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THE ART AND SCIENCE OF INNOVATION: LESSONS LEARNED FROM THE DEPARTMENT OF ENERGY'S NEW PRODUCTION REACTORS PROGRAM

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ABSTRACT: During the late 1980s and early 1990s, the Department of Energy's Office of New Production Reactors (ONPR) was charged with producing the next generation of weapons-grade tritium for the United States. Under the direction of Dr. Dominic J. Monetta, scientists, engineers, and managers were convened to fulfill this mission. Having a keen eye for the impact of social and behavioral factors on productivity and creativity, Dr. Monetta incorporated total quality management and employee engagement strategies to foster innovation within OPNR. The use of "affinity groups" for tapping into the latent social networks and intellectual capital within the organization is one example of innovative management within the governmental agency. The legacy of these managerial and employee activities for today's renewed interest in energy independence, as well as applications in the private sector, are discussed.

INTRODUCTION

When Alaric, the king of the Visigoths, led the sack of Rome in 410 AD, the Western world slid into several centuries of creative and cultural decline – a period we know as The Dark Ages. The American nuclear industry was plunged into a similar "Dark Age" of nuclear reactor design by the partial meltdown of Three Mile Island, Unit 2 in Pennsylvania on March 28, 1979, and sealed in the public mind by the disaster at Chernobyl in the Ukraine on April 26, 1986. The licensing of new reactor design effectively ceased in the U.S. due to five factors: concerns over nuclear reactor safety, new efforts to protect the environment, distrust of government and big business, unfounded excitement about all things nuclear, and skyrocketing interest rates that made financing new reactors unpalatable to investors and utilities alike. While some reactor construction continued, these projects tended to be copies of older designs built as second or third units at existing sites. At the very time when the situation cried out for innovation, modernization and standardization, reactor design development virtually halted in the 1980s and 1990s. As a result, there are only 104 reactors operating in the U.S. and 443 worldwide.

However, much like the Christian monks of Ireland who saved the treasures of Western civilization for future generations through their careful preservation and colorful adaptation of ancient documents, clusters of nuclear engineers gathered to document the past and perfect visions for the future. One such cluster was assembled under the direction of Dr. Dominic J. Monetta between 1988-1991 in the Office of New Production Reactors (ONPR) at the Department of Energy. His introduction and expansion of the use of social networks and affinity groups infused this highly technical environment with astute understanding of group behavior which allowed scientists, engineers and other technical staff to do their most creative work. At the time Monetta took over ONPR, the program was devoted to developing a new generation of reactors to produce tritium for nuclear weapons rather than developing power reactors. An isotope of hydrogen, tritium is used in small quantities to boost the reaction of plutonium based weapons by creating a hydrogen-fusion reaction. During the mid and late-1980s, the United States nuclear weapons complex faced an impending crisis. Tritium has a half-life of about twelve and a half years, meaning that the stockpile of nuclear weapons was in constant need of replenishment in order to keep it operational. With production reactors located at Hanford and Savannah River shut down in the mid and late-1980s due to aging and safety concerns, there was no on-going facility in the United States to produce tritium. Without a new and secure domestic source of tritium production, the United States nuclear arsenal would have declined to half its size within a decade and a half.

In response, in the midst of the "Dark Ages" of nuclear engineering in the late 1980s and early 1990s, Monetta directed the ONPR to jump-start tritium production while securing the future of American reactor design. He institutionalized his belief in the power of people and that dynamic leadership and world class management are just mechanisms for people to make a difference. He brought together some of the best minds from the nuclear energy industry, the government nuclear laboratories, from Hanford, Idaho and Savannah River, and from other entities, such as the Corps of Engineers and Naval Reactors to achieve this end.

Innovation at ONPR

Monetta's vision extended beyond simply establishing another government bureaucracy; instead, he implemented a set of innovative S&T management techniques successfully tested in other settings. One key to the spirit of innovation was to create competitive teams, each working on a separate technical approach to a new generation production reactor. One team focused on the application of Modular High-Temperature Gas Cooled Reactors (MGTRs), another worked on improving the design of Heavy Water Reactors (HWRs), while a third worked on innovations to the Pressurized Water Reactor (PWR). These groups focused on efficiency as well as safety modifications.

