5. Knowledge Management: The Blind Men and the Elephant of the Nuclear Era

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Dr. Gail H. Marcus is presently an independent consultant on nuclear power technology and policy. She recently completed a three-year term as Deputy Director-General of the OECD Nuclear Energy Agency (NEA) in Paris. In this position, she was responsible for the program of work and budget for the agency. From 1999 through 2004, Dr. Marcus served as Principal Deputy Director of the Office of Nuclear Energy, Science and Technology. There she provided technical leadership for DOE's nuclear energy programs and facilities, including the development of next-generation nuclear power systems. Other responsibilities included production and distribution of isotopes for medical treatment, diagnosis and research, and oversight of DOE test and research reactors and related facilities and activities.
From 1998-1999, Dr. Marcus spent a year in Japan as Visiting Professor in the Research Laboratory for Nuclear Reactors, Tokyo Institute of Technology. She conducted research on comparative nuclear regulatory policy in Japan and the United States.
Previously, Dr. Marcus had been in the US Nuclear Regulatory Commission (NRC). She served in a variety of positions including Deputy Executive Director of the Advisory Committee on Reactor Safeguards/Advisory Committee on Nuclear Waste; Director of Project Directorate III-3, providing regulatory oversight of seven nuclear power plants in the Midwest; and Director of the Advanced Reactors Project Directorate, where she was responsible for technical reviews of advanced reactor designs.
She also served as technical assistant to Commissioner Kenneth Rogers at the NRC for over four years, providing advice and recommendations on a broad range of technical and policy issues of interest to the Commission. From this position she was detailed for five months to Japan's Ministry of International Trade and Industry, where she was NRC's first assignee to Japan, studying Japan's licensing of the Advanced Boiling Water Reactor.
Prior to her service at NRC, Dr. Marcus was Assistant Chief of the Science Policy Research Division at the Congressional Research Service (1980-1985). In this position, she was responsible for policy analysis in support of Congress covering all fields of science and technology, and played a lead role in policy analysis and development for energy, nuclear power, and risk assessment and management.

Organization:
From 2001-2002, Dr. Marcus served as President of the American Nuclear Society (ANS), an 11,000 member professional society. She is a Fellow of the ANS and of the American Association for the Advancement of Science (AAAS). She is a former member of the National Research Council Committee on the Future Needs of Nuclear Engineering Education, and served three terms on the MIT Corporation Visiting Committee for the Nuclear Engineering Department. She is just completing a term as the elected Chair of the Engineering Section of AAAS.

Publication:
Dr. Marcus has authored numerous technical papers and publications. Her research interests include nuclear regulatory policy, energy technology and policy, risk assessment and management, international nuclear policy, and advanced nuclear technologies.

Education:
Dr. Marcus has an S.B. and S.M. in Physics, and an Sc.D. in Nuclear Engineering from MIT. She is the first woman to earn a doctorate in nuclear engineering in the United States.

Last October, during a visit to Japan, I had the pleasure of meeting with some staff members of JANUS. As part of my discussion with them, I noted that I have thought of many, many possible topics for essays, but I only had a few more opportunities scheduled to write for "Dr. Marcus' Room." I described my ideas and asked their views on which of the topics they most wanted to hear about. The topic of *Knowledge Management* was high on their list, so I have chosen it as my topic this month.

With all the other possible topics I proposed, it is interesting to speculate about why a group of nuclear professionals was so interested in hearing about knowledge management. However, before we can do that, we need to answer the question: "What is knowledge management?"

The Blind Men and the Elephant

During the course of the last 10 years or so of my career, the topic of knowledge management has become very important to the nuclear community. However, as I have communicated with various elements of the nuclear community, I have had the sense that everyone I spoke with had a different idea of what knowledge management was. As a result, in previous writings and speeches, I have sometimes drawn an analogy between the field of knowledge management and the ancient Indian parable about the blind men and the elephant.

In this story, a group of sightless men approach an elephant and touch it in different places. Since the only sensory information they receive is from their touch, the image they receive of the elephant depends very much on where they touch the elephant. "Aha," says the first man, who is touching the massive, leathery side of the elephant, "It is clear that the elephant is like a wall." "On the contrary," says a second man, who has grabbed a tusk, "The elephant is very like a spear." "No," says yet another man, who is holding the tail, "The elephant resembles a rope." Likewise, the man who touches the leg thinks the elephant must look like the trunk of a tree, the one who feels the air currents caused by the flapping ear thinks the elephant resembles a fan, and the one who grabs the undulating trunk of the elephant fancies that it looks like a snake.

