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Footprint of Sandia's August 15, 2016 Informal Idea Exploration Session on "Towards an Engineering and Applied Science of Research"

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Footprint of Sandia's August 15, 2016 Informal Idea Exploration Session on "Towards an Engineering and Applied Science of Research"

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Abstract

On August 15, 2016, Sandia hosted a visit by Professor Venkatesh Narayanamurti. Prof Narayanamurti (Benjamin Peirce Research Professor of Technology and Public Policy at Harvard, Board Member of the Belfer Center for Science and International Affairs, former Dean of the School of Engineering and Applied Science at Harvard, former Dean of Engineering at UC Santa Barbara, and former Vice President of Division 1000 at Sandia). During the visit, a small, informal, all-day idea exploration session on "Towards an Engineering and Applied Science of Research" was conducted. This document is a brief synopsis or "footprint" of the presentations and discussions at this Idea Exploration Session. The intent of this document is to stimulate further discussion about pathways Sandia can take to improve its Research practices.

ACKNOWLEDGMENTS

We thank Steve Rottler (00002), Rob Leland (01000), Julie Phillips (former acting CTO), Charles Barbour (former 01100), and Jerry Simmons (01000) for their encouragement and support for work at Sandia in the "applied science of science," a small piece of which we explore in this document.

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SUMMARY

On August 15, 2016, Sandia hosted a visit by Professor Venkatesh Narayanamurti (Benjamin Peirce Research Professor of Technology and Public Policy at Harvard, Board Member of the Belfer Center for Science and International Affairs, former Dean of the School of Engineering and Applied Science at Harvard, former Dean of Engineering at UC Santa Barbara, and former Vice President of Division 1000 at Sandia). That visit became a vehicle for a small, informal, all-day Idea Exploration Session on "Towards an Engineering and Applied Science of Research." The idea exploration session was attended by 20 individuals working across Sandia as well as individuals working with external organizations. Approximately half of the attendees participated in the full-day's discussion.

The goals of the discussion were twofold:

1. Explore ideas at the intersection between (a) the "macro level," the practical management of research for excellence (and boldness) at organizations like Sandia, and (b) the "micro level," emerging perspectives on research mechanisms. Discussions in yellow in the agenda below were in the (a) category, discussions in blue in the agenda below were in the (b) category.
2. Re-introduce Professor Narayanamurti to the Sandia research environment, and re-introduce Sandians interested in a scholarly approach to an "engineering and applied science of research" to each other.

This document is a brief synopsis of the presentations and discussions at this Idea Exploration Session. The intent of this document is to stimulate further discussion about pathways Sandia can take to improve its research practices. While many topics were deliberated throughout the day, three issues emerged as critical to consider as Sandia strives to improve its current research practices.

First, at the macro level, there was a recognition that the culture in portions of Sandia Research have evolved over the past 20 years to one that emphasizes accountability and oversight instead of research flexibility and boldness. Thus, the bias is towards lower-risk, foreseeably-successful outcomes, and this type of culture shies away from the higher-risk, unknowable outcomes associated with research excellence and boldness. A question that was posited in the day's discussion asked how might it be possible for Sandia to re-assert a more flexible culture appropriate for bold research within the understandably predominant culture of scheduled and foreseeably-successful outcomes?

Second, also at the macro level, scientific and engineering research are very different in their intended outcomes: the first aimed at discovery and the second at invention. However, science and engineering may be very synergistic and Sandia is particularly well positioned to take advantage of these potential synergies considering the lab's strengths in both science *and* engineering. One potential synergy: the rapid rate of research progress when idea flow is encouraged across science and engineering components. Another potential synergy: adapting scientific research process to the design-thinking "processes" that were originally developed for engineering research, as a means to better execute "research boldness" in a way that is unique to Sandia.

Lastly, at the micro level, the development of mechanistic models for simulating research processes shows promise, and is being pursued (though at a low level) at Sandia. Further, analytic and measurement tools for testing those models are simultaneously being developed in other knowledge domains. The hope is that these models and analytic tools will someday inform the macro level implementation of research management and practice at Sandia.