The structure Monetta created at ONPR was based on a recognition that science and technology do not advance simply because brilliant people are placed together in teams with problems and resources. The implicit philosophy of this arrangement suggests that innovation comes from something greater than providing good people with problems and the tools to solve them. Under that traditional, "heroic" view of innovation, progress flows in a sort of deterministic fashion, with one innovation creating the groundwork for another. A typical "think tank" approach leaves individuals and small teams working on independent projects, funded through government or grants, often organized along lines defined by technical discipline. Such a method is emulated in many government and corporate labs, and leaves progress up to the accidental convergence of factors in the various teams.

What transpired at ONPR recalls the monastic tradition that grew in Ireland after the fifth century. Those early monks created a joyful stew of innovation rooted in love of the written word burnished with intellectual curiosity and indbut ividual expression in ways unimagined by the Roman tradition that spawned them. Similarly, Monetta freed the ONPR from the previously linear concept of innovation, and a more sophisticated viewpoint recognizing the *contingent nature of progress* became the norm. This philosophy of innovation is best described by Thomas Kuhn in *The Structure of Scientific Revolutions* which examines the cultural basis for scientific and technological progress. By looking at episodes of innovation closely, historians and others have tracked what might be called the *politics and culture of innovation*. Monetta understood this and instituted it to great effect. His technical scientific managers recognized that science and technology do not automatically progress and move steadily along, but like other human endeavors, are subject to human factors like career identification, cultural landscapes, technical backgrounds, and institutions. Understanding the underlying *human* side of innovation, Monetta guided his managers to harness and channel the talents and resources of their teams in a more effective fashion than simply assembling them. The key to this management style was the fundamental recognition that scientists, engineers, designers, and safety-analysts are complete human beings like everyone else, not automatons that take input, process it, and produce solutions.

At ONPR, technical managers recognized that teams are motivated by group behavioral dynamics as much in science and technical fields as in any other field. Sensitivity to such dynamics helped create a positive, competitive environment for sponsoring and encouraging innovation. Managers recognized the interplay of competition, group identification, career-shaped cultural norms, political affinities, and other social and group-behavioral factors. Harnessing those factors in a highly conscious fashion would make progress more likely. At ONPR, there was recognition of the following factors:

- **Career identification**. Engineers with background in Heavy Water Reactors tended to believe their solution would be superior to those working on HTGRs. Such technical identification was made explicit and became a driver in the competition among technologies.
- **"Tribal" styles**. There were, and are, completely different styles of working within government laboratories, the military, the utility industry, at Naval Reactors, and at each of the government reactor complexes at Oak Ridge, Savannah River, and Hanford.
- **Group dynamics**. Physical location of workspace within the ONPR office complex was a potential issue hampering effectiveness. By assigning offices of individuals who worked on completely different aspects of the project in close proximity to one another, the benefits of cross-fertilization of ideas at "water-cooler" discussions, and such informal get-togethers as coffee-breaks and lunches was facilitated.
- **Role assignments**. During meetings, facilitator, discussants, and recorder roles were assigned. This allowed meetings to be more productive, rather than simple opportunities for venting frustrations. However, meetings to resolve managerial conflicts were also regularly held in affinity group meetings, all-hands meetings, and scheduled off-site multi-day retreats with predetermined agendas. No "tourists"— attendees without a specific role— and no "prisoners"— attendees who were assigned to participate as substitutes— were allowed at meetings.
- **Long-range career concerns**. Individuals were assured that when one technology was chosen for production reactors, those working on other technologies would be assured other program positions if they wanted them.
- **Meeting participant roles**. Individuals were made aware of the focused roles they played in groups, such as coach, honest broker, or recorder.
- **Group norms**. A set of beliefs inspired by Admiral Hyman Rickover was distributed and formed the basis of the organization's culture. These include: technical competence, unrelenting dedication, individual responsibility, and intellectual honesty (see Figure 1).
- **Cross-fertilization**. While individuals could identify with an "affinity group" within the ONPR organization, regular interaction with counterparts in other affinity groups also served to foster innovative solutions. Thus, even though identified with one technology, an individual would also share problems, insights, and identification with others performing similar roles on other teams, such as quality assurance, project management, technical evaluation, and risk assessment. Such cross-fertilization of affinity-group organizations could provide further opportunities to break out of culturally-

