
# Brazil-U.S. Workshop on Strengthening the Culture of Nuclear Safety and Security: Summary of a Workshop

**DETAILS**

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**AUTHORS**

Benjamin Rusek and Micah Lowenthal, Rapporteurs; Policy and Global Affairs; National Academy of Sciences; In Cooperation with the Instituto de Pesquisas Energeticas e Nucleares

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Benjamin Rusek and Micah Lowenthal, Rapporteurs

Policy and Global Affairs

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## BRAZIL-U.S. WORKSHOP ON STRENGTHENING THE CULTURE OF NUCLEAR SAFETY AND SECURITY PLANNING COMMITTEE

**Robert A. Bari**, Chair, Senior Physicist and Senior Advisor, Brookhaven National Laboratory
**Matthew G. Bunn**, Professor of Practice, John F. Kennedy School of Government, Harvard University
**Michael L. Corradini**, Wisconsin Distinguished Professor of Nuclear Engineering and Engineering Physics, University of Wisconsin-Madison
**James O. Ellis**, Annenberg Distinguished Visiting Fellow and Member, Arctic Security Initiative at the Hoover Institution, Stanford University
**Alan S. Hanson**, Executive Director, International Nuclear Leadership Education Program, Massachusetts Institute of Technology
**Nancy Jo Nicholas**, Associate Laboratory Director, Los Alamos National Laboratory

*CNEN Organizers*

**Ivan Salati**, Director for Radiation Protection and Nuclear Safety and Member of the Deliberative Comissão Nacional de Energia Nuclear (CNEN)
**Claudio Almeida**, Advisor to the Director of Radiation Protection and Nuclear Safety, CNEN

*IPEN Organizer*

**Antonio Barroso**, Professor and Senior Researcher, Instituto de Pesquisas Energéticas e Nucleares (IPEN)

*National Academy of Sciences Staff*

**Benjamin J. Rusek**, Senior Program Officer
**Micah D. Lowenthal**, Program Director

# Preface and Acknowledgments

On August 25–26, 2014, the Instituto de Pesquisas Energéticas e Nucleares (IPEN, the Institute of Nuclear and Energy Research) and the National Research Council[1] of the U.S National Academy of Sciences (NAS) convened the *Brazil-U.S. Workshop on Strengthening the Culture of Nuclear Safety and Security*. The workshop, held on the IPEN Campus in São Paulo, Brazil, examined how a culture of nuclear safety and security is built and maintained within the nuclear science, technology, and industrial sectors. Participants identified opportunities for cooperation to strengthen that culture. To host the workshop, IPEN received financial support from Eletrobras Eletronuclear, Banco do Brasil, and Santander. U.S. participation was sponsored by the Partnership for Nuclear Security at the U.S. Department of State.

> *Statement of Task: An ad hoc NRC [National Research Council] committee will work with counterparts in Brazil to convene a Brazil-U.S. workshop to examine how a culture of nuclear safety and security is built and maintained within the nuclear science, technology, and industrial sectors and to look for opportunities for U.S.-Brazil cooperation to strengthen that culture.*

IPEN and NAS staff worked with Brazilian officials and academics from IPEN, the Comissão Nacional de Energia Nuclear (CNEN, the National Nuclear Energy Commission), the University of São Paulo, Eletrobras Eletronuclear, the Ministério da Ciência Tecnologia e Inovação (MCTI, the Ministry of Science, Technology, and Innovation), and the Governo do Estado de São Paulo (the Government of the State of São Paulo), and other groups in Brazil to plan and host the workshop. While no single workshop could cover nuclear safety and security culture comprehensively, the agenda was designed to address some of the most important ideas, and issues, and included sessions on

[1]Effective July 1, 2015, the institution is called the National Academies of Sciences, Engineering, and Medicine. References in this report to the National Research Council are used in an historic context identifying programs prior to July 1.

- The relationship between safety culture and security culture;
- Safety analysis, vulnerability assessment, and the design of integrated solutions;
- Performance assessment and improvement of safety and security culture;
- Training and education for safety and security culture;
- The “lessons-learned” processes and implementing change; and
- The influence of leadership and hierarchy on safety and security culture.

About a dozen experts each from Brazil and the United States spoke at the workshop, presenting talks, moderating panels, or serving as rapporteurs. The workshop was well attended by Brazilian experts: approximately 80 attended during the course of the 2 days. Participants included scientists, engineers, and officials who have managed and worked on complex projects in the nuclear sector, as well as graduate-level students from IPEN. IPEN webcast the workshop and took questions from the Internet during the sessions.[2] After the sessions, IPEN leadership demonstrated the capabilities of IPEN’s research reactor and IPEN’s radiopharmaceutical production facility for the U.S. group. NAS is especially grateful to IPEN staff members Arnaldo Andrade, Anderson Andrade, Afonso R. Aquino, Jamil M. S. Ayoub, Margarete L. Bustos, Edvaldo R. P. Fonseca, Rafael H. L. Garcia, Katia Itioka, Francisco Luiz Lemos, Mario O. Menezes, Roseli dos Reis Orsini, Tereza Cristina Salvetti, Glaucia Regina T. Santos, Walkiria G. Santos, Jorge Sarkis, Fábio Fumio Suzuki, and Antonio Vaz for their assistance in organizing the workshop.

## Acknowledgment of Reviewers

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the Academies’ Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for quality and objectivity. The review comments and draft manuscript remain confidential to protect the integrity of the process.

We wish to thank the following individuals for their review of this report: Robert Bari, Brookhaven National Laboratory; Antonio Barroso, IPEN; Togzhan

[2]More information about the workshop, including the agenda and all presentations and video recordings of the sessions, is available on the workshop website: http://gescon.ipen.br/workshop.

Kassenova, Carnegie Endowment for International Peace; Nancy Jo Nicholas, Los Alamos National Laboratory; Leonam dos Santos Guimarães, Eletrobras Eletronuclear; and Jorge Spitalnik, World Federation of Engineering Organizations.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the content of the report, nor did they see the final draft before its release. The review of this report was overseen by John Ahearne, Sigma Xi, The Scientific Research Society; appointed by the Academies, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the rapporteurs and the institution.

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# Overview

Nuclear technology contributes valuable services to modern society in the form of clean energy, medical diagnostics and therapy, nondestructive evaluation of materials, and fundamental research. Nuclear facilities also exist in the defense and national security sectors. With these benefits comes a responsibility to develop, design, operate, and decommission nuclear equipment and facilities safely and securely. It is necessary to design these technologies for safety and security, but good design and manufacture alone are insufficient for this purpose. Nuclear energy, radiotherapy, and nuclear research are not just machines run by individuals. Each is a sociotechnical system made up of complex machinery and software operated by individuals and teams of people. Safety culture and security culture are, in essence, commitments by organizations and the people who make up those organizations to value safety and security above other goals and practices, and to behave according to those values by incorporating safety and security considerations in every aspect of design, construction, operation, and decommissioning. Strong safety and security cultures are essential to achieve safe, secure operations and to realize the benefits of nuclear technologies.

At the August 2014 *Brazil-U.S. Workshop on Strengthening the Culture of Nuclear Safety and Security*, participants shared research, perspectives, and practices. The key points are described in abbreviated form below.

Many workshop participants noted that successful safety and security culture is achieved through interactions among system designers, operators, and overseers (regulators). A successful independent regulatory authority requires its own strong culture. This is as true in the context of nuclear reactor safety or nuclear materials control and accounting as it is in aircraft safety or safety and security in other complex systems.

The world nuclear community is inextricably linked, a number of participants said, so sharing learned experience on safety and security culture best practices and features is critically important. Transparency is a key to a good safety culture. However, individual countries and organizations will need to determine how to balance or resolve the tension between the need for transparency and open discussion, and the restriction of sensitive or proprietary information. Major challenges include the transition from analog/direct-control systems to digital/cyber systems, insider threats, and the arrogance of excellence (complacency and belief that we fully understand the systems).

Both safety and security are reinforced by training, but training is different from education. Good training involves exposure to alternate work environments, as rotations allow for greater understanding of an entire system. It is important to learn about past failures so that these lessons can be applied to future design, planning, and operations.

Many people working on safety and security culture draw on Edgar Schein's model of organizational culture, several participants observed, whereby one understands the state of an organization's culture by examining artifacts, claimed values, and basic assumptions. The model is used widely by leaders and managers to effect improvements in safety and security culture. Culture change, noted one speaker, is only possible when basic assumptions change.

Most participants agreed that there is not a generally accepted body of metrics (qualitative or quantitative) for assessing safety and security culture. Methodologies to measure effectiveness of organizational safety culture need to be based on performance and progress and must be sound and validated. However, a speaker warned not to let the quest for measurement postpone or interfere with actions that should be taken now. Risk assessment can serve as a framework for focusing attention in this sociotechnical system on critical components, both mechanical and human, for the safe operation of the facility. This framework can help to improve regulations (as seen in the U.S. Nuclear Regulatory Commission).

Leadership, argued more than one speaker, is the most important factor in creating organizations with strong nuclear safety and security culture. Safety and security culture can be changed, both positively and negatively, by what leaders say, by how decisions are made, and by what is done in response to failures. Perception drives behavior. If leadership places a high priority on safety and security, then the organization will reflect those beliefs. Complex systems demand attention and constant vigilance. The level of risk is growing with the increasing complexity of activities undertaken. The bedrock of industrial and corporate culture in the nuclear field must remain an unwavering commitment to safety and security.

Individual participants offered additional points:

- Institutional safety culture and security culture can be changed, both positively and negatively, by
  - What is said;
  - How decisions are made; and
  - What is done in response to failures.
- Transparency is a key attribute for good safety culture.

- Communication can take a positive or negative tone. Examples cited include the following:
  - Negative: United States—Y-12 National Security Complex non-questioning complacency.
  - Positive: Brazil—Eletronuclear public outreach.
- Nuclear institutions should share experience and best practices and features of successful safety and security culture across organizations and industries.
- Organizations should link authority and responsibility for implementing safety culture by empowering and expecting employees to raise safety issues themselves, including stopping work, if necessary.
- Organizations would be wise to expose safety and security staff to alternate work environments through staff rotation to allow for greater understanding of the entire systems.
- Nuclear systems are not just technical, but sociotechnical.

# Introduction

The organizers opened the *Brazil-U.S. Workshop on Strengthening the Culture of Nuclear Safety and Security* by welcoming the assembled participants and presenting an overview of the workshop's goals.

Jose Carlos Bressiani opened the workshop, stating that the event kicked off the Instituto de Pesquisas Energéticas e Nucleares (IPEN, the Institute of Nuclear and Energy Research) 50th anniversary celebration. He noted that the international workshop focused on an area that is important and becoming increasingly relevant to Brazil and its growing role in the nuclear world. He welcomed the assembled group of researchers, professors, and specialists of the highest levels from the United States and from companies and institutions in Brazil. He thanked and congratulated all who planned and organized the event.

Robert Bari thanked the Brazilian hosts, in particular, Dr. Barroso, Dr. Bressiani, and Dr. Salati, as well as the many other organizers for all their planning and hard work and for providing a hospitable setting for the event. He noted that the U.S. team was very grateful for the opportunity to be there to exchange fresh ideas on nuclear safety and security culture. It is of paramount importance to have frank and open discussions in the area of nuclear safety and security to help build new bridges between our respective nuclear enterprises and to pave new paths for future work. He noted that the Brazilian experts attending the workshop represent several organizations and diverse disciplines within the country with diverse technical objectives. The U.S. team was composed of individuals with varied backgrounds and technical interests as well. Both countries had assembled a wide range of expertise to discuss the topic areas. The U.S. team had been assembled under the auspices of the U.S. National Academy of Sciences.

The goals of the workshop, he said, are to emphasize the importance of the culture of nuclear safety and security, to enable U.S. and Brazilian experts to share and promote best practices developed in the two countries and around the world, and to help to establish the relationships among key Brazilian and American people and organizations to strengthen the culture of nuclear safety and security in both countries. This will be done through examining aspects of nuclear safety and security culture identified by the planners, including how safety and security cultures exist in the research, industrial, and regulatory sectors. The closing session of the workshop focuses on ideas for future areas of collaboration specifically. The published summary of the workshop is intended to help the two countries move forward in this area.

Dr. Bari asked, why bring the subject of safety culture and security culture together within one workshop? He suggested that it is hard enough to just deal with either of them on their own: They have effectively different contexts, which, when bringing them together, may inhibit fruitful discussion. Some see synergies between the two areas and sense that it would be beneficial to bring them under consideration as a broader area for exploration. Can methods, progress, and lessons learned in one area inform areas in the other? There is value in considering both areas together in one workshop. Dr. Bari said we should not overplay similarities and potential synergies between the areas; nor should we underplay them. The trick is to gain insights and then test them in different contexts to see what can be learned and exploited. Safety culture as it relates to organizations with high-hazard materials and operations is broader than just the nuclear arena, and there are likely to be higher-level principles and practices, he said.

For the nuclear enterprise, there is a third area of interest with regard to potential hazards. This is the proliferation of weapons. International safeguards, as promoted by the International Atomic Energy Agency and other organizations, provide the institutional context for this area. Some practitioners advocate what is called a “three S” approach to protection against potential hazards: safety, security, and safeguards. The notion of designing and operating nuclear systems that simultaneously optimize protection across all three S’s has been discussed at international meetings. A corollary to the safety culture and the security culture would be an international safeguards culture that would promote nonproliferation. For the present workshop, however, the focus is on safety and security cultures. While both have the common goal of protecting the public, workers, and the environment from radiological materials, the cultures are quite different in at least one sense. The safety domain tends to encourage openness or transparency, sharing of best practices, open communication with the public, and peer review by diverse stakeholders. The security area, on the other hand, by virtue of the information that it must work with, tends to be closed. Information is usually regarded to be sensitive, and there is concern that vital information might fall into the hands of any adversary. However, it is broadly recognized that a nuclear organization, either an operator or a regulator, must put a high emphasis on safety and security in order to protect against unfavorable radiological consequences. This is a fundamental aspect of the cultural construct. The rest of the workshop addressed these issues and more.

# I

# The Relationship Between Safety Culture and Security Culture

*The first session of the conference covered the relationship between safety culture and security culture from the perspective of the synergy between them, the regulation to support both, and the (undesirable) side effects of new technologies. Dr. Salati moderated a panel that consisted of Dr. Michael L. Corradini, Mr. Luiz Fernando Bloomfield Torres, Mr. William Tobey, and Dr. Claudio Almeida.*

### Why a Safety Culture Matters – Michael Corradini, University of Wisconsin

Dr. Corradini began the panel by presenting an overview of why *safety culture* matters. He started the discussion by talking about engineering safety in general. Engineering safety is an integral part of any sort of system design. However, there are a number of safety levels. Firstly, the system has to embed safety in its basic design. Secondly, the system operation has to strive for high reliability, such that if a reliable system is operating as designed, safety has been automatically integrated and is considered, and components work well together. All systems also have to think about "off-normal" events. The aeronautical industry is a good way to illustrate to a wide audience how to think about safety.

The first leg of Dr. Corradini's flight to São Paulo was on a two-engine passenger jet, designed and built by Embraer, the Brazilian aviation company. An off-normal event for this aircraft would be an event where something goes wrong with one engine, but there is no failure because of the two-engine system design. A twin engine plane is a robust system engineered to account for rare events. Nuclear facilities have adopted the concept of defense-in-depth. The purpose of defense-in-depth is to create multiple diverse and redundant layers of defense, hopefully as independent as possible, so that you can protect against accidents and threats if one level of defense—one barrier for radioactive release—is defeated. Dr. Corradini said:

> "But the thing that people tend to forget is that risk analysis, that is, the concept of what can go wrong and the frequency of things going wrong, is inherently part of defense-in-depth, because if you think of defense-in-depth without risk analysis, you always can come up with an additional barrier. But, as you do that, the probability, the frequency of it happening gets smaller and smaller. So, eventually, you have to come to a decision as to what is safe enough and risk analysis is the only method to think that through."

In nuclear power operation, operational safety is the first tool that plant owners and operators have to minimize incidents and improve reliability. In the United States, the Institute of Nuclear Power Operations (INPO) uses this as a metric to think about things, look at the root cause of what would be reportable events, and prevent future events by improving maintenance and operation procedures and continued and credible responsible regulation by the U.S. Nuclear Regulatory Commission (NRC). Not only does the plant operator review and report the events and try to keep the number of unanticipated events to a minimum, but these become elements of reliable and responsible regulation.

There is always a focus on early detection of generic safety issues. If a problem arises at one institution and one installation, and it continues at others, there should be an integrated approach in the industry to address these generic issues. In the United States, many of the more than 100 reactors have just gone through their 40-year license renewal or are in the process of either going into license renewal or asking for license renewal for another 20 years. A key safety issue that is assessed is material age, whether it be concrete structures, steel structures, electrical cabling, or systems.

Dr. Corradini also discussed measuring safety performance. In the United States, safety is measured quantitatively, whether by the industry and INPO, the first-line of operators at the operating plants, or the NRC. This is a risk-informed oversight process. Risk analysis helps to categorize events and find out what is important based on not only the event but also its potential frequency of occurrence. Seeing more adverse events indicates that operators are getting into a region that requires improvement. The NRC uses quantitative performance indicators, an inspection program, and an enforcement program that is geared toward safety significance. It is very important that it is a combination of not only observing the events and trying to understand their root causes but also intervening by working with the operator if something potentially dangerous becomes too frequent. Performance indicators should dictate a level of regulatory oversight beyond the baseline program.

When people talk about nuclear safety defense-in-depth, they always think about physical barriers, such as containment, a vessel, or fuel rods. Dr. Corradini stated that good defense-in-depth actually goes into the human element of nuclear safety (see Figure 1-1). This is probably the most important part. First, we need to continuously improve engineering: simpler designs, better instrumentation, more robust materials for harsh environments, which will not require re-placing or changing out materials that are aging. Next, we need reliable operation. Safety is foremost in all of these and it includes culture. Culture means "do it right," and doing it right means that at times we are going to have to shut something down and reduce performance so that we can understand a safety issue better.

Dr. Corradini brought up the necessity of credible regulation. It is not just having a good design or operating that design reliably and safely. We also need a third party, a different individual or a different organization, that reports to the public and openly communicates on safety performance. If the safety performance does not meet expectations, then this third party intervenes. It is important that the public be able to look at the regulator, look at almost everything the regulator is looking at, and come to some of their own judgments. We need top-notch people to continue to be part of these organizations, explained Dr. Corradini.

He presented definitions of safety culture, noting that the International Atomic Energy Agency (IAEA) and the U.S. NRC definitions are similar. Fundamentally safety culture is a set of core values and behaviors that result in a collective commitment by the leaders and the workers to emphasize safety over other goals. We cannot help but realize that performance is key. If an operating plant has to produce electricity for the utility, the industry, and the public, that is clearly a performance goal. But, if something is not going as expected, safety has to take precedence.

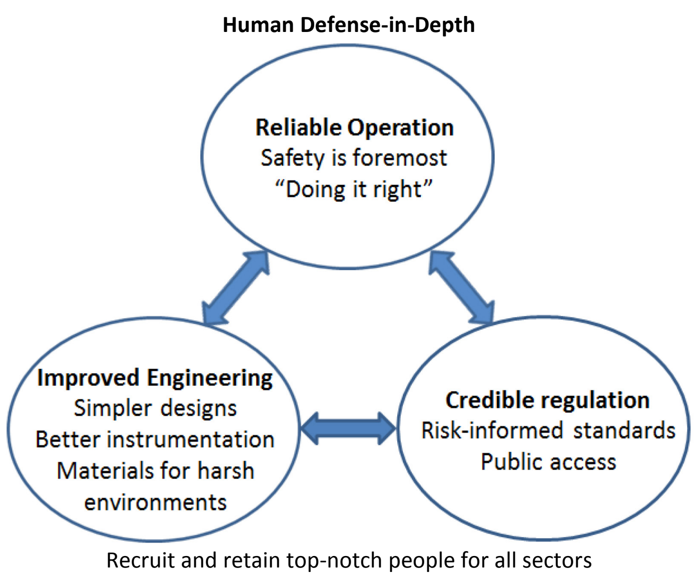


**FIGURE 1-1** Human defense-in-depth model.

Dr. Corradini made several statements to stimulate discussion. Firstly, improvements to safety and effectiveness falter through efforts to overly prescribe correct behavior. It is not always clear that there is an exactly correct behavior, and rigid scoring systems can be counterproductive. He posed that as a question because there is a diversity of views. Secondly, we need to emphasize thinking and safety awareness over scorecards and metrics that can induce complacency and compliance. Sometimes the measures are right, but the awareness and robust thinking process is not there, which is not a proper safety culture. Thirdly, qualitative evidence suggests that there are cultural traits that lead to improvements in safety. It is not clear whether we can measure them or not, but, clearly, there is qualitative evidence. And finally, culture cannot be legislated, but is actually seen. That culture among organizations and utilities with different leadership, and how they emphasize safety within performance, goes a long way to improve and actually maintain safety culture.

## Nuclear Security Culture – William Tobey, Harvard University

Mr. Tobey's presentation covered factors influencing nuclear security culture, the definition of good nuclear security culture, and practical examples. He drew on the World Institute for Nuclear Security (WINS)[1] "best practices" for nuclear security culture. He qualified that best practices are provisional: They are the best that can be done at a given time or place. In fact, they will almost certainly be superseded by better ideas as both offensive and defensive capabilities improve. Also they are an invitation to dialog to improve those practices through sharing.

