*GENCE), you will find a sustainable decision. We define these areas or universes as follows:

- ***Knowledge***: what is known about the problem and possible solutions?
- ***Values***: what is important to those affected by the decision?
- ***Resources***: what is available to implement possible solutions or improve knowledge?

This **mental model** helps analyze and visualize what is happening as decisions are made and kept. Why is there disagreement? Is there movement toward *k*on*ver*gence? Is a past decision drifting out of *k*on*ver*gence? The framework includes **strategic** improvements, i.e., expand the spectrum of alternatives to include adaptable alternatives and decision networks. It includes **tactical process** improvements derived from experience, ***values***, and relevant literature. This paper includes diagnosis and medication (suggested path forward) for intractable cases.

OVERVIEW

Some cleanup decisions, such as cleanup of intractable contaminated sites or disposal of spent nuclear fuel, have proven difficult to make. Such decisions face high resistance to agreement from stakeholders possibly because they do not trust the decision makers, view the consequences of being wrong as too high, etc. Our project's goal is to improve science-based cleanup decision-making. This includes diagnosing intractable situations, as a step to identifying a path toward sustainable solutions.

We are two-thirds through an internally funded project to develop improved decision making approaches. Earlier papers describe the underlying philosophy of the *K*ON*V*E*R*GENCE Model for Sustainable Decisions,(1) the overall framework and process steps,(2) and diagnosis and prescription for intractable cases.(3) There is a detailed guidebook for decision making,(4) containing more details, examples, and rationale than can be included here. This paper summarizes the project, emphasizing how to visualize disagreements and ways to make progress on stalled or intractable decisions. Testing of the ideas and process steps is underway; one successful test is described below. We invite your suggestions and opportunities for additional testing and exploration of these concepts. This is research and does not represent official positions of the Department of Energy or its contractors.

Our framework addresses decision challenges with the following characteristics - complex and/or unusual relationships (of related decisions, among stakeholders, etc.), high likelihood for conflict, relatively high "stakes", and ramifications that extend over long time periods. We find relatively little decision science/decision engineering work focused on this domain. Our particular field of application is cleanup of contaminated waste sites and facilities, but the framework should be applicable to other decision challenges with similar characteristics.

The inadequacy of current approaches to long-term decision making is illustrated by the high degree of controversy and resultant stalling of some decisions, as well as revisiting past decisions. The National Research Council states,

> "Because uncertainty is inherent in many of these areas, and because DOE's preferred solutions – reliance on engineered barriers and institutional controls – are inherently failure prone, step-wise planning for DOE legacy sites must be *systematic*, *integrative*, *comprehensive*, and *iterative* in its execution through time, *adaptive* in the face of uncertainty, and *active* in the search for new and different solutions. Planning for long-term institutional management should commence while remediation is underway."(5)

Note that a recent study did ***not*** find evidence that involving stakeholders in decisions lowered their quality.(6) We encourage engagement of stakeholders as early as possible, recognizing that there are limits on who can, should, and wants to participate at any given time.

One cause of difficulty in making long-lasting decisions is the way we approach them. The typical way we try to make controversial decisions is to attempt brute force to overcome resistance. Yet, in democratic societies, resistance can generally react to such brute force. We then get a force-resistance battle, stalling a decision, while the original problem remains. Perhaps it would be useful to break the single tough reaction (decision) into stages or reduce resistance by reducing the consequences of being wrong (more reversible thermodynamics).

We have melded our experiences and analyses with ideas from decision science, action science, sociology, psychology, political science, ethics, history, "hard" sciences, risk assessment, and many engineering disciplines. Our *K*ON*V*E*R*GENCE framework combines new ideas, modifications of others' ideas, and existing ideas. The framework is based on a mental model that states: where ***Knowledge***, ***Values***, and ***Resources*** *k*on*v*e*r*ge (the K, V, R in *K*ON*V*E*R*GENCE), you will find a sustainable decision – a decision that works over time.

- ***Knowledge***: what is known about the problem and possible solutions?
- ***Values***: what is important to those affected by the decision?
- ***Resources***: what is available to implement possible solutions or improve knowledge?

The framework includes (left side of fig. 1):

- A mental model, *K*ON*V*E*R*GENCE, that describes some of the underlying decision dynamics that require cleanup alternatives to be (and to remain) *konvergent* with ***knowledge***, ***values***, and ***resources*** so the decision works over time (right side of fig. 1), it helps visualize what is happening,
- Strategic improvements to frame the problem and expand the spectrum of alternatives to include adaptable alternatives and decision networks;
- Tactical improvements such as processes and analytical tools derived from experience, ***values***/principles, and relevant literature; and
- Implications for R&D into possible solutions, to increase adaptability while reducing risk of residual hazards.

We view regulations as an imperfect overlay or "snapshot" of ***values***.(fig. 2) The fact that regulations can never totally substitute for ***values*** is one of the underlying challenges. Also, the number of participants in a decision is always less than the full set of stakeholders, everyone potentially impacted by a decision. The framework suggests more effective, appropriate, and timely involvement and analysis to improve the validity of the ***values*** considered. An improved ***values*** component should make the decision more robust against "late entry" players.

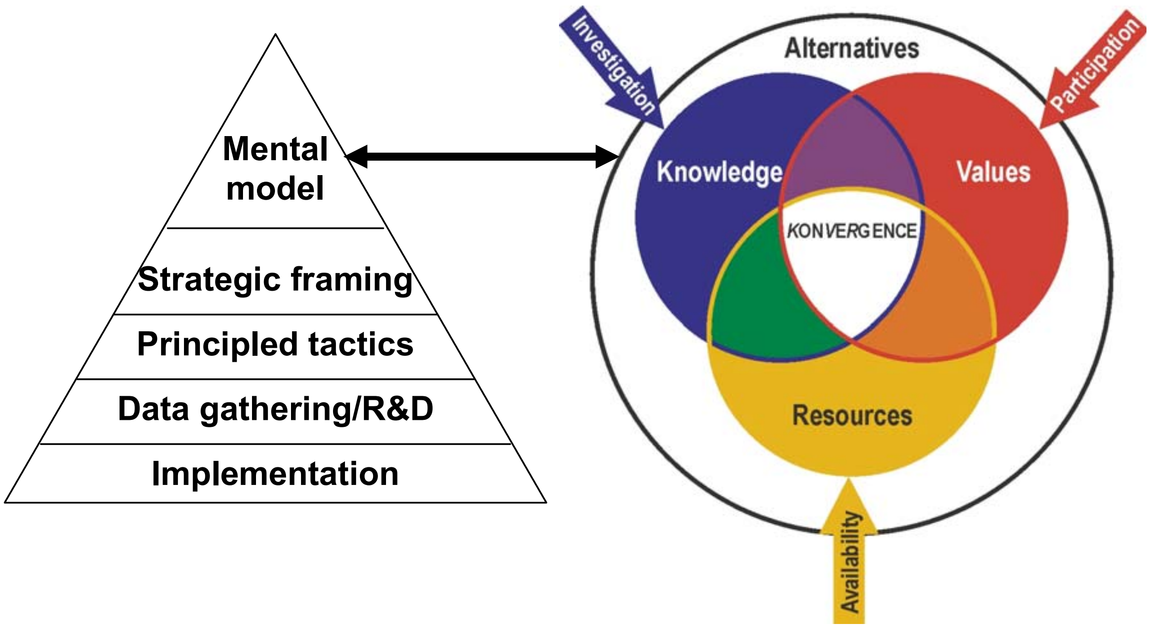

Fig. 1. The KONVERGENCE Framework (left) is an integrated package that will improve the odds to make and keep cleanup decisions; it is built on the *K*ON*V*E*R*GENCE model (right) that posits the need to keep *k*on*v*e*r*gence among *Knowledge*, *Values*, and *Resources*.

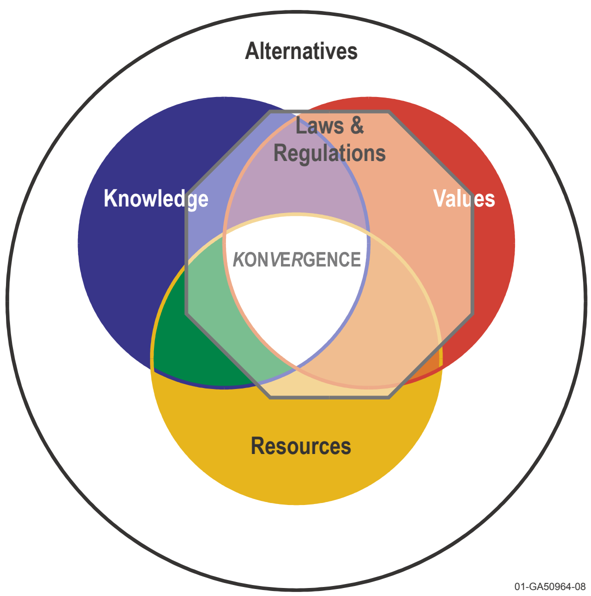

Fig. 2. Laws and regulations are an "overlap" of the *Values* universe

The framework includes a generic set of 4 ***values*** and 20 principles that are a starting point for establishing "common ground" on both the *process* and *objectives* to select among alternatives. The four ***values*** are *equality*, *democracy*, *trust*, and *reason*. As an example, the generic 20 principles include two Precautionary Principles.