1. AGENDA AND ATTENDEES

The day's events began at 8:30 am and concluded at 4:00 pm. An outline of the agenda is listed below. The discussion topics highlighted in yellow indicate a "macro level discussion" and the topics highlighted in blue indicate a "micro level discussion"

- Welcome & Introductions
  - *Facilitator: Jeffrey Tsao (1120)*
- Challenges to Managing Research in Sandia's Science, Technology, & Engineering Enterprise: The View from One Center
  - *Facilitator: Grant Heffelfinger (1100)*
- Idea Generation/Selection: A Simple Mechanistic Model
  - *Facilitator: Jeffrey Tsao (1120)*
- Building Institutional Ecosystems that Nourish Out-of-the-Box Research
  - *Facilitator: Venkatesh Narayanamurti (Harvard University)*
- Assessing the Environment for Bold Outcomes in Sandia Research
  - *Facilitator: Lynne Starkweather (10610)*
- Executive Lunch Discussion
  - *Attended by: Venkatesh Narayanamurti, Steve Rottler, Rob Leland*
- Interaction Dynamics Notation and Science Thinking vs Design Thinking
  - *Facilitator: Rieko Yajima (Stanford University)*
- Frontiers of Text & Information Compression Analytics
  - *Facilitator: Travis Bauer (5635)*
- Leadership Challenges & Opportunities for Shoot-for-the Moon Team Research Innovation in Silicon Valley and Sandia
  - *Facilitator: Rick Schneider (glo USA)*
- Group Discussion & Adjourn
  - *Facilitator: Jeffrey Tsao (1120)*

Table 1. List of Attendees

All Day	
Tom Brennan	Arch Venture Partners
Mike Coltrin	Advanced Materials Sciences Department 1126
Scottie-Beth Fleming	Human Factors Department 431
Donald Guy	Technical Library Department 9536
Wendell Jones	Systems Analysis and Decision Support Group 150
John Mareda	Knowledge Systems Department 9537
Venky Narayanamurti	Harvard University Belfer Center for Science & International Affairs, Harvard John A. Paulson School of Engineering & Applied Sciences
Rick Schneider	glo USA
Jeff Tsao	Semiconductor and Optical Sciences Group 1120
Jessica Turnley	Galisteo Consulting Group
Rieko Yajima	Stanford University Center for Design Research
Partial Day	
Travis Bauer	Analytics & Cryptography Department 5635
Ben Cook	CTO Office Group 1910
Grant Heffelfinger	Physical, Chemical and Nano Sciences Center 1100
Curtis Johnson	Analytics & Cryptography Department 5635
Tina Nenoff	Physical, Chemical and Nano Sciences Center 1100
Austin Silva	Cognitive Sciences & Systems Department 1463
Lynne Starkweather	S&T and Partnerships Business Operations Group 10610
Christina Ting	Analytics & Cryptography Department 5635
Tim Trucano	Computer Research Center 1400

2. CHALLENGES TO MANAGING RESEARCH IN SANDIA'S SCIENCE, TECHNOLOGY AND ENGINEERING ENTERPRISE: THE VIEW FROM ONE CENTER

This discussion was facilitated by Grant Heffelfinger, Director of the Physical, Chemical and Nano Science Center 1100. Division 1000 is considered the Science and Technology "research" Division of Sandia, and Center 1100 has historically been among the most research-oriented organizations within Division 1000. The discussion centered on the challenges associated with innovative and bold research in Sandia's current research environment. Among the points brought up in the discussion were:

- Some portions of Sandia research have adopted a conservative culture which values tight accountability/oversight to achieve pre-negotiated, short-term and low-risk milestones.
- Some portions of Sandia research have also been under severe budget pressure for a number of years, due to an increasing fraction of funding coming from less-predictable, sources. This has resulted over time in a "fee for service" (will do anything for funding) culture that rewards salesmanship over technically deep and honest brokering, which dis-rewards uncertainty and risk, and which drives hiring for short-term program needs rather than for technical excellence over a 30-year career.
- Both of the above characteristics and trends are incompatible with the uncertainty and risk associated with research excellence/innovation/boldness and with the autonomy, psychological safety and strategic technical engagement necessary for research staff *and* research managers. Staff who worry where the next paycheck will come from, and who are moved from one knowledge domain area to another to follow available funds, cannot engage as deeply technically. Managers who spend most of their time worrying about customers become responsive to customers' *immediate* needs and cannot engage in deep, technical and strategic thoughts so as to anticipate customers' *future* needs.
- That said, Sandia research has much to offer: an unrivalled legacy ability to tackle hard interdisciplinary national problems and an attractive and secure work-life-balancing environment for its research staff.