Mr. Tobey discussed the IAEA's definition of *security culture*: "the assembly of characteristics, attitudes, and behaviors of individuals, organizations, and institutions which serve as a means to support and enhance nuclear security." Nuclear security culture is important because a good or bad culture can make systems that are in place more or less effective. A robust nuclear security culture and sense of professional responsibility are necessary for effective implementation of the procedures, which are developed and, in some cases, mandated by regulation. A poor culture can undermine those practices and regulations. The factors influencing nuclear security culture can be divided into three basic categories: the beliefs, the principles, and the values held by an organization, usually set by the highest leadership.

These key components are implemented through characteristics of behavior and realization within the organization. Critical to security culture are the beliefs that credible threats exist, that nuclear security plays a vital role to the success of the organization, that a strong security culture is essential, and that

[1] See https://www.wins.org/.

independent oversight strengthens security—it is not simply a nuisance. An organization also must demonstrate value learning.

Mr. Tobey explained that security is everyone's responsibility, not only the chief executive officer (CEO) or the security guards. Ongoing effective security training is essential, and teamwork is important. Important characteristics include leadership and motivation, accountability, professionalism and competence, integration of security within the operations, and learning and improvement. Most important is what an organization actually does—what policies, roles, responsibilities, and operating procedures are put into place, and what communication tools, leadership, and learning are used in the implementation of good security culture.

Good security culture is made up of 10 factors, Mr. Tobey said:

1. A commitment is seen at the top of the organization and in publicly available policies and statements about the importance of security to the organization.
2. Good security is implemented because it is important, not simply because it is required by regulators.
3. There is a senior committee of directors that reviews the security program and performance measures.
4. Security is given the same priority as safety.
5. Good security is seen as everyone's responsibility throughout the organization. All employees and contractors understand their role to make security effective.
6. There are good and open relationships with the police and joint, practical exercises conducted that demonstrate the effectiveness of security.
7. Security problems are reported honestly, so that lessons can be learned. This is particularly challenging in that security is a law enforcement issue.
8. Surveys are conducted to assess the security culture.
9. Costs are fully understood, and improvements in effectiveness are sought continuously: How can we do this better and more efficiently?
10. The security department is respected and seen as an important part of the management team.

Analysis of effective nuclear security culture has to be empirically based and has to depend on practical experience of operators. If it does not, it will be essentially dissociated from those operations and therefore less effective. In sum, a good security culture establishes the corporate strategy and ensures that governance arrangements are in place to explain and enforce that culture. It ensures that there are cross-functional lines within the organization, that there is a comprehensive program, and that there are metrics to establish both successes and failures in order to learn from them and to improve the organization.

The mission statement of WINS is to provide those who are accountable for nuclear security with a forum to share and promote best security practice. The organization has produced 32 international Best Practice Guides, held 51 workshops, and published its guides in 10 languages. The guides are empirically based and are meant to be practical for actual operators. It exists at the intersection of nuclear security and safety culture. Safety culture is well understood, well developed, and largely successful. An aspiration for those who work on nuclear security culture would be that the culture become just as well understood, well developed, and largely successful. He hoped that the two could be considered together.

### Safety and Security Culture from a Regulatory Perspective – Claudio Almeida, Comissão Nacional de Energia Nuclear (CNEN, National Nuclear Energy Commission)

Dr. Almeida covered several topics. He spent 14 years at the IAEA, and helped develop safety and security culture there. He shared some of the history about safety culture and how security culture was developed and presented the perspective of the regulatory bodies, especially the position of CNEN with respect to safety culture.

He began by detailing the origin of the concept of safety culture in the nuclear industry. He noted that the Chernobyl Report is widely known to be where the nuclear community worked on safety culture for the first time. This is where the IAEA first started addressing safety culture and the difficulties of improving this culture. People believed that the nuclear energy industry was the first to use the safety culture concept, but that the word was used before. The Bhopal accident at Union Carbide in India occurred before Chernobyl and was a toxic dispersion of methyl isocyanate gas from a Union Carbide plant, killing many and still causing problems today. The first time the term safety culture appeared was in a 1985 evaluation seminar about the cause of this disaster. The report issued concluded that the plant lacked a culture of safety. The lesson is that safety in one place does not necessarily mean safety in others, as in this case a multinational corporation did not follow the safety culture of the home country while operating abroad. On April 26, 1986, 1 year after this Bhopal seminar, the Chernobyl accident occurred. An internal group from the IAEA put together a report on the Chernobyl accident. This document talks about the lack of safety culture, claiming the first mention of the term.

This lack of safety culture prompted the IAEA International Nuclear Safety Group (INSAG) to highlight safety culture as one of the critical principles in nuclear installations. When INSAG put together a second report on the Chernobyl accident, the report corrected mistakes from the first report, which analyzed the consequences of the accident, but not the accident itself. And in 1992, INSAG made a further correction to the report, showing that design aspects contributed significantly to the accident.

Around this time, safety culture started to be discussed in many IAEA documents, especially from INSAG. But, internally the agency started asking, What does safety culture really mean? What does it describe? An April 1998 document that Dr. Almeida put together about safety culture asks, "How can one practically identify the existence of a 'safety culture'?" Is safety culture an attribute of the plant, of the management, of the operating organization, of a country, of each individual, or all of the above? Are there different levels of safety culture in plants? And how could we assess the safety culture of a plant, a country, or an individual? Could one define safety culture indicators? And if so, are those different from the safety indicators that the agency had developed at that time? Are the INSAG safety principles required for a safety culture? Is there a single safety culture for siting, design, construction, and operation, or different safety cultures in operation, siting, and design? Would an effective implementation of all the quality assurance requirements, such as the definition of responsibilities, training, qualification, and accountability, be sufficient for the existence of a safety culture? Is the Operational Safety Review Team (OSART) methodology capable of identifying the existence of a safety culture or lack thereof? Could a regulatory body lack a safety culture?

Dr. Almeida stated that at the time many on the IAEA staff working in safety recognized that we cannot measure safety culture. For a sense of the perspective at that time, as IAEA staff members were discussing these documents, they were also discussing INSAG reports and the Nuclear Safety Standards (NUSS), which were documents prepared by a group of consultants. The documents were prepared and published without international review. Others at the IAEA thought that INSAG did not have detailed knowledge or perspective and that the safety culture documents only covered past practices, and were not being incorporated into best practices. Interestingly, although these documents describe what a safety culture is, they were not able to identify the criteria to determine whether an organization or facility has one.

So, these documents are a list of questions without answers. They should be asked, but are not definite determinants of a good safety culture. An example is the question, "Do you have a resident inspector in the plant?" Some answer yes, and this is good, and others no, but this can be okay, too, in the right circumstances. So many questions in INSAG 4 do not have a right or wrong answer.

He stated that the same phenomenon occurs in security culture. It is not addressed in the NUSS documents, nor in the IAEA Safety Standards. The IAEA Safety Standards today mention the physical security of fissile materials and radioactive materials of nuclear power plants where appropriate, but it is not treated in detail with supplements in the IAEA Safety Standards or agency documents addressing security. At the Convention on Nuclear Safety, the gathering of experts in nuclear safety, the Review Meeting of 2002 directly followed the 9/11 terrorist attacks, and there is one statement in the Review Meeting Summary that says, "In light of the events of 11 September 2001, the issue of assuring the security of nuclear installations from terrorist attacks was a matter of significant concern to contracting parties." However, noting that security and physical protection matters do not lie within the scope of the Convention, do not relate to safety, and do not readily allow for meaningful discussion in the current forum due to the sensitivity of the information involved, the Review Meeting decided to exclude consideration of these issues from the scope of the Country Group Sessions.[2] Contracting parties were to address these issues in other appropriate international fora or in bilateral consultation. This justification is used to separate safety and security culture. The safety professionals recognized that there are synergies and interfaces between security and safety, but for a long time refused to combine the two.

Amidst pressure, particularly from the United States, to amend statements to include security, more and more agencies started to build on security methods. First, in 2006 the IAEA issued guidelines on border monitoring equipment. Next, in 2007 the IAEA issued documents on combating illicit trafficking of nuclear and other radioactive material. Then, in 2008, for the first time, security culture was mentioned in a document stating the objective and essential elements of a state's nuclear security regime. The definition shown by Mr. Tobey was issued in 2013. The challenges encountered in developing guidance on safety culture persist here. The current regulatory perspective is that safety and security can be regulated, but safety culture and security culture cannot, because they depend on behaviors. Instead, they can be assessed.

CNEN does not have specific regulations about safety culture. CNEN monitors safety culture by the way that resident inspectors observe plant behavior, by analysis of operational experience and daily events, and by performance indicators. Safety culture is not mentioned explicitly in CNEN licenses. Operational safety regulations require that the management of power plants consider safety culture, but they do not define or specify requirements or implementation details. CNEN has developed safety culture principles and conducted seminars with the help of IAEA, but it does not have specific requirements.

In conclusion, Almeida said, defining safety culture or security culture is not the solution to the problem, but just the beginning. The regulatory body and the operator have to ensure that these ideas are a commitment of the organization and permeate throughout the staff. But CNEN does not intend to measure, monitor, or make requirements for safety or security culture as a rule.

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[2]In order to expedite reviews of National Reports, the Convention stipulates organization of the Review Meeting into Country Groups. These groups are not limited by geographical area and should contain Contracting Parties with equivalent expertise in the management of spent fuel and radioactive waste. Country Group Sessions discuss each country's National Report, beginning with a presentation on the report and followed by questions and discussion. (Available at https://www.iaea.org/sites/default/files/publications/documents/infcircs/2002/infcirc603.pdf.)

## DISCUSSION

Dr. Barroso began the discussion with Dr. Corradini's concept of human defense-in-depth, which dealt with reliable cooperation, engineering, improved engineering, and mainly credible regulation open to the public. He asked Dr. Corradini to expound further, if possible with an example, on credible regulations based on risk assessment and how people should be granted access to information.

Dr. Corradini discussed a couple of examples, including the corrosion incident and near accident at Davis-Besse Nuclear Power Station in the United States. The operator postponed the replacement until a future refueling outage when, on March 5, 2002, a football-sized pit was discovered in the vessel head of the Davis-Besse reactor. It was a result of unmanaged corrosion. Before the event there was a focus on the corrosion issues on the reactor vessel head, with the replacement of the vessel head identified as the best option to assure reliability. The incident was an indication that Davis-Besse was missing the roots of safety culture, because the utility allowed the operation to continue knowing that they did not understand the root cause of the problem until it became a very public matter. Any of three independent groups should have prevented this, and eventually the regulatory agency and the Institute of Nuclear Power Operations came in to hold people accountable. At least in the United States, if it is not a public discussion, the public immediately starts thinking that something is being hidden. All of the interactions among the designer, the operator, and the regulator have to be in the public eye.

Another quick example is spent fuel pool storage and potential disposition of where spent fuel should be stored—in wet pools or in dry cask storage. There is a current debate in the United States about design and operation, as well as where waste should be stored. All of this discussion has to be done in the open, questions have to be asked as to whether the current designs are safe and how safe they are. The regulator has looked at calculations and studies and made some decisions. This issue will be debated continually because there is still a concern about how security measures could affect the safety of spent fuel pools.

One of the speakers raised the point that the Portuguese language has a single word, *segurança*, for "security" and "safety." This causes confusion in some circumstances. This is common to several languages. In the nuclear environment it is useful to separate these two terms to avoid confusion. In Portuguese, *physical protection* is used as a substitute for "security."

All three presentations mentioned the interfaces and synergy between these two concepts. The speaker put forth his view that the security and safety approach is focused on a single threat. When we talk about safety, we are trying to protect the installation from several different threats, from all kinds of sources, such as from external natural sources. There are external threats that are human as well, and security deals with this specific niche. He expressed a small concern about separating these two concepts, as they are separate more because of politics than because of techniques. He called for further discussion on the interaction of these two concepts.

Dr. Salati suggested that this difference among safety, nuclear safety, and nuclear security is an older concept that has been enriched with newer approaches. Physical protection or security some time ago was more focused on protecting the installation, and the concept encompasses more aspects. It may be a little bit closer to the word safety. He asked the presenters for more depth on these concepts.

Dr. Corradini said that while protecting against human attack can be regarded as a niche element of the overall responsibility for the safety of an installation, there is at least one important difference: In many respects, safety judgment is based on preventing against the combined probability of multiple actions occurring at the same time. For example, if one looks at the Fukushima accident, several things, all of which were expected to be very rare occurrences, went wrong simultaneously. In the security realm, would-be terrorists do not respect the laws of combined probability; they attempt to defeat them by design. Therefore, while robust safety measures can help prevent against security problems, they are probably not sufficient.

Because the chance of a human threat or human intervention is the key aspect of security, analysts would look at what the risk world would term *common mode failures* multiple safety measure that can be compromised by a single event. The concern right now is not that there is inadequate spent fuel safety because of extreme external events, an imprecise design, or some sort of internal event. Rather, this safety may be inadequate because of the potential for human intervention. To even think about that, we have to think about it from a risk perspective. There will always be some residual risk that we have to accept. We cannot protect against everything.

Dr. Almeida expressed tensions arising between security and safety. For instance, in the interests of safety, a facility should allow easy access in an emergency, while security interests might be best served by controlling and excluding most access. In addition, from a safety perspective, a facility would want to limit the number of people entering a central area with a high radiation field. But, from a security point of view, that facility would demand as much supervision as possible to ensure nothing is sabotaged. This competition between safety and security means one has to be very careful about selecting procedures that fulfill the requirements for both. This tension becomes pronounced in the realm of public information as well. While we strive for openness and transparency in safety, in security we often require secrecy. Just after 9/11 the latitude and longitude of nuclear power plants were removed from the public information domain. There is a very fine line between public information for safety measures and secrecy for security measures, and it is difficult to manage these sometimes contradictory commitments.

Dr. Lowenthal asked a question about measurements and indicators mentioned in several of the talks and how one goes beyond checklists alone when measuring safety culture or security culture. As Dr. Almeida mentioned, an office could have a mission of quality assurance, but that does not mean that there is a culture of quality within the organization. So, how does an organization get beyond just a checklist of: "Do you have this, yes or no?"

Mr. Tobey relayed his experience on an accreditation board for INPO, where utility executives and their staffs would discuss training. There would be interesting connections among measures, such as the U.S. NRC's Reactor Operational Performance Measures and INPO's own set of measures. For a plant with a lot of unanticipated SCRAMs (emergency reactor core shutdowns), an apparently larger amount of radiation dose per unit or per capita for the workers, and a lot of corrective actions, one starts to wonder whether the management sees the importance of a cross-cutting emphasis on safety. For INPO, that triggers another visit.

For the U.S. NRC, the response would be similar. Even without a direct measure, if the U.S. NRC senses cross-cutting issues and behavior associated with a number of unaddressed corrective actions, there might be reportable performance measures that would take them from, in the U.S. world, green to white to yellow. A qualitative sense of a cross-cutting issue will trigger a visit by the U.S. NRC as part of their inspections and a conversation with the leadership will be necessary.

Dr. Almeida stated that the definition of safety culture is a question without answers and evidence. The most important elements for managers and regulators are

- To instill a questioning attitude in their staff so that whatever they do, before doing it, they question, Why are we doing it? Are we doing it the right way?
- To maintain a good record, as was mentioned, but what next?
- To realize that excellence is not only fulfilling minimum requirements, but trying to do better.

Dr. Corradini drew an analogy with a checklist as bricks in a wall, and culture as the mortar that holds the bricks together. Strong mortar comes from leadership by management and responsibility by implementers. Both the leadership and the sense of responsibility have to pervade every corner of an organization.

General Alston asked about the ability to measure safety and security, but not safety culture and security culture. He postulated that the next Chernobyl-type disaster would have a summary assessment on whether its cause was principally a safety failure or a security failure; that words in that next failure report would point toward a summary appraisal of safety culture or security culture. So as difficult as it may be to measure the strength of the mortar, it seems that it is a worthwhile pursuit. It is difficult in the way that we have created the regulation apparatus and the objective assessments to see the empirical evidence to justify the evaluation. It seems that much more work needs to be done to actually be able to measure the culture strength of the organization. And it is right and proper to do so, as that next failure report will describe a failure in safety culture or security culture. He inquired as to whether in the continuum of intellectual development for evaluating cultural readiness, we are in the early stages and have a long way to go or we ought not to put energy here into expanding or developing our regulatory competencies.

The discussion then shifted to value judgements about culture and distinctions between national or ethnical culture and corporate safety and security culture.

Dr. Torres began by disagreeing with the idea that cultures can be better or worse. They can only be different. Bach is not more culturally advanced than a drum song of an African tribe, he said. They are different. In this sense, it is difficult to measure. After the buzzword safety culture appeared, there was a group that developed the Assessment of Safety Culture in Organizations Team (ASCOT) service, which was similar to the Operational Safety Review Team. The OSART examines facility operation. Now there is the Integrated Regulatory Review Service, which is similar to regulators. There was also a group that created ASCOT, which was supposed to be a team that examined and assessed facility safety culture. They developed guidelines on how to do it, based on the INSAG 4 documents and the characteristics and the questions without answers. Then they produced several seminars where they said to countries, "This is what we can do for you. We can assess your culture." No nations accept it. Nobody accepts that someone can come and look at their culture and try to compare it with another, so that one is better than the other, Dr. Torres said.

Since we cannot compare cultures, Dr. Torres argued, individual's cultures must use characteristics, do self-assessments, know themselves, and ask the questions. They must compare their cultures with the whole culture of the country, including engineering and safety and fire protection and security. But it is not possible to measure the culture or to compare safety cultures, Dr. Torres concluded.

Dr. Haber stated a preference for discussing understanding a culture, as opposed to measuring it. We are not actually measuring the culture, she said, but trying to understand the community outcomes or safety and security performance aspects of the culture. We understand the culture through the behaviors that we observe and measure. In Brazil, self-assessments of safety culture using the IAEA as the guide have been successful.[3] But she does not think they would pretend to say that they are measuring culture. Rather, they would say that they

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[3]In the late 1990s and early 2000s, Brazil undertook efforts to determine safety culture traits and characteristics and to remedy deficiencies at the nuclear utility Eletronuclear and at the fuel cycle facilities of Industrias Nucleares do Brasil (INB). This was done with the assistance of the IAEA by conducting safety culture self-assessments in both companies. Results of these projects were discussed extensively at the IAEA International Conference on Safety Culture in Nuclear Installations (Rio de Janeiro, Brazil, December 2002).

are helping the organization understand the behaviors that drive that performance that results in safety or security.

Mr. Tobey noted that the beliefs and principles that guide an organization are typically set by the most senior management. The practices for how to implement them occur at the middle-management level. And finally, what actually happens because of the actions of the majority of the employees is very important.

He argued that we should not confuse national cultures and security and safety culture. Nations can have different cultures and have features in common with both their safety and security cultures. And by the same token, it is possible that not all security cultures are equal. Some are more successful than others. It is also possible for a security culture to fail. The reviewers of the recent failure at the U.S. Y-12 National Security Complex concluded that the culture had allowed people to tolerate the intolerable.[4] There were multiple false alarms that came to be ignored by guards and a subsequent revelation of cheating on internal assessments. Those are attributes of a failed culture. While nations may differ in their emphasis on ideas such as the use of humans versus technology to advance security, it is important that whatever culture is in place be a successful one.

Dr. Barroso said that it is unfortunate that there was not IAEA ASCOT action in Brazil. It would be valuable to make longitudinal observations and cross-cutting quantitative research comparing groups. Regardless of the type of assessment, it can be repeated in the future to track progress on the characteristics that are identified.

Safety culture might not have been created by the IAEA, but it is the term that the agency emphasized greatly in general conferences, guidelines, and recommendations. The nuclear area has been left very far behind. It may not be appropriate to talk about measuring culture, but we need to have good instruments to assess. The medical field is far more advanced, Dr. Barroso said. They have validated instruments. The nuclear field does not, and IAEA work is not validated statistically. This does not mean that it is wrong, and there are other ways to evaluate and assess culture for this type of mission. The observation and ethnographic studies of people interacting are very important. For the last 5 years, Dr. Barroso has been trying to use the type of statistics normally applied to social sciences to deal with this aspect. When you have a quantitative instrument, it can be standardized and adapted to different cultures, Dr. Barroso said.

Dr. Salati said we cannot measure safety culture, but we can measure results, and results are achieved through different indicators that can be assessed. Maybe the culture can be assessed indirectly through the performance indicators for the facility. He mentioned the idea he posed earlier on the interferences between safety and security, when looking at the culture. Safety culture is based on transparency and openness, and very much on internal, bottom-up discussions. But security culture or physical safety is the opposite. It is based on

[4]The Y-12 security failure is described in Chapter 5.

"closedness." It is not transparent. It tries to be as hidden as possible. It is always top-down. It is traditionally not very adapted or adaptable to discussions. So, the question is, how can we combine these characteristics from safety and the security characteristics, how can we combine them both?

Mr. Tobey agreed that it would be a mistake to underplay the differences. At a certain level, secrecy has to be maintained to have good security, and that is different from his understanding of safety. On the other hand, he stated that there are ways in which the two realms can learn from each other. For example, with respect to the idea that security must be top-down, that is actually a potential problem because it may be that those in the field will have ideas either how to implement more effective security for a given cost or to implement the same level of security at a lower cost. We have learned those lessons in the safety realm, and there can be some sharing between the two. Mr. Tobey highlighted the importance of Dr. Torres's comment on self-assessment. Effective cultures practice self-assessment, and that is a way in which we can both resolve some of the differences between those two realms and the difficulties in measuring culture.

Dr. Corradini stated his view that there are two spheres of influence. Security has a sphere of influence, safety has a sphere of influence, and there are interaction points. One interaction point after the terrorist attacks in the United States on September 11, 2001, was that human interventions in a nuclear power plant had to be considered. In the United States, Section B.5.b of the Interim Compensatory Measures Order (U.S. NRC Order EA-02-026, February 25, 2002) dealt with nuclear power plant protection after 9/11. We can have all the attributes of safety within a security framework. In Section B.5.b, the questions are loss of large areas of a plant due to causes of large fires and explosions. As long as the audience is appropriate, we can have a very open and vigorous discussion about what is good, what is bad, what works, and what does not work under that framework.