- **Precautionary Principle 1**– "Actions that pose a realistic threat of irreversible harm or catastrophic consequences should not be pursued unless there is some compelling countervailing need to benefit either current or future generations."(7)
- **Precautionary Principle 2** – "Where there are threats of serious or irreversible damage, scientific uncertainty shall not be used to postpone cost-effective measures to prevent environmental degradation."(8)

These caution in differing ways. The first cautions against *taking actions* prematurely if they pose threat of irreversible harm. The second cautions against *not taking action* to protect against the threat of irreversible harm. Some cleanup problems can encompass risk of both types. Consider a long-lived hazard that if left alone will eventually degrade, increase in risk, and become more difficult to cleanup. Precautionary Principle 2 argues to take cost-effective measures now! But which measures? Version 1 argues against taking an irreversible action that might not be wise from the long-term view. In such situations, how can we proceed? No action is dangerous; taking a wrong action is dangerous. The concept of *adaptable alternatives* (managed risk) can offer a way out.

Long-term problems require dynamic analysis, examining how the solution and/or the three universes of ***knowledge***, ***values***, and ***resources*** may change. The universes themselves interact. For example, sustained changes in ***values*** leads to changes in available ***resources***. The response time varies according to the ***resource*** in question. Opening a new waste disposal site (a ***resource*** for an existing contaminated site) takes years. Sustained allocation of ***resources*** to research can increase ***knowledge***. Increased ***knowledge*** can change ***values*** or the relative weights among ***values***. The events of 9/11/2001 changed ***values*** (or at least prioritization among ***values***). Sustained changes in ***values*** also lead to changes in regulations. Indeed, some past waste decisions have already drifted out of *k*on*ver*gence.

BASIS

The theoretical ideal test would be multiple side-by-side applications of a real, messy problem with real stakeholders with their range of real concerns, time limitations, etc. - once using the framework and once without. Wait 100 years; see what happens. We have not performed such a test. To our knowledge, neither has anyone else.

We have observed, analyzed, and done the following:

- The ***K*ON*VER*GENCE mental model** is consistent with (and derived from) experience in many fields, including Kennedy's management of the decision to go to the moon,(1) the observation that many proposed actions have been consistent with regulations but ultimately blocked (Brent Spar (9,10) being a good example), the observation that past decisions to bury waste are now being re-examined because of changes in ***knowledge*** and priority among ***values***, and the observation that decommissioning and cleanup of commercial reactors appears to be proceeding more smoothly than for DOE facilities. Regarding the last point, the ***values*** of the affected people are similar; the technical challenges at DOE sites may be slightly more difficult; but the confidence in provision of ***resources*** is very different because commercial reactors have trust funds and DOE facilities are subject to yearly budget battles.
- The **strategic framing elements** (emphasis on adaptability and decision networks) are consistent with the mental model, recommendations from the National Research Council (5, 11, 12) and National Academy of Public Administration,(7) common negotiation concepts (work in steps to earn confidence), the observation that decisions are often modified in practice (see for example (13)), and the technical realities that the decisions are truly linked and the ramifications are truly long-term.
- The **tactical process elements**, especially the emphasis on understanding the broad range of ***values***/principles, the search for common ground, and building process steps on principles are consistent with the best recommendations of facilitation/negotiation practitioners, and a range of social science studies. The "Step 1" section below summarizes many factors that can increase or decrease resistance to making a decision.
- We have **tested the basic ideas** with diverse people, including students, colleagues, waste management/decommissioning personnel, volunteers from the INEEL Citizen's Advisory Board, and facilitation practitioners. **We encourage feedback from you!**
- We have **partially tested most process parts**:
    - Real, but simple problem, Citizen's Advisory Board volunteers, knowing that this was only a test.
    - Real, messy problem, ourselves, knowing we will not make the decision.
    - Real, messy problem, class of students, knowing that they will not actually be making a decision. They *k*on*ver*ged without the need for weighting, utility functions, or controversy, but with variations that increase the "adaptability" of the selected alternative. (See below.)
    - We are looking to assist decision making; we propose to proceed in a step-wise manner starting with internal testing and proceeding cautiously.
- We have melded **our experiences and analyses** with ideas from decision science, action science, sociology, psychology, political science, ethics, history, physical sciences, risk assessment, and many engineering disciplines. The team's experience includes a former member of the INEEL Citizen's Advisory Board (who is

now a professor at the University of Idaho), an expert in the middle of the effort to site a low-level waste disposal facility in Illinois, engineers with 2 decades of experience at the INEEL, experience in commercial nuclear projects, experience in international projects (a good way to understand U.S. culture is to work and live elsewhere), experience in adjusting the direction of energy technology development to increase the chance for societal interest, and a social scientist relatively new to the INEEL.

No set of decision-support methods can guarantee that *k*on*ver*gence will emerge. The first four process steps (Table I) emphasize establishing a common ground on why the problem is difficult, what the problem is, and what stakeholders are concerned about. Although the literature and experience suggests that the combination of these ideas will increase the chance for reaching *k*on*ver*gence later, additional tests are in progress at this writing.

Table I. Process Steps

#	Our Name	Typical Names	Purpose
1	Introduction	Introduction	Establish **common ground**: • What makes the problems so difficult?
2	The *K*ON*VER*GENCE Model for Sustainable Decisions		• How to visualize what is happening?
3	Establish What the Real Problem Is	Situational analysis & Problem statements	• What the real problem is? • Who might care?
4	Discover the *Values* of those Affected by the Decision	Set objectives	• What people care about?
5	Generate Alternatives	Generate alternatives	Jointly brainstorm broad range of potential solutions
6	Understand and Reduce Scatter and Divergence	Compare alternatives	Iteratively improve and narrow the list of alternatives with qualitative and quantitative info
7	Quantitative Analyses		
8	Planning to Keep *K*on*ver*gence	Often forgotten; sometimes called Potential Problem Analysis (14)	Plan how the decision will be "kept" over the relevant long time periods.
9	Summary	Summary	Capture what has been learned; continuously improve.

Perhaps more importantly, we have not demonstrated that decisions made with the assistance of the framework will be more sustainable than would otherwise be the case. We are confident that they would not be worse; the nation is spending billions of dollars un-doing past waste management decisions. In addition to the arguments above, our basis for believing that the framework will increase sustainability is also based on having addressed weaknesses in past decisions. In particular, past decisions were made with fewer viewpoints considered; indeed, many were made in a period of high national security and secrecy during and shortly after WWII. Clearly, the opportunity for more viewpoints to be brought to bear on the decisions has increased over time; we believe that contributes to the fact that many are being re-examined. (Changes in ***knowledge*** certainly also contribute.) Our framework encourages a wide range of viewpoints to be considered earlier and explicit planning for how things may change over time. This leads to the strategic concept of explicitly considering *adaptability* as one attribute to evaluate among alternatives.

The following sections describe the process steps and illustrate how they can be applied to intractable decisions.

Step 1. INTRODUCTION - WHAT MAKES THESE TYPES OF DECISIONS SO DIFFICULT?

There is a mix of several answers to this question: time, trust, filtering of information, uncertainties, etc.

Time - Some hazards, e.g. toxic metals, will exist indefinitely; there is no known practical way to destroy them. The same is true for long-lived radioactive isotopes and for some very stable toxic organic compounds. However, some hazards, e.g. short-lived radioactive isotopes, will decay naturally even if left alone. Others, e.g. toxic organic compounds, can sometimes be destroyed using existing technologies. The long time horizon means that the problems are multi-generational. And, the further out in time one looks, the greater the uncertainties.

Societal experience in making such cleanup decisions is not long; indeed decisions made a few decades ago are being re-done. Furthermore, there are different time horizons embedded in different regulations, which were produced for different hazards in response to laws passed at different times in response to different real and perceived needs. Sometimes the regulatory time horizons are short compared to the duration of hazards.

Thus, the framework has a central theme of **time**. Time influences the mental model, motivates some of the strategic re-framing and consideration of adaptable alternatives, influences the scope and boundaries included in "situational analysis," and determines qualitative and quantitative analyses to perform.