3. IDEA GENERATION/ DISCERNMENT/SELECTION/TEST: A SIMPLE MECHANISTIC MODEL

This discussion was facilitated by Jeff Tsao, a Distinguished Member of Technical Staff in the Semiconductor and Optical Sciences Group 1120 at Sandia. The discussion centered on mechanistic models for idea generation/discernment/selection/test, what he and his colleagues hypothesize is the universal "engine" of research process, and thus the engine of research process at Sandia as well. If we could develop such a mechanistic model for research process, perhaps we could improve macro level research outcomes through better grounded insights connected to micro level of mechanisms and interactions.

In the short-term, even without quantitative validation, the models might serve to confirm/disconfirm/improve internal mental models that research managers and policy makers *already* use to make decisions. In the long-term, the models should be predictive, and thus should suggest experiments to refute or improve the models.

Among the points brought up in the discussion were:

- One current framework emerged from Sandia's June, 2013 Forum & Roundtable on the Art & Science of Science & Technology, in particular, the notion that idea generation and discernment/selection/test is the basic engine of research. Two processes are happening in series: first, there is a divergent thinking process in which new ideas, good and bad, are generated; second, there must also be a convergent thinking process in which the good ideas are discerned/selected/tested and the bad ideas are discarded.
- For what constitutes a "good" idea, one might borrow notions advanced recently by Professor Dean Simonton (UC Davis): it is the product of originality, utility, and counter-intuitiveness. By originality, we mean how novel is the idea to the knowledge domain of interest (how unlikely is it that someone would come up with such an idea)? By utility, we mean if the idea were to work as envisioned (that is, suspending disbelief in whether the idea would work or not), how useful would the idea be to the knowledge domain of interest? By counter-intuitiveness, we mean how much does the idea contradict current beliefs in the knowledge domain of interest (how unlikely does it seem to experts that the idea would work at all)?
- For what constitutes quality discernment/selection/test, one view is that the ideas that are generated must undergo first and foremost a "discernment process" involving domain-area expertise and critical thinking. At the beginning of the discernment process, a "peer review" group might evaluate the ideas but the initial evaluation would be noisy. As the discernment process and individual/group critical thinking proceeds, the noise in the evaluation would be reduced, and the discernment of the three characteristics (originality, utility, and counter-intuitiveness) would become more accurate.
- Note that both various kinds of individual and group processes and various "kinds" of thinking enter into both idea generation and idea discernment/selection/test. Creative thinking certainly enters into the generation of ideas with a wide distribution of originality, utility and counter-intuitiveness. Critical (rational, first principles) thinking certainly enters into the discernment/selection/testing of ideas. Cognitive biases also enter into both idea generation and idea discernment/selection/test – and might predispose researchers towards ideas with high utility and low counter-intuitiveness.
- What kind of impact could mechanistic models like this have on practical research management? It's too early to really say but some possibilities might be the following.

1. Understanding how to separately score research ideas on each of the three characteristics so as not to confuse the three (or so as to minimize systematic biases against any of them).
2. Catalyzing deeper thinking on "creativity," and how this is a dynamic interplay between co-evolving problem and solution spaces.
3. Measuring the salient features of a research environment so as to understand which mechanistic processes are "rate limiting."
4. Catalyzing deeper thinking on the importance of groups and diversity separately on creative and critical thinking processes.
5. Understanding the role of human emotional considerations that create biases in decision-making over research directions: bias against proposers who have "unproven" track records, or against fields that are less "quantitative," or against problems that one "knows" cannot be solved.

4. CYCLES OF INVENTION AND DISCOVERY: RETHINKING THE ENDLESS FRONTIER

This discussion was facilitated by Venky Narayanamurti, former Sandia VP Division 1000, former Dean of Engineering at UC Santa Barbara and Dean of Engineering and Applied Science at Harvard University, and currently Benjamin Peirce Research Professor of Technology and Public Policy at the Harvard Belfer Center for Science and International Affairs. The discussion centered on the key characteristics of research environments conducive to excellence, characteristics that Venky distilled from his experiences at Bell Labs, Sandia, UCSB and Harvard, some of which are discussed in his recent book with Tolu Odumosu, "Cycles of Invention and Discovery: Rethinking the Endless Frontier."

