



WNA Personal Perspectives

The Evolution of Nuclear Safety

Zack Pate and Jim Ellis

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22a St James's Square

London SW1Y 4JH

United Kingdom

www.world-nuclear.org



Zack Pate

Dr Zack Pate has earned a worldwide reputation as a nuclear pioneer - first as President of the Institute for Nuclear Power Operations (1983-1997), and later as Chairman of the World Association of Nuclear Operators (1997-2002). Dr Pate's emphasis on standardized, rigorous, accredited training gave impetus to the concept of a worldwide "safety culture" in the nuclear industry. In guiding the industry toward high and consistent levels of performance, his career helped to lay the foundation for a renaissance of nuclear power worldwide.

A graduate of the US Naval Academy, Pate holds a PhD in nuclear engineering from MIT. Serving in the US Navy from 1958 to 1980, Pate commanded nuclear-powered submarines and was a special assistant to Admiral Hyman Rickover. Dr Pate is a recipient of the James N. Landis Medal, the William S. Lee Award for "visionary leadership in encouraging and promoting excellence throughout the nuclear power industry", and the Henry DeWolf Smyth Nuclear Statesman Award. In 2002, Dr Pate was honoured by the World Nuclear Association for his "distinguished contribution to the peaceful worldwide uses of nuclear energy" as a founder and leader of WANO. He is Chairman-Emeritus of both INPO and WANO, and currently serves as Chairman of the World Nuclear University (WNU).



Jim Ellis

Admiral James Ellis, Jr., USN (Rtd.) has been the Chief Executive Officer and President of the Institute of Nuclear Power Operations (INPO) since May 2005, and currently serves on the board of WANO.

He retired from the US Navy in July 2004 as an Admiral and Commander, and served in US Strategic Command, Nebraska. As Commander, he was responsible for the global command and control of US strategic forces to meet decisive national security objectives. His Command mission areas included full-spectrum global strike, space operations, computer network operations, Department of Defense information operations, strategic warning, integrated missile defense, and global Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance. Admiral Ellis became Commander in Chief, US Naval Forces, Europe headquartered in London, England, and Commander in Chief, Allied Forces, Southern Europe headquartered in Naples, Italy, in October 1998.

His personal awards include the Defense Distinguished Service Medal (three awards), Navy Distinguished Service Medal (two awards), Legion of Merit (four awards), Defense Meritorious Service Medal, Meritorious Service Medal (two awards), and the Navy Commendation Medal, as well as numerous campaign and service awards. Ellis holds Master of Science degrees in Aerospace Engineering from the Georgia Institute of Technology and in Aeronautical Systems from the University of West Florida. A distinguished naval aviator, he is also a 1975 graduate of US Naval Test Pilot School. He completed US Navy nuclear power training in 1987, and is a 1969 graduate of the Senior Officer Program in National Security Strategy at Harvard University. In 1991 he took command of the *USS Abraham Lincoln* in the western Pacific and Arabian Gulf.

ZACK PATE

When the Three Mile Island (TMI) accident occurred in March 1979 I was working for Admiral Rickover at Naval Reactors Headquarters in Washington DC. Admiral Rickover, widely recognized by that point in history as the “Father of the Nuclear Navy”, took a keen interest in the accident and the new Presidential Commission and, of course, the lessons that could be learned. As soon as the TMI Commission was formed he negotiated to place a senior staffer - Ronald Etychison - on the Commission.

Captain Etychison kept Admiral Rickover and others at Naval Reactors fully informed throughout the six-month proceedings of the Commission, and through his involvement Naval Reactors was able to keep abreast of the proceedings and have an input.

My doctoral thesis at MIT was on reactor safety. To a degree, that at TMI was the kind of severe accident I had studied. So, needless to say, I had a high level of interest in the Commission’s work, and as their study and conclusions unfolded, I made the decision to leave the Navy and in 1980 to join the organization recommended by the Commission – which was to become the Institute of Nuclear Power Operations, or INPO.

The first CEO of INPO, Vice Admiral Dennis Wilkinson took the recommendations of the Commission very seriously, and INPO soon began implementing those that were within our scope. I served as the Institute’s CEO for many of its formative years, from 1984 to 1998.

By the mid-1980s INPO had a staff of about 400. We had acquired capable people from the industry and from the Navy. By 1986, for example, we had 78 employees who had previously served as officers in the Navy nuclear program. These people brought with them the very high standards expected of everyone in Admiral Rickover’s program, and most, like Dennis Wilkinson and myself, brought a passion for nuclear safety and excellence.

By the 10th anniversary of TMI we were able to say that INPO and its member utilities had made considerable progress in improving safety and reliability and in responding to the Commission’s recommendations. This progress was detailed in a comprehensive report sent to each member of the TMI Commission and to a wide range of government officials and congressmen.