Participation and Trust - Making cleanup decisions is difficult at best. Why?

> "The lack of trust in DOE and its site operators is a major impediment to reaching consensus not only on the type and degree of remediation needed, but also on the process to reach these decisions. … The representatives of the general public, workers, and the Native Americans – all of whom expressed notably low confidence in the technology and in the current understanding of the risks associated with the sites – were frustrated by their inability to participate substantively in the making of key decisions related to environmental and health monitoring, agenda-setting for risk assessment, and the choice of remedial alternatives. For them, the process by which a decision is made was *as important as the decision* itself, both because the process shapes the decision and because an open, inclusive process can provide stakeholders with a much fuller understanding of the alternatives than a closed hierarchical one. *Furthermore, these stakeholders were fundamentally distrustful of DOE's and its contractors' ability* to understand stakeholders' values and concerns and to incorporate them into decision-making." (11) [*Emphasis added*.]

These difficulties are not limited to DOE nor cleanup. Indeed, political science observers note the ineffective adversarial, procedural, regulatory manner in which many decisions are approached today.(15,16) Kemmis writes, "collaboration has arisen and spread because it offers an alternative to the highly adversarial form of public involvement that now dominates almost all public decision processes. … Collaboration slices through this Gordian knot in a totally unexpected way."(16)

The framework includes ideas to increase participation and improve trust. Examples include: importance given to ***values*** in the *K*on*ver*gence mental model, a chapter devoted to discovering ***values***, careful monitoring of the ***values*** component while assessing alternatives, and recognition that ***values*** will change over the time horizon of interest.

Lack of holistic approaches - In the energy field, Rose describes a problem he calls "selective inattention",(17) which we believe applies equally well to cleanup:

> "Faced with such a wealth and breadth of information, views, goals, and paradoxes, the reader, company, government agency, or other group molds some particular subset of the whole into a locally logical framework, then acts as if that construction were the whole of it. What is inside - nuclear power or conservation or national security - is the key to all, and what lies outside becomes either selectively ignored or recast to support the central theme. To be sure, daily life demands selective inattention, or else we would overwhelm ourselves with remembered trivia, but in dealing with naturally extensive topics like energy, it is to be guarded against."(17)

Consider a few statements found in the literature or in conversations…

- *Not in my backyard!* - yet the hazards will continue to exist somewhere until they decay or are destroyed to a level that stakeholders consider ignorable
- *I don't care what it costs, get rid of it.* - yet society does have limited ***resources*** and we need to wisely spend them.
- *All "they" have to do is follow regulations* (said by opponents of proposed actions)
- *All "we" have to do is follow regulations* (said by proponents of proposed actions)
  Everyone points to regulations when regulations agree with their position, but point to difficulties in regulations otherwise. Yet, regulations are not always protective, nor are they always appropriate. The regulatory time horizon can be less than the duration of key elements of a decision. There is a legal bias against taking action.
- *Cleanup is too complex; separate the stages of the problem* - yet the problem is unavoidably interconnected.

All are mental shortcuts that aim to simplify the "problem." People cannot process everything. Our mental model - ***knowledge, values, and resources*** - is intended to encourage a minimum level of processing of information, spanning those three universes and therefore encouraging at least some balancing of perspectives. More broadly, Table II shows factors that can stall a decision or block implementation, and how our framework attempts to help.

Table II. Factors Increasing or Decreasing Resistance to Making a Decision

Increase resistance to make a decision	**Increase pressure to make a decision**	**Our framework …**
Low time pressure	High time pressure	*Time pressure is an external constraint outside the framework. Decisions made because of time pressure may not stand the test of time.*
Accountable to constituents rather than opposing negotiator	Accountable to opposing negotiator rather than their constituents	Encourages group setting and collaboration.
"Prospective outcomes are framed as losses rather than gains." (18)	Frame outcomes as gains (versus status quo)	Encourages decision networks that maximize risk reduction (a key gain) faster than loss of adaptability (a key loss)
"When parties have a good rather than bad alternative to an agreement." (18) Good "Best Alternative to Negotiated Agreement"(19,20)	Poor alternatives to agreement	Emphasizes the consequences of "no action"
Polarized decision environment (9)	Collaborative consensus	Promotes collaborative environment
Bargaining over positions (20)	Exploring ways to meet both sides' interests, Principle-driven negotiations	Encourages establishing values/principles to guide both the process and the result
Considering the problem in only one way (21)	Approaching problems with pluralist mix of methodologies and methods.	Provides a broad balance perspective on the three universes; a broad range of specific methods can be applied as needed.
Failing to consider both process and content of decisions (21)	Consider both process and content.	Process and content are considered throughout; the search for ***values*** explicitly addresses both.
Late entry players bring new viewpoints to decision (10)	Inclusive decision process to obtain diverse views earlier	Identifies and invites stakeholder participation, includes a generic set of ***values*** as a minimum to consider, includes scoping analyses and earlier testing generic categories of alternatives with participants
Lawsuits (15,16)	Collaboration	Stresses that regulations are an imperfect "snapshot" on ***values***; stresses the need to understand the ***values*** universe
Lack of compelling reasons to act, situation too complex (22,23)	Situation understandable; compelling reasons to act	Includes subject matter info to clarify the situation
Precautionary principle caution <u>against taking action</u> leading to irreversible harm	Precautionary principle caution <u>against not taking action</u> to protect against irreversible harm	Include both viewpoints, offer strategic re-framing to put adaptable alternatives on the table.
Uncertainty (24)	Certainty	Includes adaptable alternatives as a way to proceed if certainty of "permanent" solutions inadequate
High risk/high cost	Low risk/low cost	Includes (preliminary) extensions to tools to provide earlier indication of risk and cost
Incomplete or misleading boundaries of the problem (25)	Inclusive problem boundaries	Includes examination of problem boundaries and appropriate decision level.

Research in different areas shows that when people perceive solutions as **gains rather than losses**, they are more likely to want to proceed. Even the process used to rank and compare alternatives shifts. In well-defined behavior testing, often the gains and losses are clear - monetary incentives. The cleanup arena is more complex. What are the key gains and losses?

Losses: Losses are more than hazard or risk to people. The threat to workers during cleanup activities is a potential loss, as is irretrievable use of financial ***resources***. Another is the irretrievable use of political capital. The risk to the public has both short-term (hazards released during cleanup actions) and hypothetical longer-term (hazards slowly escaping over long time periods) components. Buried waste is not an immediate loss, but a longer-term threat. People want certainty (make the problem go away, it might hurt me or my children later). Therefore, perhaps a "loss" if the hazard is not eliminated now is the *loss of certainty* of future protection. Another "loss" seems to be the flexibility to do something different later if a "permanent" "wrong" alternative is implemented now. This relates to the concept of *regret*.

Gains: The hazard exists. One alternative is often framed as a gain versus another because it is cheaper, less risky, faster, etc. This can be both true and an attempt to frame the overall solution as gains versus losses. The real gain is *reduction of risk* relative to the status quo, which is the existence of a hazard with its associated risk.

People have difficulty with uncertainty. People do not approach problems solely from a risk-cost-benefit standpoint; therefore standard "utility theory" is incomplete. For example, Hogarth (24) studied decision making on whether to buy a warranty on VCRs, CD players, etc. Participants had incomplete information on the probability of equipment breakdown, cost of repair without the warranty, etc.

> "Cost-benefit models did not explain subjects' choices well under conditions of risk." "It is perhaps ironic that, under ignorance, when people should probably think harder when making decisions, they do not. In fact, they may be swayed by the availability of simple arguments that serve to resolve the conflicts of choice."(24)

The literature, e.g. (22,23), suggests that people look for **compelling reasons** to justify their decisions, especially when they feel accountable to others. In fact, selections among alternatives change if the accountability (be prepared to justify your decision) is stressed *before* or *after* they receive information (in both cases before they make a decision). They process the input differently if they know they will have to justify the output selection later. Similarly, when people are satisfied that one or more existing alternatives are adequate (as opposed to continuing to look for new alternatives) depends in part on how much they feel they must justify their decisions to others.

STEP 2. THE *K*ON*VER*GENCE MODEL FOR SUSTAINABLE DECISIONS

Our approach is based on the need to establish and maintain *k*on*ver*gence among the three universes of ***knowledge***, ***values*** of those affected by a decision, and available ***resources***. We call this the *K*ON*VER*GENCE Model for Sustainable Decisions. Investigation and availability of data defines ***knowledge*** of both the problem and (later) of possible solutions. Participation of stakeholders specifies ***values***. The availability of budgets, offsite waste disposal sites, etc. drives ***resources***. Acceptable alternatives are those in the *k*on*ver*gence of ***knowledge***, ***values***, and ***resources***. *K*on*ver*gence must be maintained as the universes change if the decision is to remain acceptable. Some past decisions to bury waste appear to have drifted out of *k*on*ver*gence; such cases have become cleanup challenges.