- One characteristic is that a research environment be conducive to discovery (science) and invention (technology) occurring synergistically and side-by-side.
- A second characteristic is that it be meritocratic: recruitment of the best and the brightest; leadership that is scientifically/technologically distinguished; and periodic performance reviews based on technical merit.
- A third characteristic is stable funding with long-term interests in mind and that is insulated from short-term drivers. Indeed, this is so important that it determines the size of the research staff – one shouldn't hire more research staff than one has stable funding for.
- A fourth characteristic is a balance between freedom and focus: research should be insulated, but not isolated, from the mission and goals of the organization.
- A fifth characteristic is that it be conducive to a free flow of ideas across disciplinary boundaries, thereby allowing for collaboration to address the most challenging problems.
- Key questions are: Which of these characteristics are necessary? Are they sufficient? Which does Sandia research already exemplify? Which are incompatible with Sandia's constraints as an NNSA laboratory? Perhaps most importantly, how does one manage the differences between the culture of research – which requires flexibility, boldness and risk – with Sandia's predominant culture of scheduled and foreseeable results?

5. ASSESSING THE ENVIRONMENT FOR BOLD OUTCOMES IN SANDIA RESEARCH

This discussion was facilitated by Lynne Starkweather, Quality Assurance Specialist in the S&T and Partnerships Business Operations Group 10610 at Sandia. She and Jeff Tsao have been conducting focus groups involving Sandia Division 1000 research staff, with the aim of identifying "choke" points that inhibit research boldness at Sandia, and potential solutions to increase boldness. Although the data gathered from the focus groups was exploratory, the overall findings were consistent with information obtained from a formal L1 Manager Study conducted recently (2015-16) by Jerry Simmons and Lynne Starkweather, and from numerous exit interviews conducted by Lynne Starkweather over the last five years. Among the points brought up in the discussion were:

- Sandia research boldness is inhibited by what Sandia as a whole values and rewards. It values what is clearly doable (and thus not as bold). It values successful "mediocrity" but not unsuccessful "excellence." It values SMART (specific, measurable, attainable, relevant and time-bound) objectives, even though they do not apply to research which is inherently uncertain and impossible to schedule.
- Sandia research boldness is also inhibited by its "business model": too-small projects available to research staff, which greatly limits focused momentum; very limited access to larger and longer-term programs/research; no time/energy to think; death by a thousand cuts (administrative/compliance demands); less long-term commitment to career development compared to that in previous years; the "target needs" and review processes of Sandia's LDRD proposal process emphasizes utility and short-term program management unit (PMU) needs over originality and counter-intuitiveness; no perceived flexibility in co-evolving an LDRD project's problem and solution space to increase boldness; and a "hunt to eat" mentality regarding the constant need to look for funding that promotes unhealthy competition and knowledge non-sharing amongst staff.
- Portions of Sandia research have quite poor morale, which leads to backing off on "fire in the belly" and "I want to change the world" research passion and instead leads to a more complacent workforce, with a reduced willingness and energy to put in the extra time and energy typically necessary for research breakthroughs. In fact, backing off on research passion is itself rewarded by a Sandia work environment that encourages work-life balance (that is indeed a distinguishing feature for Sandia in its recruiting efforts).
- This type of environment leads to lower quality research, decreased rewards and recognition from the external research community and a shift to "artificial" internal rewards and recognitions such as promotions and salary raises. Work environments in which employees are "fed" by the sense of doing something hugely impactful require less of the internal rewards and recognitions: for much of Bell Labs' history, all research staff, even Nobel-class, were simply Members of Technical Staff; and start-up companies have famously lean and flat organizations.
- One possible solution could be targeted refocusing of the research business model and culture to communicate, value and reward research boldness: shifting from "fear of failure" to feeling safe to be bold; where appropriate, provide the opportunity for deliberate "collaborative thinking time" where innovation becomes possible; reward boldness with non-traditional incentives like research dollars intended to breed more boldness.

- Related to the above solution, could one shift to a *people-centric* management philosophy that gives researchers freedom (and incentive) to do bold research they believe will have the greatest impact, and shift away from a *project-centric* management philosophy that ties researchers' hands to pre-determined milestones and to a narrow problem and/or solution space. A key challenge here, however, is how do we give research staff freedom but also guard against complacency? How do we ensure high quality work by bringing into Sandia the outside research world's opinion (peer review, interactions, feedback)? There is nothing that is more harmful to research excellence than insularity from the larger (and highly competitive) world of research.
- Another suggestion is for management training in mentoring millennials: learn to communicate to them the "exceptional service to society" benefit of research. Will millennial researchers feel the same sense of pride and intrinsic reward that previous generations of researchers have felt, so that giving them the freedom to do the best research will be as motivating to them as it has been to previous generations of researchers? Or will millennial researchers be driven by a different set of desires and motivations?