All the elements of safety, where a technical discussion is necessary can be conducted openly. Such a discussion can be shared across cultures and across nations, if they are interested. When this discussion began within the Advisory Committee on Reactor Safeguards of the Nuclear Regulatory Commission, there were questions and they received information about what was happening in France and in other countries. Dr. Corradini believes information sharing can be accomplished, and where these realms intersect, as long as the audience is appropriate, good discussion and the positive attributes of safety are possible.

# II

# Safety Analysis, Vulnerability Assessment, and the Design of Integrated Solutions

*The second session of the conference covered safety analysis, vulnerability assessment, and the design of integrated solutions to address risks and vulnerabilities. Admiral James Ellis moderated a panel that consisted of Dr. Stephanie Morrow, Mr. Ricardo Moraes, and Dr. Jorge E. Sarkis.*

## The 2002 Davis-Besse Event and Safety Culture Policy at the U.S. Nuclear Regulatory Commission (NRC) – Stephanie Morrow, U.S. NRC

Dr. Morrow began the session with a presentation on the 2002 Davis-Besse event and safety culture policy at the U.S. Nuclear Regulatory Commission, including lessons learned and safety culture in the reactor oversight process.

The U.S. NRC was established as an independent agency in 1974 with a mission to ensure safe use of radioactive materials for civilian purposes, including nuclear power. It sought to protect public health and safety, promote the common defense and security, and protect the environment through licensing, inspections, and enforcement.

In 2002, massive corrosion was found in the reactor vessel head at the Davis-Besse Nuclear Power Station at Oak Harbor, Ohio. Its Babcock and Wilcox pressurized water reactor had a history of boric acid leakage. On March 6, 2002, a cavity was discovered in the reactor pressure vessel head adjacent to a control rod drive mechanism (CRDM) nozzle penetration. Corrosion was caused by boric acid leakage from CRDM nozzle cracks. The cavity extended though the base metal of the vessel head to the 3/8-inch stainless steel cladding on the inside of the head. The stainless steel cladding had not been designed to maintain the reactor coolant pressure boundary.

The lessons from this event highlighted the importance of safety culture through:

- Leadership safety values and actions: Davis-Besse had prioritized production over safety.

- Questioning attitude: There had been a shift in focus to justifying minimum standards.
- Decision making: There was a lack of conservative decision making or systematic safety analysis of decisions.
- Problem identification and resolution: Corrective actions addressed symptoms rather than causes.
- Continuous learning: Davis-Besse had a failure to integrate and apply operating experience to plant conditions.

The U.S. NRC now considers safety culture in the reactor oversight process (ROP), as introduced by a 2006 revision to the ROP. This revision gave U.S. NRC staff more opportunities to consider safety culture weaknesses before significant performance degradation occurs. It also instituted two processes for the ROP Action Matrix: (1) a process to determine the need to evaluate a licensee's safety culture in the degraded cornerstone column of the ROP Action Matrix; and (2) a process to evaluate a licensee's safety culture assessment and independently conduct an assessment in the multiple/repetitive cornerstone column of the ROP Action Matrix.

In a joint effort with the U.S. nuclear industry from 2011 to 2013, the U.S. NRC underwent a safety culture common language initiative, where they developed common terms for describing safety culture. These terms have been incorporated under the ROP cross-cutting areas.

The 2011 Safety Culture Policy Statement sets forth the U.S. NRC's expectation that individuals and organizations performing regulated activities establish and maintain a positive safety culture commensurate with the safety and security significance of their actions and the nature and complexity of their organizations and functions.

Dr. Morrow also presented a definition of *nuclear safety culture*: The core values and behaviors resulting from a collective commitment by leaders and individuals to emphasize safety over competing goals to ensure protection of people and the environment. She maintained that safety and security are closely intertwined, and that licensees should emphasize the need for integration and balance to achieve both safety and security in their activities. In addition to the definition, she presented a table of safety culture traits (see Table 2-1).

Lastly, Dr. Morrow discussed outreach and education efforts to foster understanding of safety culture and disseminate good practices. Such efforts include interactions with licensees and external stakeholders, international involvement, conferences and training, educational tools (e.g., brochures, case studies, discussion of safety culture traits, posters, and support materials), and a safety culture website.[1]

[1]Available at http://www.nrc.gov/about-nrc/safety-culture.html.

**TABLE 2-1** Safety culture traits

| **Leadership Safety Values and Actions** | **Problem Identification and Resolution** | **Personal Accountability** |
|---|---|---|
| Leaders demonstrate a commitment to safety in their decisions and behaviors. | Issues potentially impacting safety are promptly identified, fully evaluated, and promptly addressed and corrected commensurate with their significance. | All individuals take personal responsibility for safety. |
| **Work Processes** | **Continuous Learning** | **Environment for Raising Concerns** |
| The process of planning and controlling work activities is implemented so that safety is maintained. | Opportunities to learn about ways to ensure safety are sought out and implemented. | A safety-conscious work environment is maintained where personnel feel free to raise safety concerns without fear of retaliation, intimidation, harassment or discrimination. |
| **Effective Safety Communications** | **Respectful Work Environment** | **Questioning Attitude** |
| Communications maintain a focus on safety. | Trust and respect permeate the organization. | Individuals avoid complacency and continually challenge existing conditions and activities in order to identify discrepancies that might result in error or inappropriate action. |

## New Sociotechnical Approaches for Safety and Vulnerability Assessment – Embraer experience –Ricardo Moraes, Embraer

Mr. Moraes described sociotechnical approaches to safety, drawing on his experience at Embraer. Different approaches to safety engineering are found in civil aviation, nuclear power, and defense. System theory, which was developed for biology and engineering, forms the basis of systems engineering and system safety. It focuses on systems taken as a whole, rather than their individual parts taken separately. Some properties can only be treated adequately in their entirety, taking into account all social and technical aspects, and these properties derive from relationships among the parts of the system. System theory is also concerned with two pairs of ideas: hierarchy and emergence, and communication and control. Failures are often system emergence, and these events raise questions of what the formal structure and functional interactions are, as well as how failure emerged.

Mr. Moraes presented a framework developed by Nancy Leveson known as System-Theoretic Accident Model and Processes (STAMP), which includes an entire sociotechnical system, component interaction error, software and systems design error, and human error. STAMP is a systems engineering, top-down approach to safety. It offers a more comprehensive view of causality, examining interrelationships rather than just linear cause-effect chains and going beyond current models. It treats accidents as dynamic processes and looks at the processes behind events. Finally, STAMP includes organizational, social, and cultural aspects of risk (see Figure 2-1).

In comparison with traditional approaches, STAMP includes software and system design errors, human error and human decision making, and behavioral dynamics that change over time. Understanding why controls drift toward ineffectiveness over time enables an organization to detect that drift before accidents occur and, if possible, change its underlying factors. In sum, STAMP handles much more complex systems than traditional safety analysis approaches, Mr. Moraes said.

Embraer is evaluating whether STAMP is a viable methodology to be used as a complementary or alternative means to the current methodologies of the aerospace industry—particularly for highly integrated, complex, and software-based systems. STAMP is also now starting to address cybersecurity issues.

Mr. Moraes provided his definitions for the terms *accident*, *hazard*, and *concept*:

> Accident: An accident is an undesired and unplanned event that results in a loss, including a loss of human life or human injury, property damage, environmental pollution, mission loss, financial loss, and so forth.
>
> Hazard: A system state or set of conditions that together with a worst-case set of environmental conditions, will lead to an accident (loss).
>
> Concept: The requirements and constraints derived from an analysis of the potential failure modes, dysfunctional interactions, or unhandled environmental conditions in the controlled system that could lead to the hazard.

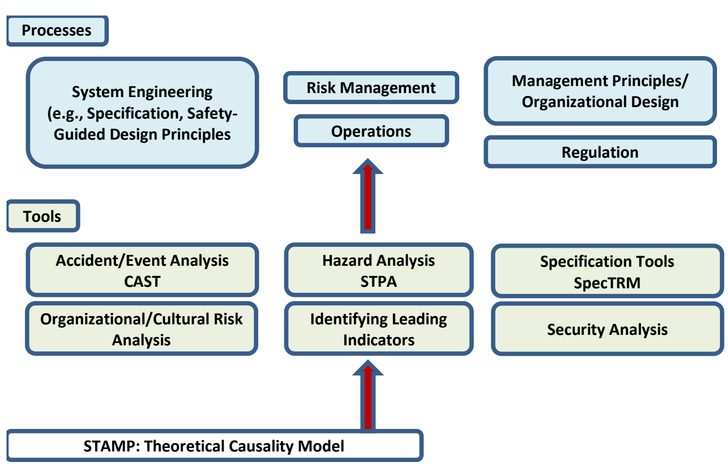


**FIGURE 2-1** System-Theoretic Accident Model and Processes. SOURCE: Leveson model adapted from Morales presentation.

The requirements and constraints are derived from an analysis of the potential failure modes, dysfunctional interactions or unhandled environmental conditions in the controlled system that could lead to the hazard.

He then walked the audience through an application of STAMP to the use of landing gear in an aviation setting. Embraer is just starting this evaluation of STAMP, and the initial cases are very simple, but the results are promising, he said. The next step is to apply this methodology to fly-by-wire systems.

Finally, Mr. Moraes asked the group to consider how the software affects traditional safety methodologies, the increase of the integration and complexity of systems, and cybersecurity implications.

### Threats Involving Nuclear and Radioactive Materials: Nuclear Forensic Capability within a National Nuclear Security Infrastructure – Jorge E. Sarkis, Instituto de Pesquisas Energéticas e Nucleares (Institute of Nuclear and Energy Research)

Dr. Sarkis presented on threats involving nuclear and radioactive materials, and the nuclear forensic capability within a national nuclear security infrastructure. The creation and maintenance of a nuclear safety system, he said, needs to be the responsibility of each state. Threats that involve nuclear material or radioactive materials are a collective safety issue that requires actions that many times depend on collaborations between nations. He emphasized the importance of collaboration with the International Atomic Energy Agency (IAEA) and other agencies that are dedicated to nuclear safety and exchange with countries and university research centers that have a greater experience in these areas.

Dr. Sarkis concluded that threats that involve radioactive or nuclear materials are not going to go away. Radioactive sources and nuclear materials are widely used, but in the hands of criminals they can become a threat to societies. To fight these threats effectively, we need to adopt preventive measures and train specialized personnel, exchange information, and collaborate with other nations. Very few countries have training courses and specialist information in nuclear forensics and response actions. Responders need to consider the legal aspects to preserve the evidence of the crime scene while allowing the sentencing and imprisonment of the culprits. He put forth the need to establish a nuclear forensic culture in the heart of the infrastructure of a nuclear safety system and program.

## DISCUSSION

Admiral Ellis invited questions dealing with safety culture specifically related to nuclear power plants and the Davis-Besse accident. He began by asking how we can learn from the processes described with regard to aviation and forensic issues in terms of nuclear security.

Dr. Almeida wondered why the U.S. NRC decided to have a different definition and what the implication of having these two definitions will be.

Dr. Morrow explained that even at the time when the policy statement was being developed, a number of different definitions were in common use in the United States. For example, the Institute of Nuclear Power Operations (INPO) definition of safety culture was different from the IAEA's. So a goal of developing a definition with the policy statement was to try to come to some consensus on a definition. In addition, Dr. Morrow mentioned that on expanding beyond nuclear power reactors, to include, for example, parties from the medical communities, there is a rich discussion of safety culture in terms of medicine in general. Different parties brought different definitions to the discussion and there was not a consensus. Therefore, the U.S. NRC needed to develop a definition that would appeal to all different licensees and certificate holders.

Admiral Ellis answered Dr. Almeida that there were two separate standards and discussions when it came to safety culture: the INPO approach, which had been embraced by the industry, and the regulator's approach, which used different terms of reference. It was very confusing, and some facilities hired different consultants to work towards satisfying the self-regulatory model from INPO on the one hand, and the regulatory view of safety culture on the other. It was felt that a single, common point of reference and terms of reference and definitions were essential.

A participant noted that the 2007 TAM aircraft accident at Congonhas Airport was caused by human error. The pilot did not land or did not approach the landing strip in the right position. Landing in Congonhas is not easy, as the conditions of the runway are not optimal, and there have been two other incidents in Asia where the same problem was cited. This methodology can analyze the environment, behavior, and the chances of wrong behavior from the pilot if the pilot is not trained to act under these circumstances. She asked what different actions might be taken if we see within the analysis of these situations that there is a condition of the environment and pressure from such conditions that raise risks substantially.

Mr. Moraes commented on the methodology, explaining the idea of including many possible operational contexts under all foreseeable conditions. By analyzing the pilot with different scenarios the tool begins to capture the human element with all the different possible interactions with the environment and can achieve better insight into the human-machine interaction under a range of environmental conditions. Embraer deals with recommended practices based on context and behaviors, and it conducts research to understand where this methodology can yield the greatest insight.

Admiral Ellis, as an old fighter pilot, recognized that it is often easy to blame the accident on the pilots when, in fact, the system and conditions failed to put the pilot in a position that maximized the probability of success. There are technical elements involved such as instrumentation and training. There are pressures, especially economic, from the company, whether real or imagined. It is a complex situation, and he said that he always cringes when he hears the term *pilot error* because the real determinant is the culture. Does pilot error give an honest assessment of all of the factors in play or does it put the blame on the person who was at the control panel or in the cockpit? That is an important piece in talking about individual accountability and responsibility. Being just and being accountable is not the same as blaming.

There was agreement that improving the system is constructive and useful. The goal is not to find root causes but to understand how to make these accidents not happen anymore. When we talk about Fukushima, for example, an analysis in terms of culture before the accident would have considered it a perfect cultural environment. A participant suggested implementing a System-Theoretic Process Analysis to try to understand interactions between components regardless of failure or errors, but noted that when there is an error, the interactions happen, regardless of whether it is due to a failure or not.

Admiral Ellis summarized key points from the panel discussion: Dr. Morrow described the challenges that come with systems that have been working well and normally for a long period of time. In the commercial nuclear industry, it is called the *arrogance of excellence*, where things have been done so well for so long that it is assumed it is as good as it can possibly be done. She commented as well about the importance of common definitions for safety culture and principles and described the efforts that the United States completed in 2013 to bring the two separate definitions and approaches of the regulator, on the one hand, and the industry, on the other, into a common language. The objective of harmonizing it with the IAEA still remains. She reminded us that, even though a system has been in operation for decades, there are still unknown unknowns, despite our impression that we know all the elements and all the aspects. U.S. industry thought, in this case, that it understood the corrosion mechanisms, and that while there was corrosion, it was not really important. It turned out to be very important. Continual reassessment and reevaluation of even longstanding and long-operating systems is of benefit and importance.

Mr. Moraes described systems as not just technical, but as socioeconomic, with all of the complexities and interactions that that requires, and the importance of examining the interrelationship of all of the factors, not just the technical or the mechanical. The participants talked more about that from a human standpoint and, most importantly, the piloting perspective. Mr. Moraes introduced software and cyber issues that are continually growing in their importance in our increasingly complex digital world. He asked how we should assess these issues and how we apply models that now have the ability to deal with them effectively in the safety and security context. He described a real-world model for risk and safety assessment that is under evaluation and may have some promise. If we can learn from other industries, it might have benefits in the nuclear world.

Finally, Dr. Sarkis talked in real terms about security and lapses or failures. In an accountability model for security issues, it is not just prevention that is important, but who stole it, where did it come from, and what were the sources. Despite the gargantuan size and complexity of the global nuclear industry, including medical and other efforts, the number of incidents is very small. Thinking back to the infamous Pascal's Wager, Blaise Pascal noted that the probability of an outcome is not the same as the consequences of an outcome. Just as the threat was global, the corrective actions and processes, up to and including the legal framework, need to be global as well. That is something that we can all help move forward, Admiral Ellis said.

# III

# Performance Assessment and Improvement of Safety and Security Culture

*The third session of the conference covered performance assessment and improvement of safety and security culture: methodological and deployment issues, and how to get a virtuous cycle of the process to achieve safety and security culture and those related to other organizational goals. The session included presentations from Michael O'Brien, Antonio Barroso, and Ivan de Souza Azevedo and was moderated by Marcos A. Viana Tavares.*

Mr. Tavares, representing Embraer, saw great similarity between the aeronautics and nuclear fields, which can form the basis for an exchange of experiences.

## Experiences in Nuclear Security Culture – Michael O'Brien, U.S. Lawrence Livermore National Laboratory

Mr. O'Brien provided background on his perspective beginning in 1989, when, after approximately 14 years working in the military and for the military at U.S. Department of Defense agencies, he entered the Department of Energy (DOE) when it was undergoing very rigorous inspections. Admiral James Watkins, the secretary of energy at the time, strongly emphasized safety culture and security culture, and the U.S. National Laboratories were found deficient.

Mr. O'Brien was hired to correct deficiencies, conducting inspections of U.S. National Laboratories and contractors that did work for the Department of Energy. He was part of a DOE working group tasked with rewriting the regulations (called *Orders*). At that time, there was a policy emphasis, though it was defined more in terms of responsibilities than culture. People had responsibilities for safety and security all the way from the top down to the bottom. The working group placed an emphasis on performance-based practices and put more ownership of an organization at a lower level and on individuals' responsibilities. It also started conducting self-assessments, which were a really critical component. The organizations started to take responsibility, to police themselves, and to identify and then remedy deficiencies and security issues before receiving an inspection from the government.

Mr. O'Brien initially took some issue with the term *culture* in the context of safety and security deficiencies, but over time found that it really does resonate as culture. Different organizations do have different cultures. An agency could promulgate a certain attitude and belief system, and it does take a while to change those.

He also discussed the common ground between safety and security. Both require a coordinated approach and there are sometimes conflicts, but safety and security have to work together. One common scenario in vulnerability analyses is planning for emergency evacuation. Work stops because there is a safety issue, and people egress out of the environment without securing their work. From a security standpoint, material is now vulnerable, and people could use the emergency situation as a means to take material out of the facility. We have to design procedures to meet both goals, to allow people to safely egress out of buildings, but to do it in a contained environment.

Implementing a security culture has to start at the top. The Nuclear Security Summit process among heads of state resonates through all of our organizations in every participating country. Providing a safe and secure environment for nuclear material instills public confidence. Moving from a national-leadership level to operational considerations, many aspects of a strong security culture begin through hiring practices. During their careers the best applicants migrate into more sensitive positions with stricter requirements. The organization adds to their job functions and provides additional measures to assure that their work achieves the best results supported by a positive work environment.

But we can also minimize problems by separation of duties, so that employees do not have free access and their authorities are limited. One of the common problems in dealing with insider threats is access authorities, or access to sensitive areas. The basic principles we try to adhere to from a security standpoint are deterrence, detection, delay, and response. Applying these principles to an insider threat protection program is more difficult than addressing external threats. The people that work in this environment are expected to have good, strong security culture, but they could also themselves become adversaries. It is very difficult to have deterrence against an insider. Coworkers and systems can help with detection. Delay is difficult, but through separation of duties, some of those measures can be applied. And response is done by a guard force or protective force, but oftentimes coworkers themselves provide that response.

Mr. O'Brien stated that the security culture of a facility is reflected in people's attitudes and the way that they conduct their business. We can tell whether an operation is done with efficiency and awareness, or lackadaisically. Operation, how systems are maintained, is a reflection of their overall security culture. We tend to overemphasize technology and underemphasize the human aspect. Most of the focus in physical protection is on systems, but it takes people to design, install, operate, test, and repair the systems properly. The operating procedures for these systems have to be correct.

Most security incidents point back to the human element. It is rare for a system itself to fail. Sometimes a system or sensor is misapplied in the wrong environment. Sometimes it is not maintained. Sometimes cameras are not assessed properly. But it generally points back to the human element. Oftentimes the solution is not more technology or better technology, but the human aspect that might need to be addressed in a particular situation. Mr. O'Brien presented several illustrative examples:

About the incident at the Y-12 National Security Complex, Mr. O'Brien reported that there was a sense that everything was fine with security culture at the site, which is generally true for most U.S nuclear facilities. But due to factors such as changes in management, decisions that result in apathy among workers, security forces, or operators, security culture can degrade rather quickly. It is thus critical that security culture be monitored closely; that we look for indicators that security culture might be degrading. And generally, when people examine major incidents such as at Y-12, they will often find ignored indicators.

Another example is the major breach of security at Pelindaba in South Africa in 2007. Subsequent interviews with the management of this facility suggested a lack of recognition of the threat. It was stated that "people broke in, and they were just looking for some computers." We must ask why anybody would breach a major secured facility just to steal computers. Adversaries will often exploit the weakest moments. At the time of the breach, attention was not focused on security. A party was going on onsite, and in the Operations Center that was ultimately attacked, the individual that was supposed to be working at that time was handicapped. Instead, the adversaries were confronted with a woman, who had replaced the scheduled worker, and her fiancé, the man who was ultimately shot, who was there to keep her company. He tried to resist the adversaries, and he notified security, but security didn't respond quickly, and he nearly died from his wounds. In addition, a separate team penetrated the facility and was confronted by the response force, and all the adversaries departed the facility without being apprehended. After the fact, questions arose about the security culture at this particular organization.

Good security policies and regulations need to include all levels of management, especially the worker. All must understand their responsibilities. Mr. O'Brien described the integrated work scope program his laboratory employs: For any new activity, managers must define the safety hazards as well as the security measures to put in place so that everyone involved in the activity understands the safety and security aspects. When that activity is conducted, any employee has the right to stop work. Managers also look at the security environment: If an activity requires a security guard or a security escort to be present, and if someone notices that the security measures are not correct, they will stop work until security corrects it. Empowering the employee is a powerful tool, and it can help avoid many problems. Having these types of mechanisms in place and adhering to them with support from management are good indications of a strong security culture.