We believe that many decisions appear to be attempting to only achieve *k*on*ver*gence among regulations, *knowledge*, and project *resources*. The problem is that following prescriptive regulations is neither always sufficient nor always necessary. It is possible to point to examples where a selected alternative was completely consistent with regulations, but ultimately blocked by public pressure. And regulations themselves often include provisions that allow exemption to, exclusion from, or modification of prescriptions in the regulation provided that those impacted agree. Decisions must be built on something deeper than regulations—the ***values*** of those potentially impacted by the decision or implementation of one or more possible alternatives. Thus, we model regulations as an imperfect overlay or "snapshot" of ***values*** and suggest that a better way to view the challenge is to achieve ***k*on*ver*gence** of ***values***, ***knowledge***, and ***resources***.

This is consistent with the thinking of political science observers such as Kemmis, who writes (15) that the American representative democracy has become too dependent on regulations, procedures, and lawsuits with too little attention to communities and the people that live in them. This often leads to stalemate and controversy, and to complex and often conservative regulations. By restating the decision challenge from

> **convergence** of regulations, ***knowledge***, and ***resources*** to
> ***k*on*ver*gence** of ***values***, ***knowledge***, and ***resources***

we hope to encourage a different understanding of how to address and discuss cleanup decisions.

This mental readjustment must go further than simply changing regulations to ***values***. The three universes of ***values***, ***knowledge***, and ***resources*** each change over the time-period of interest—the time that hazardous materials remain hazardous or until society ignores the remaining level of risk from the hazard. This is true even if the selected alternative is to remove hazards and transport them elsewhere. Until the hazards are destroyed or decay naturally, the problem is in someone's backyard.

Long-term problems require dynamic analysis because ***knowledge***, ***values***, and ***resources*** - or the solution - may change. Sustained changes in ***values*** leads to changes in available ***resources***. Sustained allocation of ***resources*** to research can increase ***knowledge***. Increased ***knowledge*** can change ***values*** or the relative weights among ***values***. Sustained changes in ***values*** also lead to changes in regulations. It is less obvious that changes in regulations can induce changes in ***values***. Said another way, we believe that ***values*** are more fundamental, it drives regulations rather than the inverse.

Previous fig. 1 illustrates how we view the challenge. Among the set of possible alternatives:

- Find those that intersect with ***knowledge***, ***values***, and ***resources***.
- Include adequate <u>investigation</u> of the problem and possible alternatives so that the ***knowledge*** brought to the decision problem is as complete as possible.
- Stimulate <u>participation</u> sufficiently so that diverse objectives, viewpoints, and concerns are included in the ***values*** component of the process.
- Consider the <u>availability</u> of all of the key ***resources*** needed to implement the decision.
- Consider how the three universes may change and what mixture of two strategies for keeping *k*on*ver*gence is appropriate—alternatives that are adaptable as ***knowledge***, ***values***, and ***resources*** change - or - managing the three universes to increase the chance that the selected alternative remains in *k*on*ver*gence.

To further illustrate the challenge of time—and part of the difference between regulations and ***values—***consider that the U.S. has existed for less time than such hazards will last. People sometimes intuitively doubt whether regulations and associated implementing authorities offer adequate protection for centuries. Our first 42 presidents had average terms of about 5 years. Thus, a waste disposal site intended to operate for 1,000 years spans about 200 U.S. presidential administrations. Further, there are inconsistencies in time-horizon among regulations, which inhibits having a clear dialogue and societal approach to long-term hazards, especially for contaminated sites involving multiple types of hazards. The regulations were developed in response to laws passed at different times by different people in response to different perceived needs. To illustrate this, note the inconsistency of the following regulatory time-horizons:

- 10,000 years—Nuclear Regulatory Commission and EPA regulations for high-level and transuranic waste (10CFR60, 10CFR63, 40CFR191, 40CFR197);
- 1,000 years—EPA regulations for near-surface uranium and thorium mill tailings (40CFR192) and DOE policy for new land burial (DOE Order M 435.1);
- 500 years—NRC regulations for near-surface burial of low-level radioactive waste (10CFR61);
- 30 years—baseline EPA RCRA time-period for near-surface burial of chemical hazards (40CFR264);
- Indefinite—baseline EPA CERCLA time-period for residual hazards (CERCLA requires a 5-year review).

Meeting a 30-year regulation by "do it once and forget" is not adequate for longer-lived hazards. People recognize that there are limits to ***knowledge*** and large uncertainties in assuring ***resources*** for such long periods of time. Thus, regulations do not always adequately substitute for identification of the ***values*** of those impacted by decisions.

- There may be inadequate trust in those working the details, the regulators, or those implementing the decisions - now or in the future.
- There is a long time horizon. There maybe a significant time lag between changes in ***values*** and then regulations. The longevity of regulations/regulators may be in doubt. Uncertainties generally increase the further out in time one looks. There may be doubts about how much we really know about solutions far into the future, or how to provide ***resources*** for long time periods.

Thus, previous fig. 2 illustrates that we consider regulations to be an overlay on ***values***. ***Values*** are more fundamental than regulations. An alternative can be in *k*on*ver*gence with ***values*** but not regulations or with regulations but not ***values***. ***Values*** are the deeper, more fundamental basis for decisions.

STEP 3. ESTABLISH WHAT THE REAL PROBLEM IS

All decision processes include studying the situation and identifying the problem. Here, we emphasize some aspects of this step that need special attention.

A classic difficulty is restricting the range of alternatives by embedding a solution in the problem statement. Compare—"what is the best way to remove this hazard?" to "what is the best way to manage the risk from this hazard?" The former statement pre-selects removal as the only class of alternatives to consider. Instead, attempt to write the problem statement as broadly as possible. The problem statement starts creating a "box"; at this point you do not want to draw that box any tighter than needed.

A related problem is making assumptions that artificially (and erroneously) truncate the boundaries of the problem.(25) For example, assuming that offsite places to take waste will exist; rather than considering that decisions to take waste elsewhere will impact decisions to remove waste here. Thus, carefully analyze how decisions may be related - in time, in space, in function (A must happen before B), etc. If there is a relationship, account for it by either:

- Assumptions - Representing the other decision(s) via assumptions, to be re-examined over time. In these cases, the decisions are logically related but analyzed separately.
- Combined decision process → network of decisions - Decision processes to be worked through together with stakeholders (including regulators). This does not mean actual decommissioning actions would have to be done together, they may indeed be separated by decades. But, a single "decision" effort would work through the combined sets of decisions.

In our experience and testing, we find that people are often unaware of fundamental aspects of hazards associated with cleanup. We have found Table III helpful in clarifying the nature of the beast.

Table III. Generic Types of Hazards Found in Facilities to be Decommissioned

Type	Typically found in nature?	Importance of chemical form to toxicity	Does hazard decay naturally?	Do we know how to destroy hazard?
Radio-active isotopes	**Yes**, with the exception of some transuranic isotopes (a)	Can affect the level of exposure to the hazard by altering the ingestion or inhalation uptake of isotopes	Natural decay is fixed for each isotope, ranging from under a second to billions of years depending on isotope	Nil prospects for in-situ destruction or treatment. Ex-situ treatment may be practical to separate long-lived isotopes from short-lived isotopes.
Toxic organic compounds (b)	**No**	Affects ingestion and inhalation uptake Determines toxicity level	Decay generally slow (years, decades) and often dependent on specific chemical environment, e.g., trichloroethylene	In-situ decay may be deliberately enhanced by microbes Ex-situ destruction generally possible, but with associated risks and costs during transportation and destruction.
Toxic metals	**Yes**, although sometimes not in the more hazardous chemical forms	Can affect ingestion or inhalation uptake Generally affects toxicity	Metals won't decay but the chemical form may naturally change into less toxic forms	Destruction (changing one element into something else) is not practical. In-situ alteration of chemical form can sometimes be enhanced by micro-organisms Ex-situ destruction generally possible, but with associated risks and costs during transportation and destruction.
The specific radioactive isotopes associated with cleanup are often not the specific isotopes found in nature.				

Another difficulty is that some contaminated sites and nearby facilities are regulated separately. If the decisions proceed separately, there is the potential that more money is spent reducing a lower risk, missing the opportunity to reduce risk more cost-effectively nearby.

Identify everyone who may care about the decision, their best alternative to a negotiated agreement (BATNA) (19, 20), their interest, and their history associated with related decisions. If people have a better alternative than to negotiate, then it is unlikely that the decision process can proceed. It is best to discover this earlier rather than later. For cleanup decisions, we stress the "no action" alternative because blockage of decisions tends to result in "no action." The more people agree that "no action" is unacceptable, the more force there is to proceed with a decision, or network of adaptable decisions. In general, invite as many diverse people to participate as is possible.