6. FACILITATING SOCIO-TECHNICAL TEAMS AND IDEA GENERATION USING SCIENTIFIC AND DESIGNERLY PERSPECTIVES

This discussion was facilitated by Rieko Yajima, a Visiting Scholar at the Stanford University Center for Design Research. Rieko is investigating how design thinking paradigms can catalyze scientific research and innovation. The discussion centered on ways design thinking might be used to re-organize and improve the practice of science in general, and thus how it might be used to re-organize and improve the practice of science at Sandia in particular.

- Design is a deeply humanistic and sociotechnical process that applies universally to all knowledge domains: one might say that design is the creation of artifacts that enable humans to interact with their environments. Science is just as deeply a humanistic and sociotechnical process that applies universally to all knowledge domains: one might say science is the creation of "ideas" that enable humans to interpret and understand their environments. Many of the underlying sociotechnical processes of design and science are shared: creatively generating new artifacts and ideas (using individual and social mechanisms), testing those artifacts and ideas against the environment and context they are expected to function in, iterative improvement of those artifacts and ideas, and sharing and diffusing the artifacts and ideas throughout a larger human community. Thus: can science learn from design?
- Interestingly, despite their similarities, the everyday environments in which designers and scientists work are very different. In June, 2016, Rieko organized a "Shared Exploration Across Design & Science" workshop at Stanford that brought together a small group of elite designers and scientists from academia, industry, and national laboratories. One striking conclusion from that workshop was that designers typically work in an environment that is self-perceived to be nurturing, while scientists typically work in an environment that is self-perceived to be hostile ("hostile" is the exact word that was used). Why exactly this is so, and what aspects are fundamental to science in general, is not clear; but from the discussion that Lynne Starkweather catalyzed (described earlier), certainly pockets of Sandia research have environments that could be considered hostile (or at least not nurturing) to researchers.
- One aspect of design that *is* clearly nurturing: an openness to a diversity of input from a diversity of people and disciplines. Indeed, in design, it is now commonly understood by designers that team interaction behavior is predictive of innovation outcome, and much effort is expended in facilitating team interaction (e.g., design of physical and intellectual interaction space, creation of psychological safety and empowerment). In science, there is neither a common understanding amongst scientists (though there is amongst funding agencies) of the importance of team interactions nor of the ways in which such interactions can be facilitated and improved.
- The Stanford Center for Design Research is developing a new methodology for micro-analysis of team interactions: the "Interaction Dynamics Notation" (IDN). This methodology is a way of breaking an overall flow of team interactions into micro-events such as idea blocking, deflection, overcoming, and support. The resulting "musical score" can then be analyzed for "musical passages," and these passages can be correlated with innovation success, neutrality, or failure. For example, passages with blocks followed by overcoming of blocks appear to be associated with innovativeness.

- Note that IDN is content independent, using content merely as a means to label the interaction. But ultimately combining IDN with content, which Sandia has expertise in (e.g., text analytics), could be fruitful. For example, teams that spend a lot of time in either knowledge space OR concept space are apparently not as effective as teams the flow between the two spaces, and a combined IDN+text analysis could quantify this.
- Perhaps Sandia's biggest challenge, if it were to begin to incorporate design thinking into its research processes, would be combatting the prevailing notions that (a) research is not a socio-technical system (i.e. a complex infrastructure that considers the interface of people and technology), and (b) psychological and social conditions of highly technical researchers do not play a strong role in their technical success (or research boldness).

7. INFERRING TRAITS OF GROUPS FROM TEXT AND EVENTS THEY GENERATE

This discussion was facilitated by Travis Bauer, a Distinguished Member of Technical Staff in the Analytics & Cryptography Department 5635. The discussion he catalyzed centered on the use of text analytics to infer traits of groups. Text analytics is a rapidly advancing set of methodologies for computationally analyzing communications between people. Text analytic tools could be used to quantify, possibly in real time, some of the features of the mechanistic processes discussed in Section 3 of this paper, features such as idea generation and idea discernment/selection/test.