(It should be noted that there are several versions of this story, and sometimes different parts of the elephant are named and/or the men draw different conclusions. I have drawn my examples from a version of the story written in verse by John Godfrey Saxe (1816-1887), a poem I remember hearing as a child. This poem can be found in its entirety at: http://www.noogenesis.com/pineapple/blind_men_elephant.html;
other versions of the story, as well as more information on its origins, are summarized on a number of websites,
for example: http://en.wikipedia.org/wiki/Blind_Men_and_an_Elephant)

What is Knowledge Management?

Let me start the discussion by identifying the two main themes I have heard in my discussions of knowledge management with various segments of the nuclear community.

Data Preservation: I have spent a fair amount of my career working on research programs, so my first encounter with the idea of knowledge management came from the research community. There is a lot of concern that much of the research data collected in the early days of nuclear power development has not been properly archived and preserved.

There are a number of reasons for this. Perhaps the primary reason is the waxing and waning fortunes of the nuclear power industry. In the heady early days of the nuclear power development program, a variety of research initiatives were started to explore different types of designs. As nuclear power fell out of favor in many countries, research programs were stopped, sometimes rather abruptly. This left neither the time, nor the funding, nor the interest to archive the material properly for possible further use.

Probably much data has already been irretrievably lost—thrown away, preserved on magnetic tapes or other media that are crumbling with age, or stored in unlabeled boxes. Furthermore, the people who did the research and who might be able to fill some of the gaps based on their recollections of the experiments are getting old. Most are retired, and some, unfortunately, have died or have reached a point where their memories are no longer reliable. If we need to tap whatever remains of what they can recall, it must be done very soon.

Finally, many of the facilities in which the research was conducted have been permanently shut down and dismantled. Therefore, today, as interest in nuclear power is renewed, the facilities are no longer available to reproduce the early results.

I have heard different terminology used for this aspect of knowledge management: *knowledge preservation, data preservation, knowledge generation, data collection and analysis*, and perhaps others. What they have in common is that they deal with the generation of new information, the analysis of that information, and the maintenance of the information in a useful form.

I should note that this problem is most severe in countries like the United States, which had an extended gap in its nuclear program. Most likely, countries like Japan, which had less of a gap, have a more limited problem. Nevertheless, most countries, including Japan, experienced some redirections in their research efforts over the years, so share some elements of this problem.

Knowledge transfer and retention : Outside the research community, the biggest concern is the increasingly obvious need to pass the knowledge of the older workers on to a new generation. As in the research community, the age of the early workforce is at the root of the concern. Many of the workers who built the plants and operated them for years have already retired, and many more soon will. Even in the world we in the nuclear community know, which is replete with written procedures and explicit regulations for seemingly just about everything, it turns out that there is still a significant level of activity that is based on individual experience and is undocumented.

This kind of knowledge, usually called *tacit knowledge* , applies to all parts of the nuclear enterprise—to research activities, to the operations of nuclear power plants and other nuclear facilities, to the work of architects and engineers, to the construction trades, and to the oversight activities of inspectors and regulators.

Once again, the problem is most severe in countries where there have been serious cutbacks in the nuclear industry. In those cases, the entire supply chain of human talent has been disrupted. Academic programs in the nuclear field have been halted, research and training reactors have been closed, and young people have not been attracted into the industry. Where the nuclear power program has not been cut, the problem is much less severe.

Why is the Nuclear Community Concerned?

It is legitimate to ask why there is such a special interest in knowledge management in the nuclear community today. After all, based on the definitions above, knowledge management is something that should always have been a normal, ongoing part of all the activities in the nuclear field. Research results should always be analyzed, papers should routinely be published reporting the results of the research, and important materials should be documented and saved in a retrievable fashion at the end of every research project. That is a normal part of research. New employees should always be mentored, taught, and given on-the-job training to pass on the knowledge of the experienced workers. That is a normal part of the operation of any competent, forward-thinking company or organization.

Furthermore, all of this is common to every other discipline as well. Those who build and operate aircraft, buildings, automobiles, ships, factories or anything else one can imagine all need to assure that research results are accessible and that operational knowledge is transferred from one generation to the next.