Mr. O'Brien went on to provide a personal example of flagging security culture while conducting vulnerability assessments at a foreign nuclear facility. A manager wanted to speak with him, and while he was waiting for an escort to the office the other people said,

> "Aw, Mike, you know the way. Just go on in. We don't need to go with you." This was a severe security breach because here I am a foreigner and I am allowed to walk through their nuclear facility unescorted. I walked from where we were. And we were looking at some of the alarm sensors that were covered up by equipment with cobwebs growing over them. I went to this manager's office and walked by a guard and waved, and he recognized me, so he told me to continue. Then, I walked by a guard asleep on the stairwell. So, I walked up to the office and met with my colleague. And the first thing he said was, "Why are you here? There's nobody with you." It just shocked him.

This episode highlighted the differences between security culture and security awareness. Security awareness involves training conducted for employees, so that they understand security, but security culture goes deeper than that.

The integrated work scope program links roles and responsibilities to certain work activities and to training requirements. The training requirements go into a lab-wide database. And this training is also integrated with an access control system (ACS). For example, if someone has not fulfilled the training that is required to enter a Category I nuclear area, access is not allowed by the ACS. Work cannot be conducted until training requirements have been met. There are also built-in, engineered features to keep adherence to training or other requirements for work in controlled areas. If security requirements are not being met in the training system, a badge can be revoked.

Lastly, he discussed the human reliability program, which evaluates in depth the risks, if any, that an employee in a sensitive position poses. As employees migrate to more and more sensitive positions, they may need to adopt additional requirements. The human reliability program has not advanced as far as safety culture, but the goal is to add more filters, so that the potential to have an insider threat is further and further mitigated and reduced.

Mr. O'Brien summarized by emphasizing that security awareness should permeate everyone from the director of an institute through every line of management, down to the individual employees. This permeation can be assessed by examining among workers their attitudes, ability to understand security procedures, roles and responsibility for security, and ability to act accordingly when confronted with anomalies. We want people to be inquisitive and to question, but also to act responsibly and expeditiously. Action could be by an employee if he or she is empowered to act or it could be by someone who is in a security position.

**Assessment Instruments for Safety Culture: What Are We Measuring? – Antonio Barroso, Instituto de Pesquisas Energéticas e Nucleares (Institute of Nuclear and Energy Research)**

Dr. Barroso outlined his presentation, focusing on measuring nuclear safety culture by discussing the origin of the term *safety culture* and the guidance of the International Atomic Energy Agency (IAEA), the concept of security culture and how it is used by practitioners, the assessment instruments, and what we are measuring.

The nuclear field has systems, equipment, controls, procedures, management, and people. The first conclusion of the International Nuclear Safety Advisory Group (INSAG) 1 is the importance of placing both authority and responsibility for the safety of the plant on a senior member of the operations staff of the plant. Of equal importance, formal procedures must be properly reviewed, approved, and supplemented by the creation and maintenance of a nuclear safety culture. From that point on, the IAEA started to try to understand safety culture. They read Edgar Schein's levels of culture,[1] which discusses the relationship between safety culture and real culture within an organization (see Figure 3-1). Dr. Barroso cited Monica Haage illustrating the three levels: basic assumptions, guiding principles, and espoused values. There are also beliefs, known strategies, and physical artifacts.

Dr. Barroso then presented a time line of work on these principles, beginning with INSAG 1 in 1986. INSAG 4 appeared in 1991, and safety culture was recognized in INSAG 7, which also corrected, complemented, and expanded the work of INSAG 1. INSAG Series 15 was also about safety and security. After Fukushima in March 2012, Safety Report 74 discussed safety, the nuclear power plant projects, and a new TECDOC in 2013.

These guidance documents were written by specialists, and they represent a consensus, but it is almost impossible to guarantee universal agreement. Creating a standards document is a different process. It is much slower, and must ensure greater consistency.

People are the basic agents: Nothing happens in an organization if a person does not make a decision or take action. Dr. Barroso therefore suggested an addition to the standard definition "Safety culture is the assembly of systems, characteristics, mindsets, and attitudes of the organization and individual levels which assures that, as an overriding priority, nuclear safety issues receive the attention warranted by their significance." He added, "and adequate resources, information, and actionable knowledge are empowered at the decision or action points where safety issues are dealt with."

He noted that the chief operations officer at the Fukushima nuclear power plant said that if he were in charge he would have flooded the cooling system

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[1] Schein, E. H., 2010. *Organizational Culture and Leadership*, 4th ed. Jossey-Bass: San Francisco.

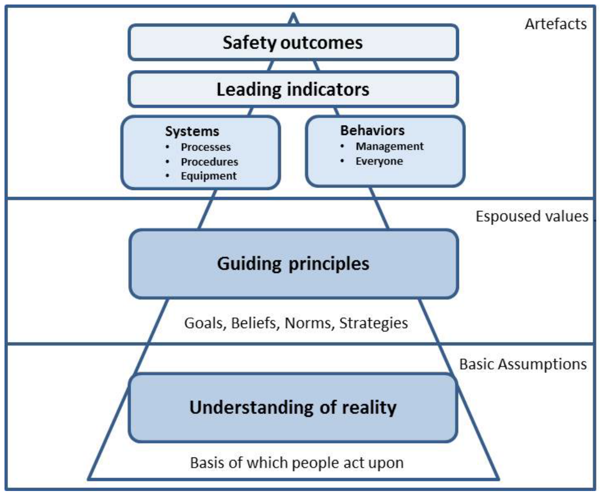


**FIGURE 3-1** Edgar Schein's levels of culture. SOURCE: Adapted from Haage, Monica, 2010. "Oversight of Management Systems, Leadership and Safety Culture" First ICTP-IAEA School of Nuclear Energy Management, November 8, 2010, International Centre for Theoretical Physics, Trieste, Italy.

with seawater, but at the time the utility was still thinking about the economic value of the plant. This is an example of lax culture, Dr. Barroso said. The report from the Japanese Commission[2] noted that the events that caused the Fukushima crisis happened before the earthquake. Decisions of minimal economic expense could have been made to help prevent the Fukushima accident. The accident was partially due to a Japanese culture that had shame and protection at its core. We need to direct resources to where safety and security issues are a problem.

Believing that change starts with an awareness of safety culture, Dr. Barroso assessed the frequency of the term *nuclear safety culture* in the Scopus database of relevant journals and conferences. From 1997 to 2011, nuclear safety culture was largely absent from the nuclear industry literature. During the first period he looked at from 1990 to 2000, the term appeared in an average of 1.82 publications per year, with this number decreasing every year. During the second period from 2001 to 2011, this number increased slightly, but citations decreased even more. This suggests that nuclear safety culture is not part of the agenda.

Better measurement leads to better management. Documents from agencies may be valuable with in-depth and thorough insights, but they contain incomplete quantitative assessment models.

[2]*National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission (NAIIC)*, 2012. Available at http://warp.da.ndl.go.jp/info:ndljp/pid/3856371/naiic.go.jp/en/report/.

He inquired whether safety culture is a reflective construct or a formative construct. Examples of the latter are the U.N. Human Development Index, which yields a number indicator. If a researcher asks about a well-balanced diet, regular exercise, and sleep every night, the formative result is informative for human health. It is something else if one asks, "Do I have a healthy lifestyle?" which is a reflective construct. To evaluate safety culture, one can try to identify the key variables that influence an organization's safety performance, which leads to structural equations that are very different from the reflective construct. The way to deal with this is statistically from observation.

His third example involved the direct link between blood alcohol level and intoxication. A formative construct would involve taking notes at a party on how many drinks each guest has and then quantifying blood alcohol level. On the other hand, a reflective construct is how drunk a guest is, measured by variables that are manifestations of this top variable. In this case, such indications could be a breathalyzer test, a physical reaction test, or a clocked memory test. In the formative construct, observed variables like drink number (which are not correlated) define the alcohol content. On the other side, observed variables are indicators of mental capacity and drunkenness level. These variables need to be correlated. It is almost impossible to pass a breathalyzer test and fail a physical reaction test.

With safety culture, he argued, we need a reflective construct to conduct reliability tests and validity tests, and we need valid and reliable assessment instruments. We need to know the dimensionality of the construct, content validity, convergent validity, discriminant validity, and then predictive validity. Does the instrument indicate that the culture is indeed better? Validation is cumulative.

Dr. Barroso looked at the nuclear safety literature on another similar database, the Web of Science, for validated assessment instruments. He also read abstracts and papers on assessment instruments and their validation and found only two articles. The first was by Lee from 1998.[3] The model has a top construct and several variables that are able to be measured individually: 172 items were observed through questionnaires from almost 6,000 participants. Lee did the exploratory factor analysis with a matrix rotation model and came to 38 factors—a very high number—that cannot be directly measured. Working on variances came to 19 factors and 81 items. This was a first validated instrument to build on, but nothing else appeared on the assessment of nuclear safety culture until an article last year from Lopes de Castro.[4] In order to assess the IAEA safety culture model, Lopes de Castro based the model on Table 1 of the IAEA Safety Report Series no. 42 (2005), in which the agency describes 5 characteristics and 37 attributes that should be used in evaluation and self-evaluation in-

[3]Lee, T., 1998. "Assessment of Safety Culture at a Nuclear Reprocessing Plant." *Work & Stress*. Vol. 12. n. 3 217-237.

[4]*Accident Analysis & Prevention* 60, 231–244 (November 2013). Available at http://www.sciencedirect.com/science/article/pii/S0001457513003291.

struments. The characteristics were used as factors or latent variables and attributes as indicators or sampling variables. The validity was low with only moderate convergent validity and very poor discriminating validity. So there is not an instrument to assess nuclear safety culture that has been duly validated.

Dr. Barroso advocated applying instruments from other fields to help assess safety in the nuclear field. Hospitals and medical organizations have taken many steps towards cumulative validation and are assessing the safety culture for the patient using a model developed in 2005. It has been applied and validated in at least 5 countries and 10 different organizations.[5]

**The Synergy Between Safety Culture and Operational Excellence – Ivan de Souza Azevedo, Eletrobras Eletronuclear**

Mr. Azevedo stated the need to improve continuously to achieve a good safety culture and proceeded to discuss safety culture principles at Eletronuclear power plants. He said that Eletronuclear does not have specific indicators to assess safety culture because it is difficult to create such indicators, but he said that the company has other means to assess safety culture.

One of the 16 companies of the Eletrobras system, Eletronuclear is subordinated to the Brazilian Ministry of Mines and Energy. Its mission is to generate safe and reliable electric power to an interconnected system throughout a country about the size of Europe. The share of power produced by nuclear is very small, just over 3 percent, and most power comes from hydroelectric generation. Two nuclear power plants, ANGRA 1 and ANGRA 2, built with American and German technology respectively, are in operation. About 70 percent of the more than 1,800 employees work at the power station in the city of Angra dos Reis. The remaining workers are employed at the headquarters in Rio de Janeiro. Eletronuclear is working on the 1,405-megawatt ANGRA 3 reactor, with construction foreseen to be completed by the end of 2018. When ANGRA 3 is complete, 60 percent of all energy consumed in the state of Rio de Janeiro will come from these plants.

Eletronuclear embraces the defense-in-depth concept. Human and organizational factors are at the root of all the accidents, he said. Fukushima was not a natural disaster, but a profoundly man-made disaster, as the investigation report concludes. Eletronuclear has adopted the most recent IAEA definition of safety culture from 2006. It conveys the same classic concept of INSAG 4, but adds "protection and safety." These concepts are applied to all steps and procedures, from project development to special operations.

The five main characteristics that the IAEA establishes as an indication of a strong safety culture are that safety (1) is a clearly recognized value, (2) is a

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[5]See Halligan, Michelle and Aleksandra Zecevic, February 8, 2011. "Safety culture in healthcare: a review of concepts, dimensions, measures and progress" *Quality & Safety in Health Care*.

leadership responsibility, (3) requires clearly established accountability, and (4) must be integrated into all activities, and (5) the organization is learning driven. The safety culture assessment program was only carried out in five power plants with promising results, but the program was interrupted. Eletronuclear requested one of these assessments, but, Mr. Azevedo said, the IAEA was unable to carry it out.

Mr. Azevedo suggested that in addition to the IAEA, U.S. Nuclear Regulatory Commission, and Institute of Nuclear Power Operations definitions of safety culture, one should also look to the World Association of Nuclear Operators, which is a partner of Eletronuclear. The nuclear safety culture definitions from all these organizations talk about values, behaviors, leadership, and safety as a priority. Safety culture at organizations is internalized by individuals. It considers individual and technological variables and their organization.

Founded in 1997, Eletronuclear was created from two companies with more than 20 years of experience: Furnas Centrais Elétricas (a regional power utility) built and operated ANGRA 1 and built ANGRA 2; and Nuclebrás Equipamentos Pesados (Nuclebrás Heavy Equipment) was an engineering and design company that created projects for ANGRA 2 and ANGRA 3. In 2009, Eletronuclear became fully integrated into the Eletrobras System and changed its brand once again.

This merger is an important case study in creating safety culture. It took a long time for assimilation of the two companies, and worker animosity became a concern. The chief executive officer asked for support from the IAEA to help the company to assess the level of its safety culture. The group developed a survey instrument with 22 safety categories, a questionnaire with 70 questions that was distributed throughout the company. Eighty percent of the company participated. The results of this first assessment showed that there was a satisfactory safety culture.

The poor performance areas were motivation; job satisfaction; view of mistakes; absence of safety versus production conflict; and working conditions in regard to time pressure, workload, and stress. The survey allowed management to address these issues. The ensuing integrated management policy was updated in 2004, will be updated again this year, and remains part of an ongoing review.

Eletronuclear also established an integrated policy for the whole company, stating: "Nuclear safety is a priority, precedes productivity and economic aspects, and should never be impaired for any reason." The IAEA helped convene a successful conference on safety culture in Rio de Janeiro with power plant operators from all over the world. The company increased involvement with the nuclear industry, adopted partly developed indicators, and developed a self-assessment cycle of internal and external assessments and audits. These include regulatory and nonregulatory self-assessments, and internal audits, both corporate and at the plants. When assessing nuclear safety culture, it is important to communicate with the greater world nuclear community to benefit the entire industry.

Mr. Azevedo presented a performance indicator from the plants and a power history developed from experiences in other countries such as project and design modifications, maintenance, alarms, and manual controls. Several plant operational indicators, such as readiness to supply energy to the system, were consolidated in a single indicator that also reflects the safety practices adopted by the company. The safe operation of Eletronuclear's plants starts with good design and extends through operational practices. Reporting small events, training personnel, and maintaining a good relationship with the regulating agencies are essential to a safe environment.

Mr. Azevedo said that Eletronuclear needs to continue the efforts of communicating the established safety policy so that everyone in the company can understand and internalize it. Good training is absolutely essential for this so that this policy is adopted throughout the company, so people understand why we are talking about safety all the time. It should also reflect a respect towards society, the surroundings, the environment, the important relationships with international organizations and the adherence to international conventions. When we talk about synergy of the operations and safety culture, we mean the integration of all of this, Mr. Azevedo said.

## DISCUSSION

A participant noted the importance of forensics in nuclear safety and its absence in the workshop. Forensics is essential to global safety and security. Brazil is starting to conduct studies on nuclear risk analysis based on articles on nuclear security failure. He asked whether Dr. Barroso had found related information in his work.

Dr. Barroso responded that he believes forensics is a lot more relevant to security than to safety, but it has a relationship to safety as well. But risk analysis is not part of the culture assessment. Quantitative analysis of nuclear safety culture should be far more developed than what is found in literature. Nuclear forensics is a useful intelligence tool and can be incorporated mainly in security culture.

Mr. O'Brien commented that Dr. Barroso may be a bit too harsh on the nuclear community, and that the medical community is in fact not doing a better job. In the United States, the third leading cause of death with disease is iatrogenic disease, or disease caused by medical mistakes. A culture that produces in excess of 20,000, and maybe as much as 200,000, deaths a year is obviously not operating to a high level of safety, and there is much room for improvement. A National Academies report has been very critical in this area as well.[6] By a measure of outcomes, the nuclear industry has been quite successful because the level of fatal accidents is minuscule.

[6]IOM, 1999. *To Err is Human: Building a Safer Health System*. Available at https://www.iom.edu/~/media/Files/Report%20Files/1999/To-Err-is-Human/To%20Err%20is%20Human%201999%20%20report%20brief.pdf.

Dr. Barroso responded that considering different assessment methods is valuable. Patient safety may not be very good in terms of total death, but patient safety culture is much more widely discussed than nuclear safety culture.

Dr. Haber mentioned that after Chernobyl the U.S. Nuclear Regulatory Commission and the U.S. nuclear industry did not use the term safety culture, but a search for "organizational management" might find more documentation. The term safety culture was not widely used until the mid-late-nineties in the U.S. nuclear industries.

A participant inquired what the right balance between preparing for insider and outsider threats is, given that each are very different. An outside terrorist might be interested in attacking a nuclear power plant and causing a lot of damage, not in consequences 10 years from now. On the other hand, investigating nuclear plant workers goes on continuously, and although it is very difficult to initiate, workers inside the plant know what they have to do to cause a real accident. In addition, insiders can immediately cause an accident because of access beyond protection systems.

Mr. O'Brien explained that assessments examine all threat possibilities, with outsiders trying to penetrate a facility and insiders acting alone to sabotage it. They also examine the possibility of an insider colluding with an outsider and at targets of opportunity within a nuclear facility. The goal is to balance the threat spectrum through measures that will reduce risks overall. Assessments look at the entire threat spectrum and develop scenarios that prevent sabotage of all the targets within a given location.

Admiral Ellis outlined several themes from across the different sessions. He noted:

- The importance of interaction among designers, operators, and overseers or regulators. This is important in the context of reactor safety, nuclear materials control, accounting, and even aircraft safety. Today, systems are not just technical, but sociotechnical; technical systems are as important as the people who operate them.
- The importance of leadership to take responsibility for implementation.
- That measuring the effectiveness of organizations with respect to safety culture is critical to improving safety culture. The methodologies need to be sound and validated, but few exist.
- The value of sharing experiences across different industrial sectors with thorough lists of best practices.
- The need to balance openness with the need to keep some information, and even discussions, secret. As different countries have taken different approaches, these discussions with the United States and across industrial sectors are helpful.
- That the transition to digital systems is another challenge, as many facilities were designed before the Internet. This transition can lead to insider vulnerability by not fully understanding how the system behaves,

or through cyber intrusions and cybersecurity breaches. Countries can share best practices on insider threats as solutions are developed.
- That the arrogance of excellence leads to complacency and a belief that we fully understand the systems. Safety culture and security culture are mutable, and can be changed for the better and for the worse. Change starts with leadership, its decisions, and its responses to failures.

Admiral Ellis continued by mentioning the communication gaps between the risk analysis communities and the safety and security communities. On the importance of linking leadership to responsibility for implementation, he brought up the seven C's of leadership, the first of which is commitment. A leader has to believe that an initiative is important and remain committed to it. We should factor in the idea of empowerment, he said.

On continuing to aspire to better measurements of safety culture, he drew an analogy to the struggle to find a metric to measure readiness in the armed forces. Outputs, attributes, and aspects of good cultures can be measured, but there is no culture meter on a reactor control panel. It is worth considering and exploring and continuing to research, but if we wait for a perfect metric begin to build, encourage, or in some cases demand a better culture, we will be waiting a while.

Other members of the audience commented on Admiral Ellis' remarks:

- If we want to improve safety and security, we need an objective.
- Formal surveys do not necessarily convert to an improvement in safety culture. There are definitive elements that contribute to and enhance good cultures, but a score of 89.2 on a safety culture exam should not necessarily be indicative of the quality or the integrity of the process.
- There are some behavioral indicators that can signal that an organization has a good or bad culture of safety or security, such as worker satisfaction. Complaints to the Nuclear Regulatory Commission from employees onsite, for example, are an indicator, and there are other indicators that ought to trigger further assessments.
- While there is no safety culture meter, there are many other indicators of a problem. Imperfect measurement does not mean that we should wait. We have to use whatever indicators we have today, even if they are not solid, to track progress. When we set goals, we have to have indicators. Assessors should be aware that we do not have a solid foundation for measurement in the nuclear area, just a scale.
- Safety needs to be applied to the entire fuel cycle from design to disposal.
- There are four M's of risk assessment and management that are useful to follow: measure; minimize the risk through system design; manage the remaining risk; and then, in the case of failure, mitigate it in an effective way.
- Safety indicators and performance indicators cannot be joined with safety culture indicators.

A participant noted that embedded safety or security culture leads to adherence to requirements. Quoting an old admiral, he said, "I have seen clean ships that could not shoot, but I've never seen a dirty one that could." A trend in failures, accidents, or mishaps is worth exploring further to uncover a safety culture issue. It may be just an incredible string of bad luck, but that is unlikely.

A participant cautioned the group about indicators for measuring safety culture. Indicators are ways to examine outcome or performance, but the culture we are trying to understand is how you got to the performance. In a nuclear power plant, one indicator for evaluating maintenance technicians is how many times a task has to be redone due to an initially incorrect execution. The goal is to have a small amount of rework. A maintenance technician can follow procedures, do everything according to specifications, and perhaps issue the rework. He could also cut corners and do workarounds to meet the goal (to reduce rework), and he will still meet the maintenance rework indicator. Indicators or metrics are not the same as understanding culture in an organization.