STEP 4. DISCOVER THE *VALUES* OF THOSE AFFECTED BY THE DECISION

Participation may be inadequate to get an adequate picture of ***values***. What key stakeholders or stakeholder viewpoints (from Step 3) are not represented among participants? How different could the missing viewpoints be? How well can you anticipate their ***values***, etc.? What is the risk of continuing without their participation?

Armed with participants and an understanding of those who (for whatever reason) are not participating, generate a list of ***values*** and principles for your problem. Address both process and desired outcomes. We *encourage* grouping and ordering them so that *every*one can see *all* the ***values*** on the table – we suggest doing that in the form of a structured hierarchy of ***values***, principles, etc. We *discourage* attempting to weight or discriminate in any way among ***values*** at this stage. Everyone's ***values*** should be brought to bear on the problem - this does **not** mean granting everyone a veto. Rather than jump to detailed objectives (e.g., cleanup a site to some specific risk limit), start with broad ***values*** to maximize the chance for establishing a common ground and increasing collaboration, then work downward to principles, strategic objectives, etc. This is intended to maximize the chance for establishing a common ground and either reduce polarization or find a way to proceed in the face of polarization. Review Table IV, which is a generic list of ***values*** and principles culled from past studies and our analyses. They provide a minimum set to consider, even if key diverse viewpoints are not yet participating for whatever reason. They may not be sufficient, but they are necessary to be considered. What should be added, removed, or changed in that list?

Table IV. Generic Set of ***Values*** and Principles

Equality – the decisions are fair and just for current and future generations • **Trustee Principle** – "Every generation has obligations as trustee to protect the interests of future generations."(7) • **Sustainability Principle** – "No generation should deprive future generations of the opportunity for a quality of life comparable to its own."(7) • **Chain of Obligation Principle** – "Each generations' primary obligation is to provide for the needs of the living and succeeding generations."(7) • **Precautionary Principle 1**– "Actions that pose a realistic threat of irreversible harm or catastrophic consequences should not be pursued unless there is some compelling countervailing need to benefit either current or future generations."(7) • **Precautionary Principle 2** – "Where there are threats of serious or irreversible damage, scientific uncertainty shall not be used to postpone cost-effective measures to prevent environmental degradation."(8)
Democracy – the decision-making process is open with participation by all • **Involvement Principle** – The process should incorporate meaningful community and stakeholder involvement in all phases of decision-making now and in the future. • **Information Principle** – Complete, accurate and useable information should be provided to both current and future peoples. • **Invisible Man Principle –** The decision, the decision process, and supporting information must be transparent and understandable by interested parties now and in the future. • **Poisoning of the Well Principle** – Don't poison the "well" for future decisions. The process should make future decisions involving related problems and stakeholders easier by improving the decision environment. • **Tip of the Iceberg Principle (or Canary in the Coal Mine Principle)** – Without granting veto power to individual participants, concerns must be noted, addressed to the extent possible, and the risk of proceeding in the face of strong concerns considered before proceeding.

Truth – the decision should reflect the truth, the whole truth and nothing but the truth • **Uncertainty Principle –** There will be large uncertainties in the knowledge about the hazards, the facility and its environs especially their future behavior and performance. These uncertainties need to be acknowledged, documented and communicated with all involved. • **Faber College Principle** – Knowledge is good. To be able to make a sound decision, knowledge about the contaminated situation is essential. Research will be pursued if complete understanding is not possible. • **Forest and the Trees Principle** - Understand the characteristics and context of the land and facilities near the site or facility in question. Actions that might make sense in one location may not make sense in another. • **Price is Right or Fram Oil Filter Principle –** The stakeholders have a need and a right to know not only what the cleanup activity will cost but what the life cycle costs will be.
Reason – the decision should be real, practical, and meaningful • **What if You are Wrong Principle** – Decisions must withstand the test of time amid great uncertainty. • **Paul Masson Principle** – No decision should be made before its time. • **Perry Mason Principle –** Decisions must comply with the intent of environmental regulations regardless of current language or interpretation, e.g., protective of human health and the environment. • **Hippocratic Worker Principle** – Above all else, do no harm to the current worker especially when considering minimal hypothetical future risks. • **Little Engine that Could Principle** – The decision should lead to actions that are achievable, not necessarily easy, but doable with existing resources. • **Snicker Principle** – The decision should be able to pass a snicker test by participants before implementation.

Beneath principles, consider detailed strategic objectives, tactical goals, and performance measures to the extent needed at this point. Our experience and past research (26) suggests that focusing initially on ***values***, rather than alternatives or the details of risks, is helpful when the decision is complicated and possibly controversial. It is also critical to maximize flexibility in attacking the problem – permitting out-of-the-box thinking. Regulations should be included in this process, recalling that regulations are neither always necessary nor always sufficient.

STEP 5. GENERATE ALTERNATIVES

This step is central to strategic framing. One way to increase the sustainability of decisions and react to the reality that ***knowledge***, ***values***, and ***resources*** change is to consider the ***adaptability*** of alternatives. Instead of framing the range of alternatives in a single dimension—what is to be removed versus kept in place—we suggest a two-dimensional approach - what is kept/removed and how adaptable is the situation. Then, three general areas of adaptability-hazard option space are as follows:

- **Reusable** - Relatively low hazard, variable adaptability - Facility can be released for other purposes, by other groups – with or without restrictions on use. If "any" use of the facility/land would lead to acceptable risk, the release is "unrestricted", e.g., greenfield. If some users would pose unacceptable risks, the release is "restricted", e.g., brownfield sites.
- **Closed** - Relatively high hazard, relatively low adaptability - Facility is put into state with little adaptability, with little or no intention to revisit later unless severe unexpected things go wrong. So-called "entombed" facilities would be examples. Another is deep geological disposal after site closure.
- **Adaptable** - Relatively high hazard, relatively high adaptability - Facility is kept in an adaptable state, thereby keeping future options open while keeping the risk from hazards acceptable to stakeholders for an extended period. Four examples are the concept of "assured isolation" (formerly "assured storage") of low-level radioactive waste,(27) the C reactor at Hanford, temporary spent fuel storage at commercial power plants, and the suggestion for adaptive staged decisions at Yucca Mountain.(12)

STEP 6. UNDERSTAND AND REDUCE SCATTER AND DIVERGENCE

At this point, we have the right people participating (or as close as possible), participants know the set of what is important to each other (***values***), and there is a set of diverse alternatives. Then, a miracle occurs and everyone loves a single alternative - there is low **scatter** and low **divergence**. **Scatter** is the variance among participants for each alternative. **Divergence** is how far alternatives may be from *k*on*ver*gence.

In lieu of a miracle, facilitators should guide participants through the iterative process of understanding how participants evaluate alternatives, gathering more information, improving alternatives, narrowing the list of alternatives, etc. Throughout we stress:

- Periodically ask all participants to map alternatives into ***knowledge***, ***values***, and ***resources*** universes and identify weaknesses for each alternative. We use a survey form which checks the degree of agreement with each universe, degree of certainty of evaluation, and rationale.
- Use techniques (Table V) as needed to probe more deeply to better understand the evaluations and polarization that may exist. Indicators in survey evaluations can suggest different mental models or beliefs that participants *may* be using (Table VI).
- Get more information, validate assumptions, perform quantitative analyses as appropriate.
- Refine alternatives, recognizing the limits of solving ***values*** problems with increased ***knowledge***, etc. For example, if an alternative *k*on*ver*ges with ***knowledge***, but not ***values*** because of a lack of trust—perhaps reshape the alternative to expand oversight mechanisms.
- Combine best features of related alternatives.
- Narrow the list.

Refine alternatives using the understanding gained in diagnostic analyses to improve alternatives. Alternatives that have inherent advantages but have weaknesses in some universes may warrant further attention to improve them. For example, Shrader-Frechette points out that some conflicts between inter- and intragenerational ethics can be reduced by refining alternatives to consider both perspectives.(28)

The final questions at this step are – (a) have we fixed alternatives' weaknesses by reshaping them? Those moving into or toward *k*on*ver*gence are retained; those remaining highly divergent are discarded and (b) is there an adequate diversity of alternatives still on the table? If so, continue to quantitative analyses. If not, generation of more alternatives or additional refinements to existing alternatives are needed.

We now digress to illustrative examples of how polarization can occur between reusable and closed alternatives, and what might be done about it. Consider fig. 3.