In the discussion, several examples of text analytics were presented in the context of completed research.

- Example 1: Transfer Entropy can be used to infer directed relationships among individuals. We showed that by analyzing the time series information in revisions to Wikipedia pages, transfer entropy tended to be higher between pairs of individuals who were directly communicating with one another. In other words, transfer entropy can be a useful way to determine of two people in a social network with one another. (Bauer, T., D. Garcia, R., Colbaugh, K. Glass, "Detecting Collaboration Among Wikipedia Editors from Behavior," IEEE Intelligence and Security Informatics '13, June 4-7, Seattle, WA)
- Example 2: We showed that people tend to act more randomly when acting in concert with others. The randomness of the behavior of people editing Wikipedia tended to increase during periods of time when they were collaborating with others. (Bauer, T., R. Colbaugh, K. Class, D. Schnizlein, "Use of Transfer Entropy to Infer Relationships from Behavior", CSIIRW '12, Jan 7-9, Oak Ridge, Tennessee, USA)
- Example 3: We showed that data compression can be used to find points in time when a group of people working on some common artifact make significant decisions.
- Example 4: The cohesion of groups can be quantified, as described by Professor James Pennebaker (UT Austin), by the group's use of pronouns and other function (non-content) words. After a trauma, e.g., there is an increasing rate of use of "we," followed by a decay to the normal rate. We showed this effect in Twitter after the Paris attacks in late 2015.

8. LEADERSHIP CHALLENGES & OPPORTUNITIES FOR SHOOT-FOR-THE MOON TEAM INNOVATION IN SILICON VALLEY AND SANDIA

This discussion was facilitated by Rick Schneider, CTO of glo USA, a Bay Area start-up nanotechnology company, former Senior Manager of the Semiconductor and Optical Sciences Group 1120 at Sandia, and former Senior Manager of the Basic Energy Sciences Materials Science Program at Sandia. Among the points brought up in the discussion Rick catalyzed were:

- Bold research and innovation come in all size scales. Of special interest to Sandia and other larger institutions ought to be innovation that is large in scale, and thus characterized by "big hairy audacious goals" (BHAGs) *and* teams. Indeed, these two concepts are intimately connected: only teams can accomplish BHAGs, and BHAGs are required to give purpose and motivation to teams. Moreover, accomplishing BHAGs typically requires overcoming multiple valleys of deaths, hence requires teams with a diversity of skills and perspectives, with a mindset of continual adaptation and learning (a la Carol Dweck), and with a focus on organizational health (a la Patrick Lencioni).
- Among the multiple valleys of death that large teams face en route to accomplishing BHAGs: the invention-to-innovation valley; the research-to-development valley (technology risk); the development-to-manufacturing-and-deployment valley (commercialization risk); the technology-to-customer valley (market risk); the organizational-adaption valley (continuity vs. change); and the "team's ability to leverage individuals" valley.
- A common characteristic of all of these valleys of death (VoDs) is the existence of a polarity: two opposing and difficult-to-reconcile points of view, one on each side of the valley, both of which are necessary to embrace and balance off of each other. Indeed, when the polarities are embraced, they can feed off each other and lead to virtuous cycles of progress and to the bridging of the VoDs. For example, the R&D-to-Manufacturing VoD has as one polarity a "fundamental understanding" mentality and as another polarity a "continuous improvement" mentality." Each polarity could certainly proceed on its own, using methodologies tailored to its narrower goals. However, each polarity could also proceed synergistically via a shared goal: control. Fundamental understanding enables control which in turn enables continuous improvement; continuous improvement enables high-Q (quality/quantity) data and faster cycles of learning through the revealing of control gaps, the filling of knowledge gaps, and ultimately enriched fundamental understanding.
- Polarity management is thus crucial to BHAG-accomplishing teams. And, polarity management is singularly the job of leadership. Despite the seductiveness of self-organizing and leaderless teams, BHAG-accomplishing teams *require* leadership. Leadership is required to articulate the BHAG, to hold and catalyze the full breadth of diversity required in the team, and to identify and leverage polarities. Understanding and nurturing technical leadership is thus its own super important topic, an integral part of a research environment conducive to innovativeness and bold outcomes.
- Superimposed on all of this: as a community we have a language problem. Even the word "science" means different things to different people, much less "science" versus "engineering" or "discovery" versus "creation."
- A final question: Can and should we apply the fast-paced, sink or swim, BHAG/team approach to Sandia's government-owned contractor-operated (GoCo) research environment?