A participant mentioned that often during a labor strike, particularly in the aviation sector, employees start to "follow the rules" to the letter, causing many flights to be delayed and canceled. These very small rules may need to be reexamined, as safety and security are the properties of the reactions of the components of the system. Safety should make sense more at the higher or system level than at the lower level.

A participant noted that a questioning attitude may be the single most important element of safety culture. We cannot measure the attitude, but you can measure whether or not questions and issues are raised. Any organization that goes for an extended period of time with no one raising a safety issue, whether or not it is a real issue, exists with a nonfunctioning safety culture. You can at least benchmark attempts to raise issues and bring them to the attention of the management in one organization relative to other organizations.

A participant said that regarding a questioning attitude in the military, people have a stereotypic view of the military, perhaps just as they do of chief executive officers in business. They believe that everything is declaratory. In any business there are leaders that are good and leaders that are bad. A bad leader was fond of saying three things. "When I want your opinion, I will give it to you." "What good is power if I can't abuse it?" And the final one was, "When the king is unhappy, one of the little people must die." From this, one can get a sense of what the organization was like.

On the other hand, a good leader has an open-door policy, values people in the organization, demands and asks questions himself, and does not construct situations ahead of time. While crisis can demand time compression and executive judgment, when contributions from every level in the organization are allowed, the best outcomes are attained.

# IV

# Training and Education for Safety and Security Culture

*The fourth session at the conference covered training and education for safety and security culture—training for culture as distinct from procedure. The session included presentations from Alan Hanson, Robert Bari, and Filomena Ricco, and was moderated by Michael O'Brien.*

### Teaching Safety and Security Cultures – Alan Hanson, Massachusetts Institute of Technology

Mr. Hanson began by asking the audience two questions: How many knew the location of the emergency exits for the auditorium, and how many examined the fire instructions on the back of the door in their hotel room. When in a new environment, one of the first things you should do from a safety point of view is be aware of where you are and be aware of how you get out if you need to. This is what it means to be safety conscious. In industry in the United States, every meeting starts with a safety message, such as the one just delivered. The point of this practice is not only to get the message across but to make it very clear to everyone that safety is the first priority. Mr. Hanson recommended that the Instituto de Pesquisas Energéticas e Nucleares (IPEN, the Institute of Nuclear and Energy Research)and other organizations around the world consider a similar practice.

Mr. Hanson focused his talk primarily on safety and mentioned that, at the university level, teaching security is difficult. Universities are by their nature open environments, whereas security requires a potentially incompatible level of secrecy.

Mr. Hanson described the often-missed distinction between training and education. Training requires that in response to a known stimulus you get an expected response. You can train dogs, parrots, elephants, and seals. Education is different in that it involves applying knowledge to devise a solution. He chose to discuss education rather than training.

One purpose of education is to inculcate fundamental principles so that the individual later makes the proper decision when confronted with a new situation. Inculcation means that through a process of repetition, admonition, and practice you press an idea into your mind so as to make the right decisions. That is one of the reasons to repeat safety messages, because it keeps safety in the forefront of one's thoughts.

Until recently, university engineering programs offered no classes focused on security and no discussion whatsoever on safety education. These issues were not important at that time. Their education was focused on technology and creating exceptional engineers, and it was only by accident or by later experience that engineering programs were introduced to important societal issues. Today though, the Massachusetts Institute of Technology (MIT) mission statement has a focus on the imperative of public debate and humane uses of technology.

Mr. Hanson said that the MIT Department of Nuclear Science and Engineering is built on three focus areas: (1) science, which consists of basic science, such as physics and radiation science; (2) systems and engineering, such as thermodynamics and heat transfer; and now, (3) society. The addition of that third leg distinguishes the department at MIT, and the society category is being built into the curriculum by recruiting new faculty and students specifically in this area. It is an important part of the future of nuclear education.

Mr. Hanson then described the executive education programs he leads at MIT. MIT offers a 1-week Nuclear Plant Safety Course that has been running annually for more than 50 years. Members of IPEN have attended this particular course, including two last year. MIT also partners with the Institute of Nuclear Power Operations (INPO) to educate senior executives within the nuclear community in the United States through their joint Reactor Technology Course for Utility Executives. This 3-week, intensive course on what it means to be a nuclear executive has been offered for 23 years and is aimed at new executives moving into higher positions in the nuclear industry. Often, course participants come from legal and finance departments or from general management and without a nuclear or engineering background are asked to manage technology they are not trained in.

MIT organizes the Emirates Nuclear Energy Corporation executives program, a 2-week course created at the request of the United Arab Emirates that is based on the course for U.S. utility executives. MIT also offers the International Nuclear Leadership Education Program, designed for participants in countries recently involved in nuclear energy, with most students coming from developing countries in the Middle East, Africa, and South Asia that are starting nuclear programs.

It is not unusual for a country interested in developing a nuclear energy program to designate a university physics professor to make the nuclear power program work. That individual may not understand the large difference between physics and engineering, and especially the large infrastructure issues associated with creating a nuclear power program. MIT hosts these senior leaders in the United States for a 3-week intensive program on nuclear energy, taught by outstanding subject-matter experts. The course covers the entire range of setting up a nuclear power program, from the basic technology to how to create nuclear infrastructure, how to create a legal framework, how to meet nonproliferation norms, and how to provide physical protection for materials and facilities.

This program came about after the Fukushima disaster, which made some but not all countries reconsider nuclear power. We all have a common interest that new nuclear states "do nuclear right" or make an informed decision to not go down that path. Even as a proponent of nuclear power, Mr. Hanson stated that not every country in the world should be developing nuclear power.

The focus is to bring leaders from these countries into the nuclear world to talk about safety and security. MIT's goal is to provide education and training in governance structures and business strategies to develop successful, safe, and secure programs. The program is in its second year and has been largely successful, cooperating with the International Atomic Energy Agency (IAEA) to bring not just academics but also practitioners to the course. University professors teach nuclear physics, but the practitioners with real-world experience are invaluable for teaching nuclear leadership and security.

The course reinforces the lessons in several ways, beginning sessions with regular safety messages like the one delivered at the outset of Mr. Hanson's presentation. These messages might come from Mr. Hanson and an INPO representative on the first and second days of the course, followed by participants delivering the daily safety messages on remaining days. This practice of involving the students builds thinking about safety into their regular thought processes. The course also distributes useful teaching documents like the INPO Pocket Guide, "Traits of a Healthy Nuclear Safety Culture."[1] Finally, the course creates a number of active role-playing case studies that detail real accidents that occurred in the United States and elsewhere. To encourage spontaneous thought processes, many scenarios detail historic and somewhat obscure incidents so that the participants do not already know the outcome. Experts run a tabletop exercise with participants playing their specific roles, and then compare the response of the participants to the actual accident. It is a learning tool that could be replicated in other places in the world. The course concludes with a quiz to assess the quality of learning.

Mr. Hanson closed by saying that the most important aspect of safety and security are the people involved. After the courses, students are asked what is most important when constructing a regulatory regime: independence, transparency, or a dedication to safety above all. If at the end of the course, the students do not select a dedication to safety, then the course has failed. The course also asks who in a nuclear organization has the primary responsibility for safety, and there are two good answers: the leader and everybody.

The focus of the course and the focus of the department at MIT has shifted dramatically from when it was just teaching technology in the "technosocial"

[1]Available at http://pbadupws.nrc.gov/docs/ML1303/ML13031A707.pdf.

areas of safety and security. A unique feature of nuclear power is the need for overwhelming emphasis on safety and security. While not historically a strength, this emphasis is very important for the future of nuclear power, Mr. Hanson said.

## Metrics for Safety and Security Culture – Robert Bari, U.S. Brookhaven National Laboratory

Dr. Bari discussed metrics for nuclear safety and security from a "neutral, agnostic standpoint of raising questions." It is clear that there is no generally accepted set of metrics that can be translated into qualitative or quantitative levels of safety or security. Many believe that it is not possible to establish metrics in this field.

When nuclear power was still in its infancy, there was a concern over how to protect the companies that operate nuclear power plants and insure against liability from extreme accidents. The U.S. government passed the Price-Anderson Act in 1957. The severity of possible accidents was assessed in terms of radiological emissions from the plants, but the likelihood of these accidents was not. It was acknowledged that events would be very unlikely, but it was unknown how unlikely they were, and many took the view that one could not calculate the unknown unknowns or even the known unknowns very well.

Then in 1975, under the impetus of the liability of utilities that were producing electric power, Norman Rasmussen and around 50 specialists developed the WASH-1400 Reactor Safety Study. It was the first study with real risk assessment that addressed the safety of nuclear power plants in the United States.

Today, there is a general feeling that a good safety or security culture promotes good performance overall and perhaps improves basic production from an engineering system. It may or may not be possible to correlate accident probability with a metric to safety and security culture. Is there a need for a better assessment of a safety culture or a security culture? Metrics have proven useful in the safety of plants already.

After the Three Mile Island accident, nuclear operators in the United States began to understand the value of risk assessment tools, independent of their interactions with the regulator. An owner-operator wants high reliability in a plant and a high-capacity factor for plants. The risk assessment tools actually helped owners and operators run plants more cost effectively because they helped highlight what was important in terms of system reliability and availability. Operators also found that regulations in some areas placed undue burden on them, and they were able to make arguments using risk assessments for relief of some of these regulatory burdens.

This use of risk assessment then pushed the regulator to systematically address the requests for relaxation of certain parts of regulation, and forced them to develop decision-making tools to understand uncertainties and how to deal with the risk results that the utilities were putting forth. To a large extent, risk assessment is successful in the United States and perhaps in other countries because the utilities found it to be useful for their own operation.

Dr. Bari raised another question of whether there are risk assessment approaches that can be incorporated into safety or security culture. Can these cultures be taught? Can a person who is not in a good safety or security culture environment be taught to be more savvy, more aware, and more safety and security conscious? Can one person possess a culture, or is it more of a collective phenomenon of an organization?

Dr. Bari explained that emergent behavior is behavior that is not part of a single individual element but belongs collectively to the whole. He gave the example of turbulence, which is a complex phenomenon that cannot be understood from the study of a single drop of water. Similarly, magnetic behavior cannot be understood from examining a single atom and its transition from a nonmagnetic state to a magnetic state.

He discussed the Wisdom of Crowds study,[2] which notes that you can obtain a better answer to a question by polling a group of experts than by asking a single individual. The average displays the full collective wisdom that is not seen in a single element.

While this workshop has extolled safety culture and security culture as wholly positive, in Dr. Bari's personal interactions across the nuclear enterprise over many years, he has not encountered a strong safety or security culture in the design of nuclear power plant systems.

One would think that designing good safety features and building a plant in a way that would not require later retrofits of the plant by the regulator would make a lot of sense. But some designers want to build to a specification, and performance is the real driver. Others view the system as safe enough and do not think that adding costs for safety and security revisions is necessary. During a recent plant safety study review, one stakeholder was concerned that doing a study questioning the safety of the plant would drive up the cost of nuclear power. Organizations are multifaceted; some employees are concerned about performance, some are cost analysts, and others are environmental specialists. Safety and security are sometimes seen as a different part of the organization that is not part of the core mission.

Dr. Bari concluded his presentation with a series of questions: How do we make a more convincing case when safety and security culture is really difficult to execute successfully? Why consider safety and security together? Safety has the notion of openness and transparency, and security tends to be closed by nature. Is this a complex business (difficult to get to useful answers or extrapolate from experience) or just a complicated one? What motivates safety and security

[2]Surowiecki, James, 2004. *The Wisdom of Crowds: Why the Many Are Smarter Than the Few and How Collective Wisdom Shapes Business, Economies, Societies and Nations*. Doubleday.

professionals, and what drives a professional to become interested in safety and security culture?

### Beyond Procedures: Safety and Security Culture as a Preparation for the Unexpected – Filomena Ricco, DCTA/UNIFA – Air Force University

Dr. Ricco contributed a new perspective geared towards improving behavior and using safety and security culture in preparation for the unexpected.

To ensure the safety and security of their personnel and facilities, organizations that work with hazardous materials have risk management systems involving accident control and mitigation. Two important aspects of these systems are appropriate technical training and instructions. Technical training is based on responses to past problems, and written instructions are based on situations that have already happened or can be foreseen or are considered possible. However, procedures and instructions modeled on the past are not necessarily appropriate to deal with new, unexpected situations.

Dr. Ricco showed a short video in which an acrobatic aircraft loses a wing—a completely new situation for the pilot. This video illustrated how people in unexpected situations take new actions to prevent an accident or minimize the negative results from this accident. In situations where we experience something new or unexpected, there can be a high cognitive cost for those involved, depending on technical issues, organizational structures, and cultural aspects. In unfamiliar situations, decisions are still based on rules, but they are no longer the known rules or procedures for a specific situation. Instead, they are the rules the individual invents. Individual personal characteristics come to the surface in a moment of stress, and at that moment the situation is in the hands of those making the decisions.

People in very stressful situations can react in unexpected ways. Some freeze, indicating a loss of cognitive control. People need to recognize and understand their own capabilities and limitations during stressful, unexpected situations so that they know to what extent to rely on themselves, others involved, or systems in such cases.

In psychology this is called metacognition—knowledge about self-knowledge. How much do I actually know about myself? Have I been through similar experiences? What was my reaction in those situations? Metacognition drives the outcome when a person experiences the unexpected. It consists of inductive and deductive reasoning, interpreting and understanding information that is available, trying to identify the targets or the objectives, and reaching a solution to the problem and identifying and choosing the course of action.

To illustrate this phenomenon where maintaining cognitive control might lead to a positive outcome, Dr. Ricco described a kidnapping scenario. The kidnapped person is inside his own vehicle sitting in the passenger seat. The kidnapper is driving the car at high speed and the second kidnapper is sitting in the backseat with a gun. The kidnapped person realizes that he is very unlikely to survive that situation. If he is able to maintain cognitive control, the victim might notice that the kidnappers are not wearing seatbelts and at some point pulls the emergency brake so that the car gets into an accident. This action might create a positive outcome for the victim because he was able to maintain cognitive control and, after interpreting the available information, he established a target, which was to come out of that situation alive, and decided that the solution to that problem would be to cause a car accident because he was wearing a seatbelt. He evaluated the situation and chose the course of action when he was in the position to pull the emergency brake.

This cognitive control is desired when a nuclear professional encounters an unexpected experience. An environment's organizational culture (artifacts, adopted values, and assumed values, using Edgar Schein's terminology) dictates decisions on systems and equipment, human resources, and procedures to strengthen safety and security.

## DISCUSSION

A participant responded by saying that some organizations do not highly value safety culture or security culture, whereas others do. Often this internalization depends on whether an organization knows that safety and security are important to its vitality. Creating a good culture will work to the benefit of the enterprise. A proper safety culture will provide incentives for safe behavior and disincentives for behavior detrimental to safety. One important metric for reimbursement of costs on a large construction project is the number of hours without a "lost-time accident" as it applies to the U.S. Occupational Safety and Health Administration guidelines. Working for a long period of time without a lost-time accident is not easy, and a large construction force has the potential to create many accidents, due in part to workers not always exhibiting desired behavior.

Mr. Hanson described how his team created incentives on such a project. After each one of the million-hour milestones, they had a celebration and held a lottery for prizes, escalating in value with the number of hours without a lost-time accident. When they crossed the 5-million man-hour mark, there was a lottery for a pickup truck. The workers were fully aware that they had the potential to win the truck, and behaved as desired. Not only did the group have 5 million accident-free man-hours, the project is now in excess of 11 million hours without a lost-time accident (which is extraordinary). This example demonstrates an ability to produce a cultural environment that incentivizes people to internalize behavior.

Dr. Ricco discussed the analogy between personality for a person and culture for an organization. Both personality and culture define behavior. She advocated for an investment in behavior training to show good behavior and education of what good behavior looks like so that desired behaviors increase in frequency and become a habit. The culture of the organization is directly related to the attitude of its members.

A participant described a system where an organization examines safety and security issues on work activities, including travel. Many people in his organization often travel to risky locations, so there is an approval process that helps travelers understand the safety concerns in a given location. The organization discusses concerns with health officials, and then the director decides whether the travel should take place. Employees expressing their concerns represents good communication and an important element of overall security culture.

A participant stated his belief that the greatest threat and the greatest difficulty in implementing an effective safety culture is the culture of guilt and blame in our society. When a problem happens, the first thing we look for is the cause and a person to blame. To maintain a good safety culture, one has to look for the cause and not the person to blame, which is difficult in some countries with a judicial view of the problem.

An important lesson is how to make engineering decisions in an emergency situation. Fukushima was different from Chernobyl and Three Mile Island in that personnel in Fukushima had to make engineering decisions under very stressful situations. How can we train people to act like the kidnapped person in Dr. Ricco's example? What can we do to improve or create this capacity of making complex decisions under stress?

Mr. Hanson concurred with the observation that there is a human tendency varying from culture to culture to seek a scapegoat when something goes wrong. In a good safety culture, he said, the management does not seek a scapegoat, but the root cause of the mishap. For an inadvertent mistake, an employee should not be fired with a public display, but reeducated, so that the individual can understand what went wrong and prevent it from recurring. If the same mistake is made twice by the same individual, an entirely different response is called for, but a proper safety culture is tolerant of mistakes. In order for employees to self-report mistakes, an organization must be tolerant of a certain degree of unsafe behavior. It is difficult to achieve a good balance. An organization that moves too quickly is an organization that will not function properly. In an environment with a dictatorial commander, no one will self-report mistakes because of fear. One cannot create a good safety culture if employees fear their management.

Dr. Bari noted that the notion of guilt and blame transcends an operation and an organization, and can be part of a larger society. It becomes beyond the organization's control. It satisfies a certain sense of justice, but has negative effects on the safety culture of, and individuals in, the organization. He recounted an experience of chairing a safety committee that examined mishap causes. Politicians wanted to find the culprits and assign blame, and the media reported that the committee was formed to find the culprits. This messaging did not help uphold a strong safety culture for the people in the organization.

Dr. Ricco noted that there is an element of personal choice in what kind of person decides to work with safety and security. She then addressed the question of training for engineering decisions in emergency situations. Competence depends on having skills and knowledge, as well as the will to employ them. The former attributes come from experience, which an organization can develop in its employees by simulating relevant scenarios. The latter quality is both in the hands of the organization and in the hands of the individual.

We must also consider our subconscious element. For example, in a scenario where an individual needs to stay awake for 24 hours, he or she might take certain drugs to stay awake for longer. At a certain point, the person will fall asleep either with or without drugs, as the subconscious takes over and shuts down the conscious will of the individual. To prepare oneself for stressful situations, it is important to remember this subconscious element and invest in being physically prepared.

Training self-knowledge is a personal responsibility, as well as the responsibility of an organization focused on safety and security culture, Dr. Ricco said. Trainings, scenarios, and dynamic activities in which employees can experiment with stressful situations can teach them about how they will act in stressful situations.

Given this knowledge, an organization can construct teams with the requisite leadership skill sets for unexpected situations. If a team's primary leader has deep technical and organizational knowledge, but on a personal level has seemingly less cognitive control during unexpected stressful situations, a secondary leader with greater personal capacity to take adequate actions during such situations can be designated to assume temporary control if an emergency occurs.

A participant commented that in his work with utilities protecting critical energy infrastructure, the safety culture is strong due to the hazardous nature of the industry, but a security culture is absent. It is difficult to motivate people to monitor their security to maintain their own personal safety. Often, electrical providers need to enter high-crime urban locations or other dangerous environments. An individual's understanding of personal safety and how it relates to security situational awareness helps to create a security culture that sees potential security hazards in addition to safety hazards.

Mr. Hanson noted that personal responsibility is an important part of safety culture. However, in a fire where a death occurred because the individual could not identify the exit, the mistake was the architect's or system constructor's because the exit was not clearly marked. Individuals should be sharing responsibility for safety, he said, and a large number of individuals contribute to the creation of a safety culture. It is rare when one single individual bears the entire responsibility for an undesirable outcome.

# V

# Lessons-Learned Processes and Implementing Change

*The fifth session at the conference was on lessons-learned processes and implementing change. The session included presentations from Michael Corradini, Paulo Cesar da Costa Carneiro, and Donald Alston and was moderated by Leonam dos Santos Guimarães.*

## Lessons Learned from Vulnerability Assessments for Safety and Security Culture Undertaken after Fukushima (and the NAS Fukushima report) – Michael Corradini, University of Wisconsin

Dr. Corradini presented on the U.S. National Academy of Sciences (NAS) Report on Lessons Learned from the Fukushima Accident.[1] The study was requested by the U.S. Congress, sponsored by the U.S. Nuclear Regulatory Commission (NRC), and carried out over 2 years by an expert committee appointed by the National Academy of Sciences. Dr. Corradini and Dr. Bari served on the committee of 24 experts with chair Norman Neureiter, vice chair John Garrick, and study director Kevin Crowley from the NAS Nuclear and Radiation Studies Board.

Dr. Corradini recommended that the workshop participants read the report's detailed chapter on safety culture because it accurately reflects the committee's discourse on safety culture. He focused his talk on lessons learned to improve safety and security systems and operations, and lessons learned to improve regulation on safety and security. The report draws upon past reports conducted in the United States and in Japan, and presents many findings and recommendations on key topics at a relatively high level.

[1] National Research Council, 2014. *Lessons Learned from the Fukushima Nuclear Accident for Improving Safety of U.S. Nuclear Plants*. National Academies Press. Available at http://www.nap.edu/catalog/18294/lessons-learned-from-the-fukushima-nuclear-accident-for-improving-safety-of-us-nuclear-plants.

The Fukushima nuclear accident was caused by the Great Tohoku Earthquake and ensuing tsunami. The accident and response time line, as well as the interviews of the operators on site and in emergency response centers (both offsite in Fukushima and in Tokyo), showed that the plant personnel responded with courage and resilience. Some of the operators could not determine what was happening in the darkness, so they took batteries from their cars to power their portable instruments so that they could determine pressures, temperatures, and conditions in various parts of the plant and continue their emergency actions and operations.