What is different about the nuclear community? And why is it that we are so concerned about knowledge management today? I have already mentioned what I consider the essential difference. It is the fact that, in a number of places around the world, the nuclear community has suffered a severe and extended cutback. During this period, research was stopped. Funding was often withdrawn abruptly, leaving no chance for researchers to take the final steps in any research project—analyzing the data and producing and publishing papers to share the results. Job opportunities dried up, leaving the operation of existing facilities in the hands of an aging and dwindling workforce. The normal flow of "new blood" into the industry did not occur.

If the nuclear industry were to continue to decline, the problem would still not be severe. True, as long as nuclear power plants continue to operate, and even as long as they are being decommissioned, some replenishment of the workforce is needed. However, the needs are more limited. The existing fleet of plants would slowly shut down, and the need for new workers would continue to decline. Without new construction, the need for skilled workers in those fields would be limited. There would be limited demand for the moldering files of research data.

What has made the problem of knowledge management a major issue for the nuclear community today is the emerging revival of the nuclear industry. With the expected increase in the number of new nuclear power plants, the need for new workers is suddenly growing rapidly. The nuclear industry requires people with specialized training and skills, so the pool of available people is limited. Skilled construction workers are needed to build the new plants, trained plant operators and maintenance technicians are needed to run them. The simultaneous revival of research on advanced reactor technologies raises real questions about how to take advantage of research already done.

Of course, as noted, where nuclear programs have not experienced severe cutbacks, the problem is less severe. However, we live in a global economy, and the growing interest in nuclear power around the world will likely have some ramifications, even on those countries that have maintained strong nuclear programs in the last several decades. In countries like the United States, foreign students make up a significant fraction of the student population, particularly at graduate levels in technological fields. Historically, a significant percentage of these students have stayed in the US following graduation and have joined the US workforce. As opportunities increase in their home countries, a smaller fraction of these students may stay in the US. Further, some of the countries starting nuclear programs are able to offer high salaries and attractive opportunities, and will be able to attract workers from around the globe.

Therefore, it is important for the entire nuclear community to think about knowledge management.

What Can We Do?

Increase nuclear engineering education and training programs：It is very clear that the pipeline of educated and trained workers needs to expand. That is already happening in many places. In Asia as well, several new university initiatives in Japan and Korea have been announced recently. Japanese universities starting new nuclear programs include Musashi Institute of Technology (in partnership with Waseda University) and the University of Fukui. In addition, Fukui University of Technology and Tokyo University are bringing back nuclear power specializations. The Korea Institute of Nuclear Safety (KINS) and the Korea Advanced Institute of Science and Technology (KAIST) are offering a joint master's degree program, particularly focused at members of the Asian Nuclear Safety Network.

In the United States, several new academic programs in nuclear engineering and technology have begun in recent years. Early government funding (initially from the Department of Energy, but now from the Nuclear Regulatory Commission) helped these programs get started. This support encompassed both the human element (scholarships, fellowships, grants to professors) and the infrastructure (reactors and other facilities). In addition to government support, local nuclear industries in the United States have supported universities in various ways. They have provided scholarships, served as adjunct professors on local campuses, supplied equipment and facilities, and participated in other partnerships with universities.

However, more support will be needed, from both government and industry, for the nuclear renaissance to continue. The exact mix of government and industry support, and the nature of the support, will vary, depending on the country, the proximity of campuses to major nuclear companies, and the specific needs of the schools.

I have spoken mostly of universities, but I note that the need for more training programs for skilled workers for the construction trades should not be neglected. This means that support is also needed for community colleges and for non-academic institutions that train such workers.

Enhance On-the-job Training：Most large companies already have established programs for training new workers. These may involve combinations of in-house classes, shadowing experienced workers, formal and informal mentoring programs, rotational assignments and other traditional methods of conveying to new workers the specialized knowledge needed for their jobs. For companies that have begun to expand their operations, an increase in these programs will be necessary. The cost of that increase must be factored into the planned expansion. In some cases, provision must be made for retired workers to continue to consult for their former employers to help train their replacements.