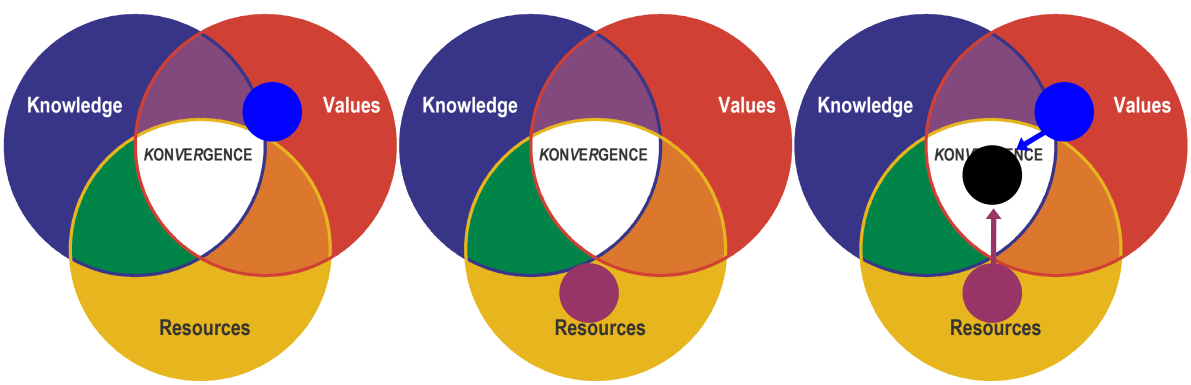

Fig. 3. Cause and resolution of potential polarization. a) reusable alternatives with *knowledge* and *resource* concerns, b) closed alternatives with *values* and *knowledge* concerns, c) possibly temporary adaptable alternative while pursuing means to bring either reusable or closed alternatives into *k*on*ver*gence

Example - How might reusable alternatives be out of *k*on*ver*gence?

There is no alternative class that works best for all cleanup problems. Consider the **reusable** class of alternatives. If we know how to cleanup a site (***knowledge***) and have the ***resources*** to do so (budget and place to send resulting waste) this solution is usually implemented because such cleanup is generally consistent with local ***values***. The pace of cleanup is typically controlled by budgets, which result from ***values***-based prioritization of various needs.

Table V. Steps that may help Diagnose or Refine Alternatives

What	Why	Inputs	Outputs
1. Map alternatives into three universes	• Identify scatter and divergence in evaluation of alternatives	• List of alternatives	• Participant surveys
2. Discuss any perceived inconsistency in survey evaluations	• Validate survey results and reduce chance for misunderstanding	• Survey results (apparent inconsistencies among scores or score/text)	• Validated/adjusted survey results • Better understanding of survey results
3. Explore mental models, context, framing, and incentives	• Reduce mis-understandings and polarization, improve trust and decision environment • Poisoning of the Well principle	• Existing team dynamics and decision environment • Survey results • Trained facilitator	• Clarification of how participants are approaching the decision • Improved trust and decision environment
4. Discuss any perceived inconsistency between regulations and ***values***	• Diagnose regulations versus ***values*** as contributing to divergence or scatter • Perry Mason and several equality principles	• Divergence in survey results • Survey text • Group discussion	• Identification of possible disconnects between regulations and ***values***
5. Identify key assumptions and uncertainties, replace with facts or decision networks as appropriate	• Information and Uncertainty principles • Understand key relations among decisions • Expose key assumptions	• Survey text • Survey "c" evaluations • Scatter in survey results • Group discussion • Information gathered by participants	• Fewer assumptions and less uncertainty • List of remaining assumptions and issues • Ways to manage uncertainties & assumptions • Plan for assumptions, R&D results, and networked decisions
6. Further refine and combine alternatives	• Improve chances for finding a *k*onvergent alternative • Fairly compare best versions of each alternative • Obtain best features of similar alternatives	• Survey text • Group discussion of how each alternative might be improved ("what if" questions)	• Improved alternatives • Variations to alternatives • Realistic adaptable alternatives
7 Use screening factors, weighting, and utility functions as needed.	• Probe deeper into causes and magnitude of scatter and divergence • Proceed in the absence of consensus	• Survey text (what are participants focused on?) • Group discussion	• Deeper understanding of how participants evaluate alternatives
8. Narrow the list and assess readiness to proceed to quantitative analyses	• Reduce cost of quantitative analysis • Move to Step 7	• Group discussion	• Narrowed, improved, diverse list of alternatives • Group decision to proceed.

Table VI. Possible Models Inhibiting Progress on a Decision

Universe	Model	Possible Indicators
Knowledge	My ***knowledge*** is certain, yours isn't.	High scatter in ***knowledge*** evaluation.
	I cannot trust knowledge from "that" group,	
	Need to pool what we know	Modest scatter in ***knowledge*** evaluation.
Values	I do not respect the values from "that" group.	High scatter in ***values*** evaluation.
	I don't trust them.	Withhold information; do not admit that "their" alternatives might be fixable.
	I might be able to trust them.	Cautiously share information, consider that "their" alternatives might have some merit.
	If you win, I lose.	Polarized decision environment, high scatter in ***values*** evaluation likely stalemate
	A win-win is possible.	They search for win-win alternatives, actively engage in trying to refine alternatives to make them acceptable to broader range of participants, shared ***values*** scores result and ***values*** scatter decreases.
Resource	Allocated resources are "cast in concrete"	Excessively pessimistic resources evaluation, high scatter in the ***resource*** evaluations.
	Endless pockets – more resources are always possible if I apply enough pressure.	Excessively optimistic resources evaluation, high scatter in the ***resource*** evaluations.
	Use of ***resources*** is limited, but the limits are not always clear. Need to find the most effective way to use resources among alternatives.	Balanced resources evaluations, modest *resources* evaluation scatter.

Consider cases where one of the above conditions is not met. For example, reusable alternatives may be within the ***values*** universe but not within ***knowledge*** (lack of confidence in the technology to remove or destroy the hazards) or ***resources*** (no offsite waste disposal, inadequate budget). Consider spent nuclear fuel – there is no current method to destroy the hazard and no place to permanently place it. Other examples are heavily contaminated sites for which no technology exists that allows cleanup at acceptable levels of risk and cost (***knowledge*** and/or ***resource*** problems). Then, fig. 3a shows how critics might view reusable alternatives. The dark blue circle shows that under these circumstances reusable alternatives would be consistent with ***values*** but possibly not with ***knowledge*** and ***resources***, it lies at or outside of the ***knowledge*** and ***resource*** circles. Advocates may view things differently.

Example - How might closed alternatives be out of *k*on*ver*gence?

Next consider **closed** alternatives. It is generally known how to fill a facility or waste site with grout, yet long-term barrier behavior may not be adequately understood. Offsite waste disposal is not needed, removing one ***resource*** constraint. (But it does require a new ***resource*** constraint, long-term land use.) Budget is typically available. Such alternatives are generally consistent with ***resources*** and partially consistent with ***knowledge***.

What about ***values***? If the hazards are recognized as relatively low and short-lived, a **closed** alternative is often acceptable. However, complying with regulations may be inadequate to convince opponents that permanent closure decisions are consistent with their ***values***. If "permanent" closure is viewed as posing substantial risk to future generations, it can run afoul of the Trustee, Sustainability, and Precautionary Principles in Table IV.

When critics view closed alternatives as having adequate ***resources***, but also having gaps in ***knowledge*** of long-term behavior and inadequate attention to intergenerational ***values,*** they are viewing closed alternatives as shown in fig. 3b. Advocates may view things differently. Indeed, advocates can be correct in saying that a closed alternative is consistent with a short-term regulation (e.g. 30 years). The underlying problem is that regulations and ***values*** are not always in harmony; our model considers regulations as an imperfect overlay of ***values***; eventually the differences should decrease. If so, a solution consistent with regulations today may become divergent later.

Diagnosis

In such situations, fig. 3a and 3b show that neither reusable nor closed alternatives are in *k*on*ver*gence. A polarized situation has developed. Even if such a reusable or closed alternative is selected, the longevity of the decision is suspect. Those favoring the reusable and closed classes of alternatives may not speak the same language. Those supporting closed alternatives may believe the problem is only that opponents are not listening to their ***knowledge***. Those opposed may understand the technical arguments but remain unconvinced about the certainty of protection over the duration of hazards. This pattern appears for many closed alternatives including buried waste and spent fuel disposition. Those supporting reusable alternatives may believe that others simply do not share their ***values***; yet people can share such ***values*** but realize that the reusable alternatives run afoul of technical and budget limits.