However, several factors related to management, design, and operation of the plant prevented personnel from achieving greater success. A large part of the Japanese government report[2] focused on management and culture. The NAS report borrowed extensively from those discussions and investigations. Both reports make observations similar to those raised in this workshop on expecting the unexpected and having a robust operator development training program that actively seeks out new information about potential plant safety hazards. At the beginning of the report process, many of the NAS study committee members believed that Japan's ability to withstand seismic events was large. The accident surprised many in Japan, and Dr. Corradini believes it should lead to better unconventional thinking about the potential for extreme external events.

He then discussed several categories of recommendations from the report. The first category, nuclear plant systems, notes that the concept of nuclear safety is different from conventional safety ideas. Nuclear power is a unique technology because of the constant presence of residual heat[3] that must be removed to an ultimate heat sink. If heat is not removed, an accident can become unmanageable. Most of the recommendations in the nuclear plant systems category involve the ability to detect, measure, and understand what is occurring during an accident, and to control the system enough to remove the decay heat to the ultimate heat sink. This mitigation step requires direct current power for instrumentation and the ability to maintain real-time monitoring of the plant, even under a loss of power. In addition to instrumentation monitoring and critical parameters like hydrogen monitoring and mitigation, the most important step is to maintain communication and real-time information flow. As the U.S. NRC's report and other reports note, the inability of plant personnel to communicate with the owner-operator, Tokyo Electric Power Company, and back to officials in Tokyo contributed significantly to the accident.

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[2]*National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission (NAIIC)*, 2012. Available at http://warp.da.ndl.go.jp/info:ndljp/pid/3856371/naiic.go.jp/en/report/.

[3]Nuclear fuel continues to generate heat due to radioactive decay even after the shutdown of the nuclear chain reaction in the reactor core. The fuel generates heat at diminishing levels for years after reactor shutdown.

The second relevant category of recommendations is training. Because the site has multiple reactors, it is important to train for an emergency with multiple reactors under stress. Three reactors were under stress in a site of six, and that caused enormous difficulties, as personnel were trying to control unit one at the same time that they were trying to stabilize units two and three. Much of the response was ad hoc, and the committee thought that the operators should have trained for a full range of conditions under emergency operation. Plants all around the world should be looking to improve operations and abilities in this area.

The committee recommended that the U.S. NRC and the industry strengthen risk assessment capabilities for extreme events that challenge the plant systems and impair critical functions. The regulatory structure needs modern risk analysis techniques, which can identify unnecessary measures so that an organization can better prioritize resources. Finally, a number of the committee members pointed out that there are advantages and disadvantages to probabilistic risk assessment,[4] and we have to understand both as we proceed to use it.

The committee also offered recommendations on offsite emergency response. The United States conducts site training exercises involving all of the relevant parties: plant operators, the U.S. NRC, the Federal Emergency Management Agency, and the states where the plants are located. The committee believed it was very important to have clear emergency management responsibilities, to know who is in charge of what when an event occurs. Training should also assess and evaluate emergency preparedness over time and be evaluated continually and revised in case of an extreme external event.

Finally, Dr. Corradini mentioned a few points from the chapter on safety culture. There were strong views on the committee about safety culture and whether it exists and should be improved in the United States. The consensus view was that it should be examined and closely monitored within the U.S. NRC and the nuclear industry. The committee built on a number of reports from the Japanese, the Near-Term Task Force of the Nuclear Regulatory Commission, the American Nuclear Society, and other groups.[5] Many of the findings and recommendations on what occurred at Fukushima are not different from these reports, but the committee tried to be comprehensive in connecting what was done in the past to important new observations, such as on safety culture. The committee

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[4]See page 188 of National Research Council, 2014. *Lessons Learned from the Fukushima Nuclear Accident for Improving Safety of U.S. Nuclear Plants*. National Academies Press. Available at http://www.nap.edu/catalog/18294/lessons-learned-from-the-fukushima-nuclear-accident-for-improving-safety-of-us-nuclear-plants.

[5]See U.S. Nuclear Regulatory Commission, 2011. *Recommendations for Enhancing Reactor Safety in the 21st Century: The Near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident*. Available at http://pbadupws.nrc.gov/docs/ML1118/ML111861807.pdf; and American Nuclear Society, 2012. *Fukushima-Daiichi: ANS Committee Report.* Available at http://fukushima.ans.org/report/Fukushima_report.pdf.

also used the term *regulatory capture* to describe the insufficient independence in Japan between the regulator and the regulated utility.

The importance of a strong safety culture and of an independent regulator that is transparent cannot be overemphasized. While many members of the committee believed that the United States has a strong safety culture, transparency, and an independent regulator, many members also suggested that relevant facts were not readily accessible. From a communication standpoint, the system has not been as effective as needed.

**Fukushima Response Plan by Eletronuclear: An Overview – Paulo Cesar da Costa Carneiro, Eletrobras Eletronuclear**

Dr. Carneiro gave an overview of Brazilian studies and the Brazilian response to the Fukushima accident. He first explained the layout of the Angra Nuclear Power Station in Brazil and its three reactors, including one under construction to become operational in 2018. Immediately after the Fukushima accident, Eletronuclear reacted by establishing a Fukushima Response Management Committee of broad experts to evaluate safety at the site. Working groups of specialists gathered and evaluated information about the Fukushima accident onset, development, and consequences; identified lessons learned applicable to Brazilian nuclear power plants; performed safety assessments; participated in national and international discussion forums on these lessons learned; and submitted a 5-year executive plan to the Comissão Nacional de Energia Nuclear (CNEN, the National Nuclear Energy Commission) in December 2011. This Fukushima Response Plan consisted of 56 initiatives, studies, and design modifications, totaling an estimated $150 million in recommended safety improvements. The plan also included developing stress tests to improve understanding of site safety, and these results formed the basis for the safety review and response.

Many of the initiatives were aimed at protection from hazardous events, provision of cooling capacity, or mitigation of radiological consequences. In the first area, protection from hazardous events, the plan considered both external events (earthquakes, rainfalls, landslides, tidal waves, and tornadoes) and internal events (fires and internal flooding). External event analysis led to updating of databases, reevaluation by updated methodologies using a probabilistic approach, and the verification of safety margins. For internal events, the plan reevaluated the plants, taking into consideration up-to-date safety requirements, and identified design gaps.

The Angra site was characterized as a “low seismic site” with a similarly low tornado probability, though action plans for further evaluation of the latter hazard are under way. Given a prospect of large rainfalls and the potential for landslides around the site, the plan recommended an enlargement of the slope drainage system and reinforcement of stabilization works protecting the station. A reevaluation of flooding levels under more severe conditions was conducted and concluded that the current design flooding level includes a sufficient safety margin. To counter the threat of tidal waves, a protection jetty allows the site to withstand waves up to 4.4 meters tall, and one initiative is expected to recommend structural reinforcement for this jetty.

The review reevaluated core cooling emergency scenarios, including station blackout scenarios and loss of heat sink conditions. Both emergency power systems met U.S. NRC requirements, and Dr. Carneiro also provided an overview of additional emergency supply alternatives.

The plan encompassed three assessment areas. Firstly, it assesses the safety margins of the project. Secondly, it determines what to do with loose safety systems, and thirdly, it evaluated the response to a broad group of natural disasters using probability approaches for safety margins. Actions range from interconnecting the emergency equipment to using external diesel generators to recharge the batteries and mobile pumps and backup generators for redundancy. All the people onsite are sensitive to the importance of these measures, Dr. Carneiro said.

## The 2012 Security Breach at the Y-12 National Security Complex – Donald Alston, Alston Strategic Consulting

General Alston presented a security culture case study of an incident at the Y-12 National Security Complex in Oak Ridge, Tennessee. He detailed the breach, how the security forces at the Y-12 National Security Complex responded, and the fundamental circumstances that set the conditions for failure. His content was drawn from websites in the public domain, mostly from the Department of Energy (DOE). He then described the initial recovery actions at Y-12 to shore up gaps in security and his personal observations and their implications for security culture.

The event began in the predawn hours on the morning of July 28, 2012, when three trespassers came through the first barrier into the secure area of the Y-12 National Security Complex. They came over a hill and began to cut the first of three fences. After cutting a second and a third, they entered the complex. They approached the Highly Enriched Uranium Materials Facility. They defaced it with the name of their organization. They threw blood on it, painted it, and hammered on the walls. Their goals were to deface the facility and then get arrested. Unfortunately, the latter took too long.

As soon as they touched the fence, the system operated as designed. Immediately, alarms alerted the proper areas and the security response began. There were cameras dedicated to that particular area, but both were inoperative at the time and had been inoperative for months. The integrated security system that included both the sensors on the fence and the cameras was already suboptimal for the incoming threat. An innovative security guard knew that there was another camera that could see this area. It was not part of the integrated system because it was a pan-tilt-zoom camera. These rotating cameras have blind spots when looking in the wrong direction, so fixed cameras are thought to be harder for an adversary to evade. It was the only camera available, so the guard seized the moment and looked right at the area with the camera, but did not see the trespassers.

While the alarm had sounded and the dispatching process had begun, a slow response was under way. When the first responder arrived and he saw the trespassers, he had already been conditioned to respond lethargically. Alarms sound all the time without an intruder, and he was told that the camera did not see anyone. So he did not respond with urgency, and he did not follow protocol when he found the trespassers. He did not get out of his vehicle and draw his weapon to put them at a disadvantage. All the training he had just escaped him at this crucial moment. Another opportunity was lost when the guards inside the large storage building heard hammering on the wall. They had the opportunity to investigate the noise by looking out a gun port, but they chose not to. The cameras were inoperative, but the guards presumed that they were down for maintenance. Because the guards were conditioned that they do not always get notified when maintenance is being performed, they did not challenge this assumption. So even though they heard a disturbance, they did not react appropriately either.

Ultimately, there was a vast and substantial response by the overall security team, but it was too late. One of the fundamental problems with this overall set of conditions at the Y-12 facility is that the system had problems from the moment it was deployed and there was inadequate developmental and operational testing. The sensors were generating many false alarms, so the security forces were being conditioned not to run to the sound with guns, but rather to log entries to fortify the documentation for the shortcomings in the security system.

The high false and nuisance alarm rates were not being addressed through maintenance. They were being logged very effectively, in very detailed logs kept by the security forces, but the problems were not being solved. The inoperative cameras were not given a high maintenance priority at Y-12, which was inconsistent with other Department of Energy facilities.

Extended outages of essential integrated features in the security system were not considered problems. These prolonged outages drove compensatory measures in order to cover the loss of these critical features while the maintenance backlog grew on several different aspects of the integrated security system.

Management had been warned a year before the incident that there was going to be reduced security funding. This reduced funding started to reduce the number of compensatory measures that had been put in place to cover the shortcomings in the original integrated security system. Overall, this negligence created a growing acceptance of suboptimal capabilities generating vulnerabilities. The culture accepted this.

In addition, the contractor responsible for management and operations at Y-12, Babcock and Wilcox, was responsible for maintaining the security system. A different contractor, Wackenhut, was in charge of security and responsible for the security personnel. One contractor's personnel could identify shortfalls, but another contractor had to perform the maintenance on those shortfalls and the operational testing on the overall system. This relationship was not working well. One of these contractors was in competition to renew its contract, and so had an incentive to not make waves. This hesitance was exacerbated by the federal "governance transformation" initiative going on at the time. While well-intended, this initiative sought ways to reduce detailed oversight—to provide broad direction on requirements, but then rely on contractor assurance systems to ensure that work was getting done. The federal officer on the site was put in a position where the mantra was "eyes on, hands off." This attitude allowed the contractors to create their own report cards and score themselves on how effectively they performed against their report card.

After the incident the facility repaired the weaknesses and plugged the holes. They immediately fortified the facility to increase the difficulty of its access by other trespassers. They reduced the false and nuisance alarm rate. Their motivation increased greatly, and suddenly things that seemed to be low priority and had been put off were getting fixed. The security personnel and the management, previously in two different reporting chains to the Department of Energy, became part of one contract, where personnel and systems were managed by a single function. The security maintenance priority system was revamped with the highest priority and immediate attention.

Months later the secretary of energy asked General Alston and two colleagues to examine the Y-12 incident, looking across the U.S. nuclear enterprise. They learned that some locations use federal marshals for security, others use contractors like Wackenhut. Another model put the security apparatus underneath a larger management and operations contract. They offered the secretary a common way ahead to secure nuclear materials in the Department of Energy.[6] One colleague described the situation well: "There was a pervasive culture of tolerating the intolerable and accepting the unacceptable." Clearly, the culture at Y-12 had to change.

General Alston observed that conditions for successful security culture are as follows:

- Responsibility for success is shared by all.
- Lines of authority and accountability are clear.
- Performance testing focuses on operation effectiveness.
- Information flow and self-criticism are incentivized.

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[6]See Alston, C. Donald and Richard A. Meserve, March 13, 2013. "Statement before the U.S. House of Representatives Committee on Energy and Commerce, Subcommittee on Oversight and Investigations. Hearing on DOE Management and Oversight of Its Nuclear Weapons Complex: Lessons of the Y-12 Security Failure." Available at http://democrats.energycommerce.house.gov/sites/default/files/documents/Testimony-Alston-Meserve-OI-DOE-Nuclear-Complex-2013-3-13.pdf.

- Circulate assignments between HQ and the field.
- "Walk the talk."

Creating a good security culture is about being able to pass on security culture to others.

In a safety context, an environment where everyone is responsible for safety has fewer safety vulnerabilities. The same is true for security. General Alston and his colleagues found that nuclear facility personnel identified with their vital, pivotal role in safety, but that most thought security was the responsibility of the security forces.

When the team visited the commercial nuclear power generating plant on the Chesapeake Bay at Calvert Cliffs, Maryland, they saw a culture where employees were encouraged to step beyond their functional responsibilities in order to focus on mission success with security or other operations within the complex. When security professionals saw something that was out of line, even if it was outside of their functional expertise, they were encouraged to report it. They took on the responsibility to cross those lines to ensure mission success. That kind of ownership of mission success and mission outcomes was missing from Y-12.

When they looked up the chain of command at Y-12 to the Department of Energy, it was unclear who was accountable for daily mission success. There were multiple organizational charts, and none of them showed who was accountable for security success on a daily basis.

Without a self-critical approach to performing testing, such as developmental testing or operational testing, an integrated system is impossible. In some cases there was rigorous component testing, but there was no system test done in a disciplined, repeatable fashion.

The security mission at Y-12 requires them to be able to answer two questions: How ready are we? And how do we know? A productive security culture feeds a good communication flow. In this particular case, bad news was not flowing up.

When there is distrust between headquarters and subordinate units, there can be a sense that headquarters cannot fully understand and relate to what is happening on the ground. In this particular case, scientists move throughout the Department of Energy. Security personnel do not. No security detailees from Oak Ridge, Tennessee, go to headquarters in Washington, D.C., to convey their special concerns, and no one at headquarters can relate to them. Additionally, no one from headquarters comes to Y-12 to recognize their distinctive needs, but also to explain that there are reasons for central influence on particular activities.

The failure to develop and circulate security professionals in and out of the headquarters allowed the mistrust that existed to persist. There was no regular, consistent emphasis on the pivotal role of security from the top that was propagated down to every member of the organization. Leadership had a serious challenge.

General Alston closed by presenting a list of virtuous attributes of a positive security culture. Culture does not exist in a static environment, and there are pressures, both positive and negative, at all times. Organizations need to deliberately consider their capacity to nurture, sustain, and pass on their culture. It cannot be left to chance. They need to develop people; control and influence the factors that create a culture enabling mission success every day; add value on a regular basis; and create leaders with the competency to pass these virtues onto the following generations.

The perpetrators of the Y-12 incident were convicted in 2014. The woman was sentenced to 35 months in jail, and the two men were sentenced to about 60 months.

## DISCUSSION

A participant asked about criticism of the regulatory system, those in charge of making this security plan, and whether the regulator had sufficient independence to protect the facility?

General Alston explained that the National Nuclear Security Administration (NNSA), a semiautonomous agency within the Department of Energy, has responsibility for the nuclear weapons complex, including all activity at Y-12. DOE regulates itself. NNSA's performance is verified both by the DOE inspector general and through the regulatory organization within DOE.

Two months before the security breach at Y-12, this organization performed a field inspection and graded the complex as having a high probability of detection of intruders. The inspectors did not do a comprehensive evaluation of the entire integrated security system and failed to anticipate the problems, for which there were early indicators: There was a growing backlog of maintenance; there was too much distance between the site federal officer and the contractor; and the main contractor responsible for testing and for security maintenance was not aggregating the shortfalls and performing a risk analysis of what each additional backlog meant for overall security.

To fix these problems NNSA proposed to have an organic role in the evaluation and inspection process and not depend on someone outside their organization for this information. This fix was not accepted, however, and the contractor assurance system enabled the contractor to grade itself.

With the inspector general and this outside organization working for the secretary of energy, the independence and transparency is present, but the competence of these other organizations were debated throughout General Alston and his team's examination.

On the importance of rotating security personnel from the field back to DOE headquarters,

General Alston said that Y-12 participates in a DOE working group bringing together individuals from different facilities to discuss processes and methodologies and form vulnerability assessments, but that a few days or a week at headquarters does not necessarily address the problem. Science officials in the Department of Energy gain experience in a variety of positions and locations, but there was no evidence of security personnel transferring between the field and the headquarters security team. The growing separation between the nuclear laboratories and the production efforts at Pantex Plant and at Y-12 led to a situation where facilities were not implementing common standards in common ways. These discrepancies would have been overcome if security personnel from Y-12 routinely took headquarters and other assignments. Such immersion broadens perspectives, normalizes the evaluation of security, and helps transmit the value of maintaining common standards. Another complicating factor is that a close and friendly dynamic between the federal office and the contractor running the facility might adversely affect objectivity and transparency.[7]

A participant asked if maintenance typically begins at predawn times or whether this practice was a deviation from the norm. General Alston responded that it is fair to correlate the rising of the sun with the start of maintenance, but for the facility in which America stores highly enriched uranium, there needs to be strong coordination on maintenance schedules. There should be vigilance by the guards that no maintenance is authorized without their knowledge and approval. The conditions to allow uncoordinated maintenance existed before the incident, and the guards were not empowered to stop this maintenance. In the breach case, this lack of coordination and empowerment was consequential.

Mr. Tobey stated that it seemed that the greatest failures of the incident were not of the guard who failed to show up in a timely fashion or to protect his weapon when he did so, or even of the management that tolerated the intolerable. The greatest failure was of the DOE-NNSA, which was oblivious to a dangerous situation that had been going on for a long time. He asked what has been done to improve NNSA's knowledge of the situation on the ground and what should be done?

General Alston recounted a personal opinion from his work with the Department of Energy while he was in the Air Force. There is a legacy in the DOE where the laboratories are very important and very powerful. Los Alamos, Lawrence Livermore, and Sandia National Laboratories have extraordinary national security work to perform, and there is occasionally a criticism that the department gets in the way of performance in the field. Over time, that message throughout headquarters not to interfere with the performance in the field eroded the appropriate centralized control, and broad direction replaced specific direction for the production sites. The officer abandoned all his training and protocol—he saw an 80-year old person looking at him, not a hostile threat. It was a difficult position, but if he had followed protocol, this incident would have had a different outcome.

[7]The national security laboratories and the nuclear production facilities in the United States are owned by the government, but operated by contractors.

Dr. Lowenthal asked Dr. Carneiro to comment on how his findings and actions have been received inside and outside of Eletronuclear. Dr. Carneiro responded that this reception was a concern since the beginning. To be transparent means to provide enough information internally and externally about the studies and the actions that the company was performing.

Internally, Dr. Carneiro's team has been integrated into the Safety Future Project, making presentations and giving updates on studies and results. Externally since the beginning, he tried to integrate different areas of the company, not only to achieve the highest competence but also to sensitize groups to the measures when implemented. It was a strong policy of the company to participate in all the meetings and budgets in Congress, in the ministries of mines and energy, inside the company, and in outside communities. They took every opportunity in a transparent way to address concerns, studies, and results.

Looking back after three years, there were social factors that might have been better. But it is hard to judge the policy response to Fukushima because the government was not involved in the performance of company activities. The overall reception of their actions was very positive with no problems in continuing operations. Dr. Carneiro credits the comprehensive and consistent nature of the initiatives, as well as the very open way they were explained and discussed with their success.

Admiral Ellis asked for Dr. Corradini's personal views on the events that continue to unfold at Fukushima. Dr. Corradini's personal impression, since mitigation was not within the scope of the NAS Fukushima report, is that onsite the biggest problem is water management. The magnitude and scale of the problem is enormously complex. Firstly, they have an open cooling system, where they inject water, which drains from the dry well and the wet well back from breaches and that water is then taken, cleaned up, filtered and reinjected. While not using additional water is an advantage, a disadvantage to the system is that they have yet to implement closed cooling on all three of the units.

Secondly, there is an issue as to what to do about wastewater cleanup, as they had great difficulty in cleaning and filtering the water. Thirdly, there is an inability to develop a policy on what to do with solid waste, which is currently being stored, and even the results of tsunami debris, which is not necessarily radioactive, but may contain chemical toxins.

Their only onsite success has been in dealing with the problems associated with the rainy season. Due to Fukushima's location at the bottom of a large sloping hill, rain flows through the site and into the sea, filtering through the soil and carrying residual radioactive elements into the sea. They have dealt with this issue and with the open pooling, but have yet to deal with waste disposal. The Japanese are looking for international guidance on appropriate standards for waste disposal. Dr. Corradini then added that his largest concerns were the lingering effects of Fukushima: While the health effects are minimal, that they are lingering is an enormous issue.