Some savings—as well as likely increases in effectiveness—can be achieved by making maximum use of technologies such as computerized self-study modules, closed-circuit TV classes, and on-line data bases of briefing videos and visual materials. These can minimize needs for travel, allow the most effective trainers to reach employees at multiple locations, and allow the employees maximum flexibility in taking their training. Some of these capabilities have significant start-up costs, and where feasible, companies should consider sharing resources. Some training, of course, will always be particular to a company or facility, and there may be other reasons that companies can't share everything, but much can be shared. There are already organizations that today facilitate different types of sharing among companies—owner's groups, trade groups, etc. Institutions like the Institute for Nuclear Power Operations (INPO) in the US currently promote industry-wide training efforts. Such organizations can provide a pooled resource for the development of computer modules and other training aides that may be prohibitive for single companies, particularly smaller ones, to develop individually.

Research Preservation : In my mind, the most difficult area to address is that of the use of the old research data. Although a lot of money was spent on this research, and although the possibility of retrieving anything will continue to diminish as the tapes further age and the original researchers become unavailable, even today, the difficulty of recovering much of value from the past work is problematical. There are a variety of potential difficulties: incomplete data and experimental information, lower levels of precision or fewer data points in some early experiments than would be acceptable today, and in some cases, research on materials or processes that are no longer of interest.

This is not to say that there is no value to the old research, and it is certainly not to say that no efforts should be made to preserve any of it. It is simply a call for reason to prevail in selecting what, and how much, to preserve. When I was first confronted by the issue of the need for the preservation of old research results, I was working in the Department of Energy. Two things quickly became clear as I talked to people who wanted my office to fund data preservation efforts: 1) no one could articulate a clear plan for deciding what was worth preserving, and 2) preserving everything would cost a lot of money, and would, in fact, take all our available funds, leaving no money for new research.

What is needed is a structured, disciplined approach for deciding what old research to preserve. Factors that should be considered include: Did the research cover materials and conditions (such as temperatures and pressures) of interest today? Research that is relevant to facilities that are still operating are obviously the most important, but research results may also be useful in cases where facilities are being decommissioned. Research on "new" technologies that we are looking at today may be a third priority, but advances in materials and other developments may make old work less relevant.

Are facilities available to reproduce this work? Although research may be expensive to conduct, the building of new facilities is probably the most costly and time-consuming obstacle to conducting new research. Therefore, the preservation of research data in areas in which it is impossible to conduct research today should have higher priority than areas in which the results can be repeated. The assessment of research capability today should be undertaken on a global scale, with the expectation that research facilities and experiments can be shared at a considerable savings to all parties.

Are the available materials sufficiently complete and of sufficient quality to enable them to be used? The real problem with old data is that it is often incomplete. Data collected by different researchers were stored in different places, so some may be lost, leaving gaps in the data base. Experimental setups and parameters recorded in laboratory notebooks don't end up stored with the data printouts, so critical information about the data may be missing. Badly degraded storage media may make full retrieval impossible or prohibitively expensive. As noted above, the equipment that exists today may mean that the precision and resolution of old data would render it of limited value.

My guess is that, if the tests above are rigorously applied, we will end up with a relatively small and manageable set of old research data that is likely to be worth our effort to process. If this material is not immediately needed or can't be processed immediately, efforts should be made to assure that it is stored so that it doesn't decay further, so that all relevant materials stay together, and so that the documentation on, and labeling of, the files is clear for future researchers.

Finally, we should again take advantage of technology wherever we can. It should be possible to digitize a lot of the research files to reduce the need for physical storage, assure preservation, and allow the sharing of the data among interested researchers. The major caution here is that, as a storage mechanism, digitized data is not necessarily permanent either. Some of the media (CDs, for example) may be subject to age-related or environmentally-caused decay, and advances over the years in technologies and in programming have already rendered early electronic files obsolete. Provision will need to be made to assure that digitized files remain usable. Such efforts carry some cost, both initially and on an on-going basis, making it imperative that the selection of such material be based on a rigorous process.

Conclusion

The changing fortunes of the nuclear industry in many countries over the last several decades, and the increasing global interest in nuclear power today have created some problems for the entire industry in the preservation and dissemination of the knowledge essential for all nuclear activities. The nuclear industry is already addressing the needs with expanded educational and training programs, and by other means. Further efforts in these areas will be needed to help facilitate the nuclear renaissance in the most efficient and effective way.

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As always, I welcome your thoughts on this topic. I can be reached at:

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