In such polarized situations, parties often seek advantage through legal/regulatory procedures. Neither reusable nor closed alternatives can be implemented. Or, if they are implemented, they are unlikely to be sustained unless the ***knowledge***, ***values***, and ***resources*** universes change so that the decision comes into *k*on*ver*gence later. Until a reusable or closed alternative comes into *k*on*ver*gence, something must be done with the hazards. If the hazard is not stable or its protective barriers are degrading or already inadequate, the worst action is "no action". It runs afoul of Precautionary Principle 2 in Table IV.

Medication

We suggest combining step-wise *adaptable* solutions with sincere, diligent efforts to increase the likelihood that reusable and/or closed alternatives may enter *k*on*ver*gence in the future. Plans to increase the range of future options are needed to prevent those advocating reusable or closed alternatives viewing step-wise approaches as a sham. Said another way, if there is no plan B, then everyone recognizes that all efforts are devoted to forcing plan A to work. This means we need a package:

- Proceed in a step-wise decision network fashion. Put the hazards/facility into a configuration where they are safe, at least temporarily, maintaining maximum adaptability - illustrated by central dot in fig. 3c. This can conceivably be a "closure" under CERCLA, followed by the CERCLA-mandated 5-year reviews.
- Research better ways to cleanup (or at least reduce) the hazard, to possibly bring reusable alternatives into *k*on*ver*gence - illustrated by the upper arrow in fig. 3c. For existing intractable waste sites, this includes research into decommissioning and cleanup technologies. For spent nuclear fuel, the volume of long-term waste can conceivably be reduced orders of magnitude by separating long-lived isotopes and separately storing short-lived isotopes. The long-term hazard could be conceivably reduced, subject to ***values*** issues, by reusing useful long-lived isotopes (reprocessing) or burning them in reactors. Accelerator transmutation of waste (ATW) may also be helpful if technical and cost issues can be overcome.
- Improve understanding of multi-generational risks, to possibly bring closed alternatives into *k*on*ver*gence - illustrated by the lower arrow in fig 3c. Improve monitoring of hazards that have already been put into closed or closed-like configurations. For example, if spent fuel were loaded into Yucca Mtn, study how the system performs for hundreds of years before further reducing adaptability. Where waste is left in existing intractable waste sites, conduct the research needed to substantially improve understanding of long-term risk. The adaptable "closure" may indeed be eventually considered permanent.

All parts are needed. If, for example, efforts that might bring reusable alternatives into *k*on*ver*gence in the future are left out, then people will conclude that the only long-term solution will be a closed one and that delay is only that – there is inadequate possibility of a different "end state," only a slower path in getting there. We offer these further suggestions:(4)

- Minimize the chance of getting stuck at an intermediate point out of *k*on*ver*gence.
- For intermediate points with a significant chance of being divergent, consider what might be necessary to move to a point in *k*on*ver*gence.
- Assess how risk, cost, and other key parameters vary with time.
- Consider adaptability as one of the desirable attributes to optimize, with cost, risk, etc.
- Explicitly discuss the risk of being divergent at intermediate points, the level of adaptability, and tradeoffs among adaptability, risk, cost, etc. with those affected by the decision.

These general suggestions are consistent with others' suggestions regarding Yucca Mtn (12,29,30) and how we observe that debate evolving - more emphasis on reversible waste emplacement, funding of ATW, reprocessing being re-considered to reduce waste volumes. We suggest more emphasis on having a network of staged decision points with multiple "end states", rather than a single path toward a pre-defined end state, and on the need to plan to sustain *k*on*ver*gence. Similar adaptable networked approaches can and should be developed for high-hazard, long-duration, intractable cleanup sites. We recognize the potential ongoing cost and risk associated with adaptable solutions but this has to be weighed against the cost and risks of a "no action" stalemate or premature action.

Test Case

Our most recent test suggests some optimism. We engaged a class of students with a simplified version of an upcoming INEEL decision. The problem is cleanup of radioactive waste tanks and surrounding soil. The simplification eliminated the issue of how to treat what is removed (and where it would go). At the step where the framework probes boundaries and decision levels, they questioned this simplification and explored how it might affect the remaining decision. After considerable discussion, they decided to proceed with the simplification. All information came from public documents; some of the cost and risk metrics have been quantified, some not.

The potential for polarization was evident early, during elicitation of ***values***. One participant suggested "minimize cost", prompting immediate strong disagreement from another. The facilitator deferred disagreement, noting that at this point we wanted to capture all ***values***, listing them did not mean consensus. Participants also struggled with the best way to express how decision makers should incorporate evaluate the public's input (process-related ***values***).

They generated 4 alternatives in addition to the four we presented to them from public documents. In their first evaluations, prior to group discussion, one (of 10 participants at this point) found "no action" *k*on*ver*gent with their ***values***; seven found "no action" divergent. All considered "clean closure" *k*on*ver*gent with their ***values***; nine also thought "clean closure" *k*on*ver*gent with ***knowledge***. However, most recognized ***resource*** difficulties. "Performance based closure" scored lower on ***values***, but higher on ***resources***.

Discussion led to *k*on*ver*gence. The concept of "adaptability" did not seem to mean much in the abstract, but it did as during discussions of some alternatives. Without need for weighting among ***values***, they reached a consensus on an alternative, which was a modified version of "performance based closure". The modifications implemented the strategy devised by the participants of achieving as much cleanup as was possible now (available ***knowledge*** and ***resources***) - remove liquids from the tanks (leaving residual "heels" and solids), remove soil hot spots, cap and "close" the site - while leaving open the possibility of more cleanup later if warranted. The "adaptability" package prohibits filling the tanks with grout at this time (viewed as too irreversible), ensures monitoring *within* the cap/tanks, re-evaluates every 10 years, and establishes contingency plans if residual contamination migration or excessive cap/tank degradation is observed or new better cleanup technologies were available.

Post-test surveys found participants had learned much and were happy with the process and the selected alternative. They reported low pressure to conform. The participants understood and positively evaluated the framework, the importance of adaptability and being included in the process.

An additional test is in progress with two parallel classes, one using our framework, the other is standard NEPA.

STEP 7. QUANTITATIVE ANALYSES

Before proceeding to quantitative analyses of any kind, it is important to consider how the resulting numbers will be used. Too often, detailed calculations are performed and then become the focal point of subsequent decision making. Worse, they may be used to justify to stakeholders why one alternative should be preferred over others. When this happens, the discussion has shifted from considering the entire range of knowns and unknowns in all three universes to a debate on the numbers. Some things can be quantified; some cannot. Over-emphasis on the quantifiable does not help in achieving and keeping *k*on*ver*gence.

One reason sometimes given for not engaging the public earlier is that we have to know how much it will cost or what the risk would be before we even put it on the table. Those are obvious questions that require some degree of quantification as early as possible. Thus, another part of the framework is to explore extension of existing screening/scoping tools for estimating risk and decommissioning cost. The idea is that approximate answers to quantifiable factors may provide enough information to make a tentative decision, or at least narrow the range of possibilities. References 2 and 4. have more information.

The difficulty, of course, is in deciding what level of precision is required for decision making. That is, how much information is enough and how exact do the numbers have to be? As a general rule-of-thumb, we propose the following guidelines:

- If one alternative is clearly superior to the others, is in *k*on*ver*gence, and has low uncertainties, do only the analyses that are required to move to the next stage.
- If, even after refinements, an alternative has little chance of ultimately being in *k*on*ver*gence (a no action alternative for example), use screening level estimates only.
- If a good set of comparable historic information exists (a rare situation), then estimates based on the data may be superior to calculations from models.
- If, however, significant uncertainties exist about the alternative's effectiveness, cost, risk, implementability or other aspects, then quantitative analysis should continue until these uncertainties are resolved.
- If enough uncertainty exists to not allow alternatives to be ranked, then quantitative analysis should continue until alternatives can be evaluated relative to each other.

STEP 8. PLANNING TO KEEP *K*ON*VER*GENCE

Management of *k*on*ver*gence is required over the lifetime of any remaining hazard. Understanding how ***knowledge***, ***values***, and ***resources*** are changing with time is required to keep *k*on*ver*gence – the situation should be managed so that either changes to decisions can be avoided or done in a controlled manner. We view this step as part of risk management or "stewardship." There are two approaches—managing one or more universes or managing the alternative (keeping an appropriate degree of adaptability). In many cases, a combination of both approaches will be appropriate. Adaptability was discussed in step 5. What can be done to manage the universes?