Dr. Guimarães cited the major lessons learned from the Three Mile Island and Chernobyl accidents. The main lesson learned from Three Mile Island is the importance of human factors, that taking the time to learn rules and procedures is important. The central lesson from Chernobyl was the importance of safety culture. He posed the question of what the central lesson from Fukushima will be 10 years later.

Dr. Corradini answered on a personal level that he and others are concerned about the lack of understanding, knowledge, or appreciation of societal risk related to nuclear power. He explained that in the Fukushima accident, immediate fatalities were not the issue, as much as the evacuation and the way in which the emergency planning was conducted. Even now, there is no policy to allow the displaced individuals to return to their homes. The major lesson learned is that a lack of robust emergency planning and the presence of lingering effects that drag on and on raise concerns over whether nuclear technology is a worthwhile investment. Fukushima was a very severe accident, not from the standpoint of the radioactivity released and direct health effects, Dr. Corradini said, but because of how it affected the population. If we are unable to adequately address these known effects—by an approach to evacuation planning, emergency planning, and offsite response, or at least a risk assessment to evaluate signs at certain sites—it is simply not appropriate to have a nuclear plant on these sites.

Dr. Carneiro concluded the discussion by echoing the importance of an emergency plan that pays particular attention to evacuation. Without this type of planning, the impact of these disasters never ends, and there is no way to fully bring comfort to those evacuated.

# VI

# Influence of Leadership and Hierarchy on Safety and Security Culture

*Session six of the conference covered the influence of leadership and hierarchy on safety and security culture. The session included talks from James Ellis, Luciano Pagano Jr., and Sonja Haber and was moderated by Donald Alston*

### Nuclear Leadership – James Ellis, Stanford University

Admiral Ellis began with the question of next steps and emphasized leadership. Recalling a saying from his navy career, "They're not lessons learned just because you write them down. You actually have to learn them," he stated that the question about what comes next is just as important as who oversees and shepherds the work that must follow. The single most important factor in shaping the present and the future of the nuclear industry is leadership. Noting that the participants are those leaders, he thanked them for their personal commitment.

Admiral Ellis emphasized the leader's role in creating an organizational culture and, ultimately, a nuclear safety and security culture. But no matter how passionate one leader is in his or her pursuit, that individual cannot do it alone, cannot be everywhere, and cannot personally oversee all the complexities of a nuclear enterprise. The leader must create an organization that is similarly committed in training both leaders and workers in the pursuit of excellence, both in routine operation and in emergencies. In a crisis when, despite every best effort of a leader and team, things have simply not gone as desired, leadership requires different skills and a different focus.

Despite the plethora of complex definitions that the workshop has reviewed, an organization's culture is simply the reflection of the organization—of its practices, its real values, its shared experiences, and its leadership. Efforts to define, measure, and consider how best to shape nuclear safety and security cultures have led to confusion and the belief that it is too hard.

But it is not too hard, Admiral Ellis said. Leaders, along with their own leadership teams, intentionally or not, shape cultures every day. According to organizational culture expert Dr. Edgar Schein, former Massachusetts Institute of Technology professor and a longtime member of the Institute of Nuclear Power Operations (INPO) Advisory Council, leadership creates and changes cultures, while management and administration act within a culture. There are many indicators available to leaders that provide insight into the organization's culture and the nature and effectiveness of their leadership. But once we have solved the cultural mystery as best we can or decided on the culture we want, we must not allow ourselves to be convinced that the shaping of a positive culture requires a program, checklist, or handbook, or that it can be infused by pill, injection, all-day meetings, a company-wide poster contest, or the most expensive of corporate consultants.

Organizational culture is not a figment of the regulator's imagination, the latest in pop psychology, or some recent management trend. It is real and important. Mohandas Gandhi once said, "A nation's culture resides in the hearts and in the soul of its people." And so it is with the nuclear industry. But as we acknowledge that changing the culture takes time, Admiral Ellis said that we cannot let that become an excuse for inaction. With the right incentives, behaviors can change overnight.

The nuclear industry has adopted a definition of safety culture: An organization's values and behaviors modeled by its leaders and internalized by its members that serve to make nuclear safety the overriding priority. This definition, with a few changes, could be applied to any of the cultures resident in an organization, including security culture. The many cultures resulting from the organizational, geographic, and role variations within companies must all reside comfortably within an overall corporate culture.

The vast enterprise's participants encompass much more than nuclear generation or research assets. This inhomogeneity presents an additional challenge of recognizing and even reconciling different cultures within a single organization. While corporate culture may not be homogeneous, it must still be solid. A solid corporate culture is necessary but not sufficient for a strong safety culture. A fatally flawed corporate culture, however, does guarantee a weak safety culture.

Admiral Ellis said that leadership and culture, like nature, abhor a vacuum. Left to their own devices, without standards, expectations, guidance, and accountability—in other words, without leadership—an organization and its cultures can arrive at many end states. Few of them are good. Admiral Ellis relayed a favorite nautical quote attributed to Justice Oliver Wendell Holmes: "Greatness lies not in where we stand but in what direction we are moving. We must sail, sometimes with the wind and sometimes against it, but sail we must and not drift, not lie at anchor." We either shape our culture or surrender the responsibility for shaping it to those winds and currents that will always swirl around us. The choice is ours.

In answering the question of how one shapes a culture, Admiral Ellis advocated hearing the thoughts of participants from around the world who have contributed to the courses, seminars, and meetings that are part of the industry. He then described six mechanisms that leaders use to embed their beliefs, values, and assumptions identified in Dr. Schein's seminal study, *Organizational Culture and Leadership*.[1] While these mechanisms do not constitute the culture, they are visible artifacts of an emerging culture and create the climate of the organization.

Firstly, one of the most powerful mechanisms that founders, leaders, managers, or even colleagues have for communicating what they believe in or care about is what they systematically pay attention to. This focus can mean anything, from what they notice and comment on to what they measure, control, reward, and in other ways deal with systematically. Even casual remarks and questions that are consistently geared to a certain area can be as potent as formal control mechanisms and measurements.

Secondly, in times of crisis the role of a leader is especially important in shaping or reinforcing values and procedures, as the leader's behavior is often stripped of its calm veneer. Crises are especially important in shaping and transmitting culture. It is then that the organizations can be bound together by the shared challenge, and that emotional involvement contributes to intense learning. People look to leadership at this time for assurance and strength, and signs of panic and anger can send powerful and disturbing signals.

Thirdly, in this time of financial challenge, cultural signals are created by budgeting processes. Beyond the priorities indicated by the resource distribution, the importance conveyed by the acceptable level of debt, the minimum cash flow, and the expected dividend level all transmit messages well beyond the boardroom about the importance of an optimized capital structure, the acceptable level of risk, and the level of innovation and strategic vision allowed, as well as the real priority placed on safety and security. Efforts to control costs are important, but especially in the beginnings of a new nuclear endeavor, if the signal being sent is that only costs are important—and not safety, security, and effectiveness—bad outcomes can result in both areas.

Fourthly, founders and leaders of organizations generally know that their visible behaviors are powerful communicators of assumptions and values. Many use video presentations to outline philosophies in trainings for new employees. However, there is a difference between a message delivered from a staged setting and those received from informal observation of the leader. The informal, everyday messages are the more powerful teaching and coaching mechanisms.

Fifthly, how leaders allocate rewards and status—both the nature of the behavior rewarded and punished and the nature of the rewards and punishments themselves—carries a message. Members of an organization learn values from their own experiences with the performance appraisal and promotion system, as well as from their observations and discussion of what the organization rewards

[1]Schein, Edgar H., 2010. *Organizational Culture and Leadership*. 4th ed. San Francisco: John Wiley & Sons.

and punishes. What is important, in Dr. Schein's view, are the practices: what really happens, not what is espoused, published, or preached.

Finally, who is hired into an organization can, intentionally or not, signal the values and behaviors that the leader endorses. Hiring for technical qualifications or experience meets only part of the organization's needs, and the recruiting process must understand all dimensions a new employee brings. The identification and advancement of those deemed the most deserving are powerful signals to the organization of expected or accepted cultural norms. And how clearly but compassionately the organization deals with the need to remove employees from positions of responsibility sets both performance expectations and cultural norms.

Admiral Ellis stated that he was not prescribing a specific approach to cultural change. Any approach to cultural change must factor in what can work within the existing culture to create an improved culture. However, one element must be shared: The culture must be fair, and, most importantly, must be perceived as fair. "Miracle on the Hudson" pilot Sully Sullenberger, who saved all the passengers and crew onboard his ill-fated flight, is an avid and career-long student of aviation safety and the cultures necessary to support it. In an interview with Katie Couric, he stated: "For 42 years, I've been making small, regular deposits in this bank of experience, education, and training. And on January 15th, the balance was sufficient so that I could make a very large withdrawal." That day, Captain Sullenberger was carrying in his suitcase Sidney Dekker's book *Just Culture*, which describes failures of organizations, even or especially those that consider themselves to have high accountability. It draws clear distinctions between a positive culture of accountability and a negative culture of blame. Dekker draws on numerous case studies to highlight that the focus after tragic events is often to move too quickly to castigate and even criminalize the individual involved, while systematically ignoring the many contributing factors that put the employee in a vulnerable position set up to fail.

Admiral Ellis said that in an attempt to paint a picture, even if in broad strokes, of an aspirational nuclear culture, there are two dimensions to consider: our corporate or organizational cultures and our overarching industry culture. We need not—and, arguably, should not—aspire to be carbon copies of each other, he said, even as we peek behind the curtain and realize that we have a great deal of commonality in the bedrock principles on which our individual cultures sit. We should focus on our strengths and explore how to build them proactively in ways that enable, motivate, and even inspire our teams. The bedrock of the culture of the nuclear industry must remain an unwavering commitment to nuclear safety. This commitment is described in the nuclear industry's *Principles for a Strong Nuclear Safety Culture*,[2] now known as "Traits,"[3] and is

[2]INPO, 2004. *Principles of a Strong Nuclear Safety Culture*. Available at http://www.nrc.gov/about-nrc/regulatory/enforcement/INPO_PrinciplesSafetyCulture.pdf.

nested in the context of both an accountable and a just culture. The key to future success will be the ability to sustain the industry's focus and develop the next generation of leaders who understand, embrace, and advance this principle.

In the May 2013 issue of the *Harvard Business Review*, A. G. Lafley, then the chairman and chief executive officer (CEO) of Proctor & Gamble, wrote an article on the most important aspects senior leaders can concentrate on, irrespective of the organization's position in the business or economic cycle.[4] Lafley takes on the conventional wisdom that suggests a leader is primarily a coach and a utility infielder, in American baseball terms, dropping in to solve problems where they crop up. In fact, he says, a leader has a very specific job that only he or she can do because all others in the organization focus much more narrowly and almost always internally. In the article, entitled "What Only the CEO Can Do," he offers several specific, externally focused tasks of a leader. And the most important of them is shaping values and standards—defining the culture.

Admiral Ellis said that there will always be tasks in business, in society, in government, and in our nations that only the elite can do, but it is in the setting of standards that leadership is most needed. As Fareed Zakaria has said, "Standards represent society at its highest aspirations, not its complex realities." When leaders acknowledge that there are certain standards for behavior, they signal their goals to society.

Admiral Ellis posed a final question: What is it we stand for and strive for at this pivotal time in the nuclear industry's history? In other words, is there a creeping sense that the way we have always done it is as good as it can get and that it is good enough? Or are we, those of us decades into this effort and those of you newly joining this journey, together ready to acknowledge still the appropriateness and elusiveness of our goal of excellence and our unique role in its achievement? President Harry Truman, once said, "Men make history, and not the other way around. In periods where there is no leadership, society stands still. Progress occurs when courageous, skillful leaders seize the opportunity to change things for the better." And Winston Churchill said, simply, "The price of greatness is responsibility." What is our responsibility as leaders, in times of change and challenge, or, even worse, in times of crisis, large and small?

Admiral Ellis offered several closing points: First, in a time of crisis, a leader and his or her team must manage anxiety. Recent university studies have shown that when people's anxiety goes up due to the challenges they face, they often lose the very capabilities they need the most: the ability to think clearly, to prioritize what needs to be done, to think outside of the box, and finally, and most importantly, to act. Dr. Edgar Schein has said that in times of great difficulty one of

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[3]U.S. Nuclear Regulatory Commission, 2012. *Traits of a Healthy Nuclear Safety Structure*. See, http://pbadupws.nrc.gov/docs/ML1303/ML13031A707.pdf.

[4]Lafley, A. G., May 2009. "What Only the CEO Can Do" *Harvard Business Review*. Available at https://hbr.org/2009/05/what-only-the-ceo-can-do.

the most important roles of the leadership team is to absorb anxiety through clear communication, a demonstrated understanding of the problem, and swift and conclusive action to deal with the looming realities. All of us are human, too, and if we are not careful, we can unwittingly find ourselves creating anxiety rather than absorbing it.

Next, especially in times of crisis, leaders must be brutally honest with their stakeholders, with their team, and with themselves. This honesty must be born of a real and complete understanding of the crisis and its depth, but must also bring an optimism that the team will emerge stronger and better. In what author Jim Collins calls the "Stockdale Paradox," Vice Admiral James Stockdale, a Vietnam era prisoner-of-war, told him, "This is a very important lesson. You must never confuse faith that you will prevail or succeed in the end—which you can never afford to lose—with the discipline to confront the most brutal facts of your current reality, whatever they might be."

Leaders must deliver results, and in a time of crisis, this is particularly important. You find your organization spinning continuously, jumping from one half-mission to another in the face of a full-blown crisis. Someone simply needs to get the job done. According to Robert Kaplan, in his book *Warrior Politics*, [5] for Machiavelli, a policy is defined by its outcome. If it is not effective, it cannot be virtuous. This is not an argument in favor of the end that justifies the means. Rather, it is merely noting that without an end, the means, however well-intended, are simply not sufficient.

Finally, we must not confuse management with leadership, though both are important. In a recent speech, American Senator John McCain described his grandfather, the commander of an aircraft carrier battle group in World War II, who lived and loomed larger than life. As an admiral, he rolled his own cigarettes, smoked constantly, and swore and drank more than he should have. He was known as one of the U.S. Navy's best cursers; probably not the sort of recognition one would want today. "Slew" was his call sign, and James Michener described him in *Tales of the South Pacific* as an ugly, old aviator. But he was more than that, especially to his men. He was a leader. Senator McCain goes on to say that today we hear a lot about management and not enough about leadership. Good managers are plentiful. In fact, our nation graduates more than 150,000 MBAs every year. But true leaders are rare. The difference, and the reason that leadership always trumps management, is that leadership is the art of inspiring others to perform far beyond their self-imposed limits.

In no other time in the history of the nuclear industry has focused, effective, and inspirational leadership been more important, Admiral Ellis said. The ancient aphorism comes to mind: If not us, then who? If not now, then when?

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[5] Kaplan, Robert D., 2002. *Warrior Politics: Why Leadership Demands a Pagan Ethos*. Vintage.

### Insights on the Role Played by Leadership and Hierarchy in Organizational Culture – Luciano Pagano Jr., CTMSP - Brazilian Navy Technology Center in São Paulo

Admiral Pagano presented on the role played by leadership and hierarchy in organizational culture using the example of the Centro Tecnológico da Marinha em São Paulo (CTMSP)—the Brazilian Navy Technology Center in São Paolo.

He first explained the reasons for concern at CTMSP. The Aramar Experimental Center houses a nuclear fuel production cycle, including conversion to uranium hexafluoride, enrichment, fuel fabrication, fuel assembly, use in a nuclear reactor, and placement into a repository. The conversion, enrichment, and fuel fabrication stages are conducted under strict International Atomic Energy Agency safeguards. There is also a small pressurized water reactor used as a land prototype for naval propulsion, not yet in operation.

Given these sensitive facilities, Admiral Pagano described the measures CTMSP takes on safety and security. The recent Safety Program, with a budget in excess of two million dollars for the 2014 to 2016 time frame, seeks to address the following: healthy radiological protection, industrial safety, chemical safety, operations and fire prevention, human resources, quality assurance, environmental management, and security. A multidisciplinary group from across the organization has been appointed to flesh out the program. The main objectives of the program are as follows:

- The creation of a Safety Culture Committee subordinate to the CEO
- Fostering organizational attitude towards safety
- Establishment of the Safety Management System
- Enhancement of the Quality Assurance System
- Enforcement of the regulatory guides
- Training

Over the past four years, CMTSP has invested 1.8 million dollars in training, leading 787 classes and more than 62,000 hours of training for more than 3,066 employees.

Finally, Admiral Pagano presented insights on the role of leadership. The leadership must commit to and provide systemic tools to enhance safety. It must provide substantial training opportunities and engender a commitment to safety among employees. Lastly, the leadership must always maintain a proactive attitude towards safety.

### Cultural Issues that Influence Safety and Security Culture – Sonja Haber, Human Performance Analysis Corporation

Dr. Haber gave the final presentation of the workshop, which focused on cultural issues that influence safety and security culture. She challenged the participants to think in a different way about what is meant when talking about culture. What we are really talking about are different types of cultures, she said: culture within organizations, safety culture, security culture, and national culture. We are talking about factors; about things that are influenced by the culture.

She put forth a working definition of organizational culture based on characteristics of the work environment, such as the dalliance, rules, and common understandings that influence employees' perceptions and attitudes. Perception is important because perception drives behavior. We perceive human nature as fundamentally good, and that perception dictates our behavior when meeting someone new. With different, perhaps negative, perceptions of mankind, we might behave less amicably on first acquaintance. Similarly, if employees perceive that an organization places a high priority on safety or security, then when they come to work every day they behave in a way that reflects that perception or belief.

Dr. Edgar Schein, when asked about the term *safety culture*, stated that in a world of culture there is no such thing as a safety culture. There is only a culture that promotes or facilitates safety or security performance. So the culture is the foundation, and the norms, the values, the beliefs, the perceptions, and the attitudes—all of which compose culture—drive behavior towards safety, towards security risk, or towards production. Culture drives the performance of an entity, and the shared norms and values and beliefs create that culture.

Safety and security then parallel each other because they are each aspects of performance that are driven by culture, Dr. Haber said. The similarities are probably much stronger than we think. Turning briefly to Dr. Edgar Schein's model of artifacts, claimed values, and basic assumptions, Dr. Haber postulated that while artifacts and claimed values are easier to observe, what drives the culture and behavior are the basic assumptions.

Like an iceberg, 90 percent of culture is below the surface. That 10 percent above the surface is easy to see, but it is the 90 percent below that will help us understand why the Y-12 security breach happened and why the Davis-Besse reactor vessel-head degradation happened. And that is why many factors influence an understanding or assessment of culture.

Dr. Haber discussed examples of artifacts presented during the workshop in contrast to underlying assumptions. Alan Hanson asking the group if they knew where the safety exit was or about the hotel fire plan was a demonstration of artifacts and claimed values. Dr. Haber asked the audience a series of questions: Do you really know what the person sitting next to you feels and believes about those safety issues? Do you really understand their opinions about it? We all work in the field of safety and security culture. Safety is our top priority; it is a higher priority than production. But the organization's parking lot has no safe walkways. Or people go down staircases without using the handrails while carrying equipment. But safety is our priority. So what do you really know about the people sitting next to you and how they behave towards safety or security issues? You know what they tell you. You know what you have seen, what you have observed, but you do not really know their underlying assumption.

She asked the audience for an artifact around safety or security, and one participant offered dress code, such as personal protective equipment (PPE) as one safety artifact. Another participant mentioned an identity badge as a security artifact, and Dr. Haber agreed that both PPE and security screening for those entering the facility are observable artifacts. She also offered examples of claimed values, such as lost time and reduction of injuries in the safety context, and in the security context, the enjoinment "if you see something, say something." Dr. Haber then asked the audience to provide a basic assumption for safety, and a participant suggested the assumption on how people are judged—whether they are praised for the knowledge, position, safety behavior, or other qualities. Dr. Haber offered another basic assumption about safety: that people always make mistakes. In security, one assumption might be that a facility is impenetrable, that is, breaches do not happen here.

She also asked about monitoring culture. In 1987 or 1988 Tom Murley, of the U.S. Nuclear Regulatory Commission, asked how we can incorporate the influence of organization and management on safety into probabilistic risk assessment (PRA). He said the idea was to quantify the notion now called safety culture and incorporate it into PRA for a quantitative assessment.

Dr. Haber managed a project on this topic at Brookhaven National Laboratory. In collaboration with George Apostolakis as well as colleagues from Penn State, their goal was to develop a methodology for qualifying forces integral to safety performance. This methodology has now been in use for many years, and the team performed the first safety culture assessment at Davis-Besse during the vessel-head outage. They also did the safety culture assessment at Vandellòs Nuclear Power Plant after their service water pipe break; at Äspö Hard Rock Laboratory, after their radioactive particle release; and across the U.S. Department of Energy. Efforts to look at culture are often performance oriented or reactive. Using these methods, Dr. Haber's team is able to examine behaviors, which are the observables of the perceptions and assumptions. Given we act in different ways, based on different assumptions, they can look at the behavioral output of an individual or an organization.

Looking at safety culture is attempting to understand how that culture drives safety behaviors. Similarly, looking at security culture is attempting to understand how that culture drives security awareness or security behaviors. And while behavior is the visible outcome of culture, culture change will only come about getting at the basic assumptions. You can change the artifacts, the claimed values, and even some of the behaviors quickly. But culture change requires sustainment over a long period of time. Culture change at Davis-Besse took 3 to 5 years, not a single 4-hour training session, because real culture change requires a change in the basic assumptions, not only behaviors, artifacts, or claimed values.