imposed paradigms by placing individuals with shared problems, but different backgrounds in regular meetings.

Figure 1

OPNR First Principles:

At ONPR, we believe that every successful research organization must embrace certain values which establish its behavior and ultimately, its very identity. For us, these values are individual responsibility, technical competence, intellectual honesty, and unrelenting dedication.

Individual responsibility
Responsibility is a unique concept: it can only reside and adhere in a single individual. You can delegate pieces of it; however your portion is not diminished. You may disclaim it, but you cannot divest yourself of it. Even if you do not recognize it or admit its presence, you cannot escape it. If responsibility is rightfully yours, no evasion, ignorance, or passing of the blame can shift the burden to someone else.

Technical competence
Properly running a complex program requires a fundamental understanding of, and commitment to, the technical aspects of the job as well as a willingness to pay infinite attention to the technical details. No amount of procedure or application of process can substitute for a disciplined understanding of the details you are dealing with. You must understand both the theoretical and applied implications of management science and decision theory, and their impact for the entire project.

Intellectual honesty
Intellectual honesty requires you to resist the natural temptation to hope that things will work out, despite evidence or suspicions to the contrary. It can affect you in subtle ways, particularly when you have spent a lot of time and money on a project. It is not easy to admit what you thought was correct did not turn out that way. If conditions require it, you must face the facts and make needed changes despite the costs and delays.

Unrelenting dedication
Complex and sophisticated projects cannot be solved by specifying compliance with one or two simple rules or procedures. Success requires strong adherence to the concepts of individual responsibility, technical competence, and intellectual honesty. This relentless adherence is very hard work and requires a constant dedication to the concept that all elements are recognized as important and each is constantly reinforced. The leader must set an example and require subordinates to do likewise.

Social Capital and the Art of Innovation

Monetta's innovative management thought extended to incorporating both social capital and affinity groups into their team functions. Social capital can perhaps be best thought of as the human element, such as learning, trust, and innovation, which is created and enhanced during interpersonal interactions. Robert Putnam's best-selling book, *Bowling Alone: The Collapse and Revival of American Community*, provides a view of social capital at a community and national level. He observes that the term social capital "… turns out to have been independently invented at least six times over the twentieth century, each time to call attention to the ways in which our lives are made more productive by social ties." In their book *In Good Company: How Social Capital Makes Organizations Work*, Don Cohen and Laurence Prusak define social capital as "the stock of active connections among people: the trust, mutual understanding and shared values and behaviors that bind the members of human networks and communities and makes cooperative action possible." One method proven to be effective at building social capital in organizations is the use of "affinity groups."

Affinity Groups

Affinity groups are defined as "collegial association of peers who meet on a regular basis to share information, solve problems, and capture emerging opportunities." In essence, affinity groups are a formal attempt to capture the emergent behaviors and human capital found in the informal channels and networks within an organization. As such, they offer a unique mechanism for tapping into the social capital and organizational intelligence of members often found below the formal surface.

By design affinity groups are horizontal and cross-cutting, representing "slices" of an organization where membership to the group is based on responsibility and duties, as opposed to departments or divisions. Affinity groups share the following characteristics:

- Group members have similar titles, duties, and responsibilities;
- Group member roles are formalized;
- Group meetings are regular and frequent;
- The group develops its own unique charter and mission.

Origins of Affinity Groups

The origins of the affinity group concept can be traced back to the late-1930s the work of Charles P. McCormick of McCormick & Company.