9. CLOSING THOUGHTS FROM PARTICIPANTS

Mike Coltrin: As a more senior staff member, who could retire anytime, I have a bit more freedom to turn work down and do what I believe will have the most impact, and that I am most interested in doing. Unfortunately, younger staff members don't have that luxury.

Donald Guy: At least in research, it's more about the people than about the projects. Modeling research may help understand research processes/methodologies. How do we converge science and engineering?

Wendell Jones: The resistance at Sandia to social engineering of research environments is understandable, especially considering the negatively connoted perception of social engineering as a "manipulation of people." But, in the end, researchers *are* people, and will respond, just as all people respond, to their environment, even if they may not intellectually like the idea that the environment might be socially engineered.

John Mareda: There are two characteristics that our Sandia research culture seems to have lost over time: (a) the freedom to fail and the patience to succeed; and (b) competition as a primary mode of individual aspiration. Indeed, perhaps there is a connection between these two absences. On the one hand, if a researcher is going to be measured by milestones, he/she has incentive to achieve the milestones and not to make them too bold (i.e. risky). On the other hand, if a researcher is going to be measured against a competitor, he/she has incentive to do his/her best and to be bold.

Tina Nenoff: The management-staff partnership is very important one in all work environments, and no less so in research. It is important in very many aspects of research, as research has increasingly become not just about the technical work but about many other kinds of work -- hiring/nurturing/managing groups of people, ES&H, budgets, intellectual property, external partnerships, marketing/selling, etc. – many of which are best championed and executed by management. A specific example of this is in VoDs, particularly the R&D-to-manufacturing (think Sandia-to-Industry) VoD, which is a serious effort and most importantly a serious *team* effort (think "it takes a village").

- Sandia Research Staff are clearly important, but they must be fully committed and supported, which means that it becomes a full-time job with a full-time project/task to charge. They must also be heard and respected throughout traversing the VoD, otherwise they might scale back their work to the bare minimum necessary for project success, with the potential to focus just on the mechanics of performing a job (e.g., 40-hour work weeks) rather than in pursuing bold and/or risky ideas that might be necessary to traverse the VoD.
- Sandia Management is also clearly important, at multiple levels: for dealing with corporate directives, legal requirements and documentation; for hiring, allocating and mentoring staff; for providing "gravitas" to industrial counterparts; for interpreting a program vision of success; for constant and consistent communication with the industrial side; and for managing polarities that might emerge if one entity is risk averse and the other is highly vested in risky/bold research.

Sandia's practical routes to traversing VoDs probably needs to be tuned to the needs and norms of the external partners. This type of teamwork is non-trivial, and may require different skill sets from the Sandians. For example, in some cases (eg., academia) the partners are used to independence in timing and direction, while in others (eg., industry) they are more beholden to shorter term corporate directives.

Rick Schneider: If the vision and BHAG is big enough, many teamwork and motivational issues take care of themselves.

Jessica Turnley: It all starts with senior leadership; they need to help "make it happen," to embody and speak about desired values, and to develop and implement reward structures that truly reward the performance of those values. One of the big issues of Sandia is its diffused (or lack of) focus – it is an organization that does everything from basic research to applied engineering and uses the same incentive and reward structures for all. Can we devise processes that reward teamwork and collaboration? Sandia has 'talked the talk' about teamwork for decades, but reward structures still focus on individual contributors. One big question: what is it that people can get excited about at Sandia?

Rieko Yajima: How can we get serious about understanding research process and inventing new ways of "doing" research? What would be the tipping point to get research organizations to be serious about this kind of self-improvement? How do we start creating a community and a collective voice? How can we find the people with the open mindedness and savvy to get the ball rolling? Can we start small, create physical and intellectual spaces to experiment and innovate research process? In fact, perhaps we should give "experimentation space" to research process just as we give it to research itself.

Another thought: By its very nature (much classified work, physically located on an Air Force base), Sandia cannot help but be somewhat insular. That's a difficult environment for research, which requires close coupling to the larger and super-competitive external world of research. How can Sandia manage that tension? So, a question: Is there a "protected" group or set of groups at Sandia that has the reputation for successful and continuation innovation in spite of all these forces working against them? If so, how is that group supported and can that support structure be repeated across the labs?

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