Finally, Dr. Haber discussed key attributes of culture that influence both safety and security. She mentioned the complexity of the system—of the roles of all the people and all the stakeholders involved. We need to understand the interdependencies and the codependencies of all the players contributing to a culture and driving that behavior. It is a mistake to think we can isolate one particular entity and one particular unit in a mishap as we saw at Fukushima, Dr. Haber said.

When visiting a facility, Dr. Haber asks for a tour of the facility led by a senior manager in order to observe the manager's behavior concerning protocol. Do they tell her what they see before she tells them? Do they waive their personal protection equipment? Do they follow the procedures and protocols of the facility? Sometimes they do not. Senior managers and leaders really need to model those behaviors and to show everybody, not just their organization, but to the world, that these behaviors are their priority and they mean it. Communication is key. Senior managers need to ensure they are heard, receive feedback, and close the communication loop in order to create change in basic assumptions and even behaviors. And finally, trust is very important in creating the right environment where people can speak up when they should to ensure safe job performance or to help security awareness.

# Concluding Remarks

Dr. Bari presented certificates to the speakers and briefly discussed the formulation of next steps for cooperation between the United States and Brazil. He noted that some of the ideas developed during the workshop will be applicable more broadly to other nations as well. Two examples of areas for progress are in how leadership affects safety culture and how indicators are important to safety and security culture. When this diverse group has further digested the tremendous and useful work done here, there will likely be additional areas for future collaboration and cooperation, he said.

Dr. Barroso affirmed that his high expectations were clearly exceeded by the quality of presentations, the exchanges, the social gathering, and the workshop as a whole. He reflected on lessons learned (or assumed as truths) from the workshop. It became very clear that we should not question the definitions of safety culture or security culture or culture in general. There are many definitions and they are diverse. He called for a more innovative paradigm for organizational culture or its manifestations concerning safety and security culture. An organization has a living culture, Dr. Barroso said, and we should not weaken it, but instead explore it.

During the workshop the word *culture* was often preceded by many different adjectives: good culture, strong culture, robust culture, resilient culture, fair culture. These adjectives connote evaluation. Paraphrasing the Bible, Dr. Barroso reminded the group that a good tree is known by its fruits. And so a good or desirable culture is known by its manifestations.

He stated that the words used, such as traits, attributes, and characteristics are not inherently important. But for assessments, especially as related to structure, integration, modeling, and factor analysis, employing these provides a common denominator.

He emphasized the importance of action, even in the absence of robust assessment. There are many steps to be taken to affect culture in a good way—leadership, role models, behavior remodeling, developing good policy that promotes reporting, and the schedule of reporting, among others. There are big steps and new social marks needed. It is one thing to have a rule, but a social norm that has permeated and has been internalized is much stronger. We cannot directly manage knowledge or culture, but we can instill culture indirectly by changing social norms.

Dr. Bari and Dr. Barroso thanked the participants and stated in closing that this self-selected group came together because of a belief in the value of this enterprise. The real charge ahead is to reach the larger community and carry the message forward.

# Appendix A

# Brazil-U.S. Workshop on Strengthening the Culture of Nuclear Safety and Security

Instituto de Pesquisas Energéticas e Nucleares (IPEN)
São Paulo, Brazil

August 25–26, 2014

**AGENDA**

Workshop coordinators: Antonio Barroso, IPEN Nuclear and Energy Research Institute, and Robert Bari, U.S. Brookhaven National Laboratory (BNL)

**August 25, 2014**

Introductory Remarks by José Carlos Bressiani, IPEN, and Robert Bari, U.S. BNL

**Session I:** ***The Relationship between Safety Culture and Security Culture***
Moderator: Ivan Salati, CNEN – Brazilian Nuclear Energy Commission; rapporteur: Luiz Fernando Bloomfield Torres, CNEN

- Why a safety culture matters (attributes and issues) – Michael Corradini, University of Wisconsin
- Nuclear security culture – William Tobey, Harvard University
- Safety and security culture from a regulatory perspective – Claudio Almeida, CNEN

**Panel Discussion**

**Session II:** ***Safety Analysis, Vulnerability Assessment, and the Design of Integrated Solutions***
Moderator: James Ellis, Hoover Institution, Stanford University; rapporteur: Benedito D. Baptista F., IPEN

- The 2002 Davis Besse event and safety culture policy at the U.S. nuclear regulatory commission – Stephanie Morrow, U.S. NRC
- New socio-technical approaches for safety and vulnerability assessment - EMBRAER experience – Ricardo Santos, EMBRAER
- Threats involving nuclear/radioactive materials: Nuclear Forensic Capability within a National Nuclear Security Infrastructure – Jorge E. Sarkis, IPEN

**Panel Discussion**

**Session III:** ***Performance Assessment and Improvement of Safety and Security Culture*** Moderator: Marcos A. Viana Tavares, EMBRAER; rapporteur: Micah Lowenthal, NAS

- Experiences in nuclear safety and security culture – Michael O'Brien, U.S. Lawrence Livermore National Laboratory (LLNL)
- Assessment instruments for safety culture: what are we measuring? – Antonio Barroso, IPEN
- The synergy between safety culture and operational excellence – Ivan de Souza Azevedo, Eletrobras Eletronuclear

Recap of day one with session moderators and rapporteurs

**August 26, 2014**

**Session IV:** ***Training and Education for Safety and Security Culture – Training for Culture as Distinct from Procedure*** Moderator: Michael O'Brien, LLNL; rapporteur: Mario O. Menezes, IPEN

- Teaching safety and security culture – Alan Hanson, Massachusetts Institute of Technology
- Metrics for safety and security culture – Robert Bari, Brookhaven National Laboratory
- Beyond procedures: safety and security culture as a preparation for the unexpected - Filomena Ricco, DCTA/UNIFA – Air Force University

**Panel Discussion**

**Session V:** ***Lessons Learned Processes and Implementing Change*** Moderator: Leonam Guimarães, Eletrobras Eletronuclear; rapporteur: Benjamin Rusek, NAS

- Lessons learned from vulnerability assessments for safety and security culture undertaken after Fukushima (and presentation on NAS Fukushima report) – Michael Corradini, University of Wisconsin.
- Fukushima Response Plan by Eletronuclear: an overview – Paulo Cesar da Costa Carneiro, Eletrobras Eletronuclear
- The 2012 perimeter security breach at the Y-12 national security complex – Donald Alston, Alston Strategic Consulting

**Panel Discussion**

**Session VI:** ***Influence of Leadership and Hierarchy on Safety and Security Culture.*** Moderator: Donald Alston, Alston Strategic Consulting; rapporteur: Benjamin Rusek, NAS

- Nuclear leadership – James Ellis, Hoover Institution, Stanford University
- Insights on the role played by leadership and hierarchy in organizational culture – Luciano Pagano Jr., CTMSP – Brazilian Navy Technology Center In São Paulo
- Cultural issues that influence safety and security culture, Sonja Haber, Human Performance Analysis Corporation

Recap of day two with session moderators and rapporteurs and discussion of next steps

Closing Remarks from Antonio C. O. Barroso, IPEN, and Robert Bari, BNL, and other representatives

# Appendix B

# Biographical Sketches of Workshop Speakers

## SESSION 1

**Moderator – Dr. Ivan Pedro Salati**
Director for Radiation Protection and Nuclear Safety, and Member of the Deliberative Commission of the Comissão Nacional de Energia Nuclear (CNEN); Member of the International Atomic Energy Agency (IAEA) Commission of Safety Standards (CSS). Dr. Salati received an undergraduate degree from the Physics Institute of the Universidade de São Paulo; MBA in engineering economics from Universidade Federal do Rio de Janeiro; an MBA in business administration from the Pontifical Catholic University of Rio de Janeiro; an MSc in nuclear energy from the Instituto Militar de Engenharia; and a DSc in nuclear engineering from the Instituto Alberto Luiz Coimbra de Pós-Graduação e Pesquisa de Engenharia (COPPE/UFRJ).

### Panelists

**Dr. Michael L. Corradini**
Wisconsin Distinguished Professor of Nuclear Engineering and Engineering Physics at the University of Wisconsin-Madison. Dr. Corradini is a mechanical and nuclear engineer whose research interests are centered primarily in thermal hydraulics and multiphase flow, with emphasis on reactor operation, reactor safety, reprocessing and recycle, and risk assessment. In 2006, he was elected to the National Council on Radiation Protection and has served as an appointed member of the U.S. Nuclear Regulatory Commission's Advisory Committee on Reactor Safeguards. He was elected as the president of the American Nuclear Society for 2012 to 2013. He also serves on the National Research Council's Nuclear and Radiation Studies Board and the Committee on Lessons Learned from the Fukushima Nuclear Accident.

**Dr. Claudio Almeida**
Advisor to the Director of Radiation Protection and Nuclear Safety, CNEN. Dr. Almeida spent 14 years in the Department of Nuclear Safety of the IAEA in Vienna, working first as a computer code specialist and later joining the Project on Safety of VVER and RBMK nuclear power plants. He also conducted several technical cooperation missions in Mexico, Republic of Korea, Pakistan, India, Iran, China, and Cuba. He has an electrical and electronic engineering degree from the Federal University of Rio Grande do Sul. He earned a PhD in nuclear engineering from the Massachusetts Institute of Technology (MIT) in 1975.

**Mr. William Tobey**
Senior Fellow, Belfer Center for Science and International Affairs and former Deputy Administrator for Defense Nuclear Nonproliferation, National Nuclear Security Administration. Mr. Tobey managed the U.S. government's largest program to prevent nuclear proliferation and terrorism by detecting, securing, and disposing of dangerous nuclear material. Mr. Tobey also served on the National Security Council Staff in three administrations, in defense policy, arms control, and counter-proliferation positions. He has participated in international negotiations ranging from the START talks with the Soviet Union to the Six-Party Talks with North Korea. He also has extensive experience in investment banking and venture capital.

## SESSION 2

**Moderator – Admiral James O. Ellis Jr**
Annenberg Distinguished Visiting Fellow and Member, Arctic Security Initiative, Stanford University. Admiral Ellis retired as president and chief executive officer of the Institute of Nuclear Power Operations in 2012. In 2004, he completed a distinguished 39-year navy career as commander of the United States Strategic Command. He holds a master's degree in aerospace engineering from the Georgia Institute of Technology and, in 2005, was inducted into the school's Engineering Hall of Fame. He completed United States Navy Nuclear Power Training and was qualified in the operation and maintenance of naval nuclear propulsion plants. In 2009, he completed 3 years of service as a presidential appointee on the President's Intelligence Advisory Board and, in 2006, was a member of the Military Advisory Panel to the Iraq Study Group. In 2013, Admiral Ellis was elected to the U.S. National Academy of Engineering.

**Rapporteur – Dr. Francisco Luiz Lemos**
Researcher, Instituto de Pesquisas Energéticas e Nucleares (IPEN). Since 2011, Dr. Lemos has been a member of the Safety Analysis Group of Centro de Engenharia Nuclear (CEN) doing work with fuzzy logic and the STAMP methodology. In 2012 he was a research assistant for Professor Nancy Leveson in the

Aeronautic Engineering Department of MIT, working on a U.S. Nuclear Regulatory Commission-financed project to study the U.S. Evolutionary Power Reactor. He has previously worked at the Centro de Desenvolvimento da Tecnologia Nuclear (CDTN) in Safety Analysis of Nuclear Installations. He graduated in mechanical engineering from the Pontificia Universidade Católica de Minas Gerais (PUC/MG) and has a DSc in environmental geochemistry from the Federal University of Ouro Preto.

## Panelists

**Mr. Ricardo Moraes dos Santos**
Product Development Engineer, Embraer (Empresa Brasileira de Aeronáutica S.A.). Mr. Santos has taken professional specialization training in safety assessment from Kansas University (U.S.) and systems engineering from MIT. He graduated in computer engineering at the University of Vale do Paraíba (UNIVAP) and has completed a latu sensu post-graduation program in safety, continuing airworthiness at the Instituto Tecnológico de Aeronáutica (ITA).

**Dr. Stephanie Morrow**
Human Factors Analyst, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission. Dr. Morrow has been with the U.S. NRC since February 2011 and serves as a project manager for various safety culture and human performance research activities. She has conducted studies of safety culture and its relationship to employee behaviors and organizational performance, developed surveys for use in the assessment of safety culture, and served as a safety culture assessor during onsite inspections of nuclear power plants. She has a PhD and master's degree in industrial and organizational psychology from the University of Connecticut. She has also worked as an engineering psychologist at the Department of Transportation's Volpe National Transportation Systems Research Center.

**Dr. Jorge Eduardo Sarkis**
Head of Group, Chemical and Isotopic Characterization, and Professor of Graduate Studies in Nuclear Technology, IPEN, since 1993. Dr. Sarkis studied chemistry at the Federal Fluminense University with postgraduate courses in nuclear engineering from the Instituto Militar de Engenharia, Rio de Janeiro. He has conducted research in thermionic mass spectrometry (TIMS) applied to nuclear chemistry at Kernforschungszentrum Karlsruhe, Germany. He did postdoctoral research in mass spectrometry with inductively coupled plasma source (ICPMS) at the National Environmental Research Council, University of London, England and in nuclear forensics at Los Alamos National Laboratory, New Mexico, United States. Since 2007, he has worked with the IAEA on nuclear forensics. He is a member of the Advisory Council of the Brazilian Society of Forensic Sciences.

## SESSION 3

**Moderator – Mr. Marcos Antônio Viana Tavares**
Systems Integration/Software Manager, Chief Engineer Office, Embraer. Mr. Tavares graduated in electrical engineering at the Universidade Federal de Uberlândia (UFU) and earned an MSc at ITA. He has worked for Embraer for 28 years in the following areas: stall protection system, automatic flight controls, flight controls (fly-by-wire) as product development engineer; and in research and development as fly-by-wire/embedded computational systems project technical leader.

### Panelists

**Mr. Ivan de Souza Azevedo**
Safety Coordination, Technical Exchange Missions, IAEA. Mr. Azevedo is a chemist with a master's degree in analytic physical chemistry from the Chemistry Institute of UFRJ and an MBA in business management from the Polytechnic School of UFRJ. Working at Eletronuclear for 18 years, he was responsible for the radiochemical and chemical control of Angra 1 and participated in various safety reviews of nuclear power plants, including some in England and Russia. In the past 4 years, he has been working in safety coordination, and in 2011 was invited by CNEN to attend the Fifth Meeting of the International Convention on Nuclear Safety at the IAEA. Currently, he works in safety culture for technical exchange missions with the IAEA, among other projects.

**Dr. Antonio C. O. Barroso**
Professor and Senior Researcher, IPEN. Dr. Barroso teaches and conducts research in nuclear knowledge management, safety culture and Web information mining of nuclear-related subjects. Previously, he served as research and development director and commissioner of CNEN and also as a Brazilian alternate governor at the Board of the IAEA. From 2001 to 2012 he was a member of the Standing Advisory Group on Nuclear Applications (SAGNA) for the director general of IAEA. He has also been a member of the Halden Reactor Project Board of Directors and of the Advisory Council for Industrias Nucleares do Brasil (INB) and Nuclebrás Equipamentos Pesados (NUCLEP). He graduated in mechanical engineering from the Universidade Federal do Rio de Janeiro (UFRJ) and has a PhD in nuclear engineering from MIT.

**Mr. Michael O'Brien**
Associate Program Leader for the Global Security Directorate, Lawrence Livermore National Laboratory. Mr. O'Brien has more than 35 years of domestic and international experience in the fields of vulnerability assessment, including insider analysis, physical protection systems, protective force, and transportation security. He has served on Department of Army, Department of Navy, and De-

partment of Energy working groups for the formulation of physical protection policy guidance and regulations and has provided similar support under U.S. government bilateral work with the European Commission, IAEA, Russian Federation, India, and China. Mr. O'Brien graduated from the University of Maryland.

## SESSION 4

**Moderator** – **Mr. Michael O'Brien** (see Session 3)

### Panelists

**Dr. Robert A. Bari**
Senior Physicist and Senior Advisor, Brookhaven National Laboratory. Dr. Bari has worked on projects and issues regarding nuclear safety and nonproliferation technologies, nuclear waste management, and development of advanced nuclear reactors and has directed numerous studies of advanced nuclear energy concepts. He is currently co-chair of the working group that has developed a comprehensive methodology for evaluation of proliferation resistance and physical protection of all new nuclear energy concepts of Generation IV International Forum. He was awarded the Theo J. "Tommy" Thompson Award in 2003 by the American Nuclear Society. In 2004, he received the Brookhaven National Laboratory Award for Outstanding Achievement in Science and Technology. He holds a BS in physics from Rutgers University and a PhD in physics from Brandeis University. Dr. Bari serves as a member of the U.S. National Research Council Committee on Lessons Learned from the Fukushima Nuclear Accident.

**Dr. Alan S. Hanson**
Executive Director, International Nuclear Leadership Educations Program, MIT. Previously, Dr. Hanson served as executive vice president of technologies and used fuel management at AREVA NC Inc. Dr. Hanson also continues his responsibilities as chief executive officer of Transnuclear, Inc., an AREVA company. He began his career in 1975 with the Nuclear Services Division of Yankee Atomic Electric Company. In 1979, he joined the IAEA, where he served first as coordinator of the International Spent Fuel Management Program and later as policy analyst in the areas of safeguards and nonproliferation policies. He is a member of the American Nuclear Society and the American Society of Mechanical Engineers. He holds a BS in mechanical engineering from Stanford University and a PhD in nuclear engineering from MIT.

**Dr. Filomena Ricco**
Professor of Aerospace Sciences, Air Force University (UNIFA). Dr. Ricco is also an advisor to the Air Force Department of Science and Technology and a

collaborating researcher for the Center for Environmental Research and Studies at the University of Campinas (UNICAMP). Her expertise is focused on management of science and technology, more specifically on methodology and management tools, knowledge management, strategic management, and organizational behavior. She holds a BS in psychology from the University of Taubaté and an MSc and DSc in administration from Faculdade de Economia, Administração e Contabilidade (FEA) of the University of São Paulo (USP).

## SESSION 5

**Moderator** – **Dr. Leonam dos Santos Guimarães**
Director of Planning and Environmental Management, Eletrobras Eletronuclear. Formerly, Dr. Guimarães was coordinator of the Brazilian Navy Nuclear Propulsion Program, professor of management at the Armando Álvares Penteado Foundation at the Escola Politécnica da Universidade de São Paulo (EP-USP), executive assistant to the chief executive officer of Eletronuclear, and technical and commercial director of Amazonia Azul Tecnologias de Defesa S.A. (AMAZUL). He has 30 years of experience in research, development, engineering, procurement, and construction of naval and nuclear systems. He is member of IAEA's Standing Advisory Group on Nuclear Energy (SAGNE) and author of several books and papers on engineering, management, and nuclear policy. He holds a BSc in naval sciences from the Brazilian Naval Academy, an MSc in nuclear engineering from the University of Paris VI and a PhD in ocean engineering on naval nuclear propulsion from the EP-USP.

### Panelists

**Dr. Michael L. Corradini** (see Session 1)

**Mr. Paulo César da Costa Carneiro**
Technical Advisor, Technical Directorate, Eletrobras Eletronuclear. Mr. Carneiro is responsible for planning and management coordination for plant operation and new projects. He is also the coordinator of the Eletronuclear Fukushima Response Committee. Previously, he worked in the safety-related instrumentation and control design for Angra 2 nuclear power plant (NPP) at Siemens headquarters in Germany, then headed the NPP's Technical Support and Commissioning Department of FURNAS Centrais Elétricas. He was also the deputy superintendent during Angra 2 construction and head of the Planning and Budget Department at NUCLEN Engineering. He has a BS in electronic engineering from UFRJ, specialization courses in nuclear engineering and project management from COPPE/UFRJ, and an MBA in Business Finance from Instituto Brasileiro de Mercado de Capitais.

**Major General Donald Alston**
Chief Executive Officer, Alston Strategic Consulting. General Alston was commander of the 20th Air Force, Air Force Global Strike Command, and commander of Task Force 214, U.S. Strategic Command, Francis E. Warren Air Force Base, Wyoming. He was responsible for the nation's intercontinental ballistic missile force, organized into three operational wings with more than 9,600 people. He has worked as a liaison officer to the U.S. House of Representatives, and also performed duties as the executive assistant to the secretary of the air force in Washington, D.C. General Alston also served as the deputy chief of staff for strategic communications and the spokesperson for Multi-National Force - Iraq in Baghdad. In 2012, General Alston retired from military service. He has a BS from the U.S. Air Force Academy in Colorado and an MA in business administration from Golden Gate University in California.

## SESSION 6

**Moderator** – **Major General Donald Alston** (see Session 5)

### Panelists

**Admiral James O. Ellis Jr.** (see Session 2)

**Mr. Luciano Pagano Jr.**
Rear Admiral Luciano Pagano Jr. is the superintendent of the nuclear program of the Marinha do Brasil (the Brazilian Navy). He graduated in Chemical Engineering from the Instituto Militar de Engenharia and graduated with a degree in Mathematics from UFRJ. He earned a master's degree in Nuclear Engineering from Pennsylvania State University and a PhD in Chemical Engineering from the State University of Campinas.

**Dr. Sonja Haber**
Consultant. Dr. Haber has been conducting work in human performance analysis for more than 30 years. She has been involved in the evaluation and intervention of human performance strategies in various applications. For the last 20 years, Dr. Haber's work has focused on improving human performance within organizations that must operate with a high degree of reliability. She has conducted fieldwork for various international agencies in efforts to enhance human performance, including cross-cultural analysis of organizational issues in safety culture and management and supervisory skills. Most recently, Dr. Haber has conducted safety culture evaluations in various organizations, including organizational interventions, leadership and management training, enhanced communication and observational skills training, and working towards the development of performance measures for organization and management processes.