Consider the decision to go to the moon and fig 4. (See ref. 1 for more explanation of this example.) President Kennedy gave key speeches in 1961 and 1962. The first suggested a goal to go to the moon; the second stated more strongly, "We *choose* to go to the moon…" In 1961, we model "decide to go to the moon" as having significant uncertainties in all three universes, with significant chance of being outside of each universe. Thus, the first diagram in fig. 4 shows the decision (shaded area) as being large (significant uncertainty) and intersecting the edge of each universe. It was not known if we had the technology, political will, nor ***resources*** to get there. By 1962, Kennedy had captured the imagination of many people and built enough support in Congress to obtain budgets. The primary uncertainty was technical; thus the decision is shown uncertain relative to the ***knowledge*** universe. In July 1969, the uncertainties had shrunk, the decision was in good alignment with all three universes, and Armstrong, Aldrin, and Collins made history. By 1972, the uncertainty in ***knowledge*** had actually grown slightly because of the near-disaster Apollo XIII. Interest in continuing to go to the moon was waning. Budgets were being cut and were more uncertain looking into the future. At present, we probably have the ***knowledge*** to return to the moon, but neither ***values*** nor ***resources*** are evident.

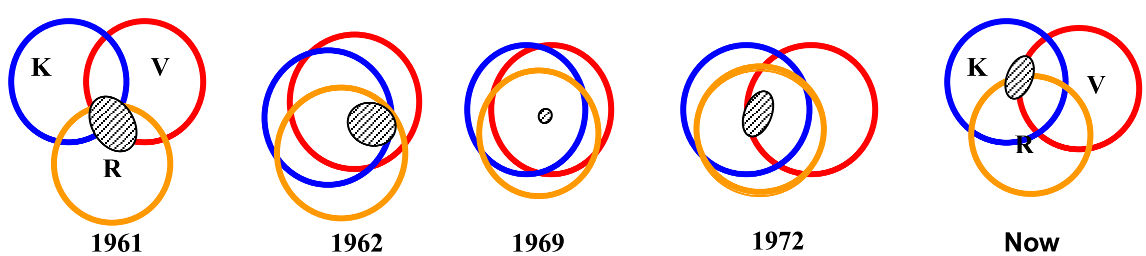

Fig. 4. Apollo moon landing decisions over time

Changes in ***values*** led to changes in ***resources*** and ***knowledge***. As *k*on*ver*gence with ***values*** strengthened, more ***resources*** became available. Then R&D provided by ***resources*** slowly improved ***knowledge,*** while the corresponding uncertainty decreased. In 1969, everything aligned. Since then, sending men to the moon has moved out of the ***values*** universe and the ***resources*** are not available. Eventually, the necessary ***knowledge*** will degrade.

Planning ideas for *k*on*ver*gence

Provide incentives. While maintaining a decision over time is often necessary or desirable, it is not clear that people will want to try to maintain *k*on*ver*gence for the timeframe of decades, centuries, or more. More research is needed to clarify under what conditions people will try to maintain *k*on*ver*gence.

A "carrot and stick" analogy* may be useful in looking at incentives for maintaining *k*on*ver*gence:

- o Incentives to acquire and use "good stuff"
- o Incentives to avoid risk or perceived risk from "bad stuff."

"Carrot" or "good stuff" incentives can *encourage* maintenance of *k*on*ver*gence (e.g. maintenance of remedial barriers or restrictions on land use) or *discourage* maintenance of *k*on*ver*gence. Some long-term examples include:

- o *Encourage*: the structure has obvious advantages if it is maintained (e.g. Roman aqueducts and roads)
- o *Discourage*: the acquisition or use of "good stuff" defeats the protection (e.g., known riches in Egyptian pyramids and tombs overcame fear of curses; commercial benefits from new uses of valuable land overcome land use restrictions).

"Stick" or "bad stuff" incentives encourage maintenance of *k*on*ver*gence to continue to do *something* about the hazard (this may not be what was originally planned, however, and as such would be particularly detrimental to attempted end-state decisions). The strength and longevity of such "stick" incentives are also uncertain—to a great extent, the magnitude of the incentives depends on the actual or perceived risk of exposure to the hazard. Examples of varying levels of this risk or perceived risk include:

- o High: Part of the strategy considered for Yucca Mountain and WIPP is to provide long-lived warning of the risks of intrusion
- o Medium: Egyptian pyramids and tombs "protected" by curses
- o Low/zero: Roman aqueducts and roads.

One set of incentives can overwhelm the other. We agree with preliminary observations by colleagues K. Kostelnik and G. Harbour that some people lost interest in keeping land-use restrictions at places like Love Canal, New York. One hypothesis for this outcome is that the incentives to use the land in non-protective ways became too great. This would be an example of "carrot" incentives trumping "stick" incentives.

Stabilize one or more universes.

- Stabilize ***knowledge*** by archiving the ***knowledge*** of the problem and the implemented solution both locally and nationally. Find ways to pass information down from generation to generation. Continue monitoring/inspection to increase ***knowledge*** of the system and research to improve ways to mitigate/manage the hazard.
- Stabilize the ***values*** universe by reducing the chance that future changes in ***values*** can induce people to try to undo protection. Be sure that the alternative was selected on the basis of wide and effective participation of people with different ***values*** in the first place; this reduces the chance that new people with new viewpoints would substantially change the ***values*** universe. Explore adaptable solutions that can accommodate anticipated changes in ***values***. Ensure that intergenerational equity is a prime factor in the decision.
- Stabilize the ***resources*** universe by providing for long-term financial ***resources*** such as by trust funds. In the context of cleanup and waste disposition, consider if waste could be looked at as a ***resource*** in the future and take this into account when making disposal decisions—potential ***resources*** in the system could provide "carrot" incentives for the movement of the ***resources*** universe boundary, which may cause decision points to fall out of *k*on*ver*gence. Invest in other ***resources*** development activities (e.g., training, building infrastructure, and ***resource*** substitution) to ensure continued ***resource*** availability.

Create an Early Warning System to give as early warning as possible of divergence. We illustrate with a medical analogy. For decades, medical experts have stressed the importance of prevention and early detection. The chance of unfavorable outcomes from diseases increases the later that problems are detected. We believe that the same concepts apply to maintaining and managing *k*on*ver*gence for decisions. Yet, too often, we are only detecting problems after the patient has died.

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* Some of the carrot/stick analogy is based on discussions with INEEL colleagues K. Kostelnik and G. Harbour.

Typically, at present, there is no organized "early warning system" for ***values*** or ***resources***. So, all of a sudden, we can find that a decision is so out of *k*on*ver*gence with ***values*** or ***resources*** that the entire decision process has to be restarted and already-implemented decisions re-done. At least there is some attempt to monitor part of the ***knowledge*** universe, specifically the onsite performance of remedial actions such as confinement barriers. Typical current practice, consistent with regulations and technology, is to monitor barrier performance by groundwater surveillance wells. This will catch barrier failures, but only long after they occur. It would be better to develop more capacity to detect early indicators of failure. This will increase protection of the environment and reduce the cost of repair to containment/barrier systems by catching problems earlier. Even better would be to extend this concept to all three of the universes described in the *K*ON*VER*GENCE Model.

Comparing the actual trends with the expected trends can alert decision-makers to the potential need for corrective action and can trigger formal action if a pre-established ***action level*** (also called an ***intervention level*** or ***trigger***) is reached. ***Action levels*** are levels at which some corrective action must be taken. As with laws and regulations, action levels are manifestations of the ***values*** universe since they are an indication of what participants and society believe to be important. Laws and regulations (e.g., CERCLA, RCRA), court orders, contracts, records of decisions, etc. can all establish required action levels for various factors.

STEP 9. SUMMARY

We believe that making and keeping decisions with long time horizons involves special difficulties and requires new approaches. Therefore, society needs the following:

- New ways (**mental model**) to analyze and visualize the problem,
- An option to shift **strategy** or reframe from a single decision to an adaptable network of decisions, and
- Improved **tactical processes** that account for several challenges.

Our *K*ON*VER*GENCE framework addresses these challenges. The framework is based on a **mental model** that states: where ***Knowledge***, ***Values***, and ***Resources*** *k*on*ver*ge (the K, V, R in *K*ON*V*E*R*GENCE), you will find a sustainable decision. We define these areas or universes as follows:

- ***Knowledge***: what is known about the problem and possible solutions?
- ***Values***: what is important to those affected by the decision?
- ***Resources***: what is available to implement possible solutions or improve ***knowledge***?

This **mental model** helps analyze and visualize what is happening as decisions are made and kept. The framework includes **strategic** and **tactical process** improvements derived from experience, ***values***, and relevant literature.

We believe our framework can make it easier to make decisions that have proven difficult if not impossible to make. We diagnose some decisions as having a very high "activation" barrier, i.e., a very high resistance to making the decision. The resistance comes from one or more stakeholders (including regulators) because they either do not trust the person making the decision or view the consequences of being wrong as too high among other reasons. In such cases, we must either reduce the consequences of being wrong (e.g., by implementing adaptable alternatives that can be fixed later if necessary) and/or split a single decision into a network of decisions (e.g., earning trust at each step as in some international diplomatic situations).

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