McCormick realized that the full potential and expertise of employees was not being tapped through traditional organizational processes. To remedy this problem, McCormick established and implemented the Multiple Management model. The purpose of this model was to supplement the traditional decision-making and problem-solving processes of his organization with the "energizing power of new ideas" found in the members of the Multiple Management group.

During the early 1960s, Monetta's mentor, Joe L. Browning, Technical Director at the Navy Propellant Plant in Indian Head, Maryland, consciously used social networks to harness the talents and enthusiasm of younger staff members in the Navy's R&D setting. Browning's innovative spirit included the creation of a McCormick Tea Company-like Assistant Management Board (AMB) of self-selected staff members that represented horizontal slices of the laboratory's governmental hierarchy.

Monetta, a member and ultimately chairman of Indian Head's AMB, further refined the process of horizontal group collaboration into the affinity group model of today. When appointed Director of the ONPR in 1989, he faced the task of bringing together a diverse population of scientists, engineers, administrators, and managers in a project of enormous complexity. In order to establish and utilize the informal systems across the agency's hierarchy, he institutionalized Browning's board model at ONPR. Monetta defined and consequently renamed the concept affinity groups to represent the affinities shared by the group members. Affinity groups at ONPR were utilized for improving communication, facilitating problem-solving activities, and empowering ONPR's employees to enhance the agency's continuous improvement efforts.

Although separated by at least fourteen centuries, both ONPR and their Irish monastic ancestors made enthusiastic use of both social capital and affinity groups. The Irish expression took the form of collaborating to promulgate and to share the illustrated manuscripts of both secular and clerical treasures they had rescued and copied many times over, infusing each iteration with their unique interpretive and decorative slant, the most articulate example of which is the Book of Kells. ONPR, under Monetta's guidance, established five distinct affinity groups, representing five levels of the organization, and they follow:

- Senior Management Group (SMG)
- Technical Directors Workshop (TDW)
- Division Directors Roundtable (DDRT)
- Executive Assistants Council (EAC)
- Senior Secretaries Panel (SSP)

Affinity groups developed ONPR's social capital, connecting the links between and among various levels of the organization and areas of technical expertise.

As a crucial building block to an organization's social capital, affinity groups also facilitate creative problem-solving and collaboration. The affinity group model ensures systems-level-thinking as members are better able to understand the "ripple effects" of actions taken by their organization. As a result, members can creatively think outside their organizational "box," yet within their specific domain of technical expertise, to most effectively solve shared problems. Figure 2 illustrates the formal roles of affinity groups.

Figure 2
Affinity Group Roles

Convener: This group member coordinates the activities of the group, develops and distributes the agenda, and ensures the meeting logistics are managed. In effect, he or she sets the boundaries for the group's organizing and problem-solving activities to occur.

Recorder: This group member records the output from the meetings, including action items, key issues, and recommendations. He or she provides the memory for the group that serves as a catalyst for learning and progressive problem solving.

Reporter: This group member serves as the group's liaison to the other organizational elements and to the other Affinity groups. As such, he or she acts as an agent in the larger system by both providing and gathering information from the other groups.

Facilitator: The facilitator is the only external member of the group. This individual is responsible for serving as an objective honest broker who coaches individual members, establishes and clarifies the ground rules, and provides process feedback to the group.

Affinity groups spark creative thought and innovation by building trust, cohesiveness, and a general appreciation for each member. By spending time together, members learn how to work together effectively while developing a greater understanding for each other's role in the organization. In addition, Affinity groups create a unique group identity and cohesiveness for members that are based on member status, title, and responsibility, instead of organizational affiliation. Action research conducted at ONPR found that affinity groups are successful in providing:

- Increased channels of communication and information-sharing.
- Identification of problems and the development of innovative solutions.
- Opportunities to capture emerging opportunities.
- Increased trust and loyalty for group members.
- Exposure and validation of informal decision-making processes.
- Increased education, development, and training opportunities.

SUMMARY, RECOMMENDATIONS AND CONCLUSION

The end of the Cold War, agreements on nuclear arms reduction, and the removal of the crisis in tritium supply meant that the ONPR effort would be "overtaken by events." Instead of seeing the down-select process of choosing a production reactor design for the future through to the end, the Department of Energy decided to close down the effort to take advantage of the progress that had been achieved. By utilizing tritium recovered from disassembled weapons at the Pantex plant in Texas, and by setting up an experimental program utilizing existing power reactors in the Tennessee Valley Authority with improved helium targets developed at ONPR, the way could be seen to meet future tritium needs. By carefully studying all the incremental improvements that had been made to safety, and by rigorously applying probabilistic risk assessment methods to design components, Monetta's group of modern day "monks" working in affinity groups at ONPR contributed to the forthcoming generation of the Westinghouse Advanced Power Reactor-1000 (AP-1000) which received revised final design approval from the Nuclear Regulatory Commission on March 10, 2006.

Their work to support the development of the AP-1000 would prove to be fortuitous. Working in parallel with the ONPR staff, the scientists and engineers in the commercial nuclear energy industry had already started working to address the very real concerns about the safety and reliability of America's fleet of nuclear reactors. In the immediate wake of the incident at Three Mile Island Unit 2 1979, William S. Lee, then President and Chief Operating Officer of Duke Power who later consulted for ONPR between 1989-1994, led his own team to Pennsylvania to help resolve the incident and begin the long and arduous challenge of restoring public confidence in the ability of the industry to operate safely.

Later that year, Lee spearheaded the establishment of the Institute of Nuclear Power Operations (INPO), an effort to share best practices throughout the industry through a system of rigorous peer review and establish worldwide safety standards. As a result, over the ensuing decades, the performance and reliability of the American nuclear energy industry improved dramatically. An industry that was once known for massive cost overruns, unplanned outages and suspect workplace safety began producing electricity at extremely competitive rates, even as many observers declared the end of commercial nuclear energy in the wake of the market reforms in many regions of the country.

By the turn of the century, the lessons of Chernobyl and Three Mile Island had been well absorbed by the industry, as the average capacity factor of the American nuclear fleet reached above 90% -- higher than any other type of electrical generation.

In the meantime, concerns about energy security, price volatility in natural gas markets, and growing concern over the potentially devastating effects of man-made global warming have helped to lead the American public, policymakers and utilities to give nuclear energy a second look. Today, the Westinghouse AP-1000 is one of three standardized Generation III+ reactor designs currently vying for business in the American marketplace, and is the only one to have already received design certification from NRC. No fewer than five companies, including the aforementioned Duke Power, have announced their intention to test the new reactor licensing process with the AP-1000 as their designated design.

Recommendations and Managerial Implications

The research findings presented in this paper are primarily qualitative. In the same tradition as many business and managerial articles published in academic and trade publications, it offers in-depth insight into the behavioral dynamics of innovation within a single organizational entity. As an inherent limitation found in all qualitative studies, this analysis does not afford the statistical rigor to ascertain 'cause-and-effect' relationships, measures of variance, or hypothesis testing. In this light, generalizing and recommending the findings presented in the paper must be done with great care and caution. Due to the lack of statistical controls afforded by quantitative approaches, we are, in the strictest sense, only able to describe in great detail what was effective and meaningful at OPNR in the early 1990s. We do believe, however, the lessons learned have much wider applicability beyond the science and technology environment within a governmental agency. It is with this important and cautionary "footnote" that recommendations and managerial implications are provided

Balancing Organizational Tension: Perhaps the single most important finding from this study is that effective leaders and managers must balance the inherent tension found between people and productivity. Examples illustrated in this paper include the following: short-term focus vs. long-term focus, tactical goals vs. strategic objectives, efficiency vs. effectiveness, technical expertise vs. human dynamics, and planned action vs. spontaneity. In essence, effective managers must acknowledge, appreciate, and manage the tension between the