Within a few weeks we received an advance copy of a press release that Professor John Kemeny, chairman of the Commission, made. Key excerpts from his March 28, 1989 release include: “A decade ago I had the privilege of chairing the President’s Commission on the Accident at TMI.----The Institute of Nuclear Power Operations has just Issued a Report of Nuclear Utility Responses to the Kemeny Commission Recommendations.----The Report takes up our major recommendations one by one, and summarizes the way they were implemented. The improvements over the past decade have been impressive, and are very reassuring. We felt that what we wrote was important. We now know that the Presidential Commission has made a difference.”

With that early history, and plenty of challenge remaining for INPO and its member utilities, I pass the narrative to Admiral Jim Ellis, President and CEO of INPO. My own endeavours in the 1990s became focused on the World Association of Nuclear Operators (WANO).

JIM ELLIS

Zack has asked me to outline the issue of self-regulation in a high-technology industry, based on INPO. This is in the context of a national regulatory body - the US Nuclear Regulatory Commission - not instead of it. There are some key factors that have enabled INPO's fostering of self-regulation to effectively help improve safety in the US commercial nuclear power industry.

The founding of INPO and the beginning of self-regulation in the US nuclear power industry came after the industry suffered its most serious accident – a partial meltdown of the Three Mile Island Unit 2 reactor core in March 1979. This was a worst-case accident within the reactor, the consequences of which were hitherto largely unknown, and the subject of much apprehension.

The event quickly became widely known as simply “TMI”, and the forlorn image of the plant's cooling towers is one that has remained with the industry even today. While there were no deaths, injuries or environmental damage caused by TMI, it did generate concerns and reactions similar to those being addressed in the aftermath of the Deepwater Horizon accident – including questions about the overall safety and integrity of the industry, a fear of the unknown with uncertainty about the causes and ultimate consequences, and a severe loss of public trust and confidence.

At the time of the TMI accident, the United States had 70 commercial nuclear power reactors in operation, with an operating record of more than 400 reactor-years of service without a major event impacting the public. Following TMI, nearly 100 nuclear power plants either planned or under construction were cancelled and no new permits or licenses for construction have been issued in the USA in 32 years.

The TMI accident was caused by a combination of design inadequacies, equipment problems, human error, and management failure. More broadly, the event showed weaknesses in the industry's approach to operational standards, training, the sharing and use of industry operating experience, and emergency response.

Recognizing the need for prompt and comprehensive action, key leaders in the commercial nuclear power industry moved quickly to form INPO. In fact, we were already incorporated by the time the report of the President's Commission on the Accident at Three Mile Island was issued in October 1979, seven months after the event. Recognizing the need for credible and authoritative leadership, the industry selected retired Vice Admiral Eugene P. Wilkinson as the Institute's first President and CEO. He had been Commanding Officer of *USS Nautilus*, the first nuclear powered vessel, and was a stalwart of the early Navy nuclear program.

Though both INPO and the industry that it serves have evolved over the years, the primary recommendations from that effort, known as the Kemeny Commission, formed the basis for INPO's cornerstone programs, which remain in place today. The four cornerstone programs are Evaluations, Training, Analysis, and Assistance.

INPO is a nongovernmental corporation that operates on a not-for-profit basis. We operate independently of the industry – and we avoid any conflicts of interest. We, specifically, legally and philosophically, cannot act as an advocate for the nuclear power industry – that is not our role. Our role is to help the nuclear power industry set and achieve the highest standards of safety and excellence in operational performance.

Since our inception, all organizations that have direct responsibility to operate or construct commercial nuclear power plants in the United States have maintained continuous membership in INPO. Currently, we have 26 members that operate 104 nuclear power reactors in 31 states. In addition, many international groups and supplier organizations are voluntary participants in INPO.

We have a staff of about 400 nuclear power professionals, which includes about 60 employees on loan to us from member utilities. Our annual budget is \$99 million, most of which comes from member and participant dues.

I believe there are five key factors that have enabled INPO and self-regulation to be effective in fostering the highest standards of nuclear power safety at US commercial nuclear plants. These are: Chief Executive Officer (CEO) engagement, a nuclear power safety focus, support from the nuclear power industry, accountability, and independence.

CEO Engagement – gaining the support and personal involvement of the member company chief executive officers – was a fundamental element in the founding of INPO.

From the beginning, INPO's Board of Directors has been comprised of member CEOs and other senior utility executives. Mayo Shattuck, Chairman and CEO of Constellation Energy Group, is our current Chairman, and all of our other Board members are CEOs or Presidents of the nuclear operating company.

We have found that working directly with CEOs is vital to maintaining industry support and responsiveness to our safety mission and initiatives. For example, we provide CEOs personally, in the presence of their line management, with detailed briefings of every evaluation conducted at their nuclear power plants.

We also communicate with and send requests for action on operational matters directly to CEOs. Earlier this summer of 2010, for example, I sent every CEO a letter that described a dissatisfying trend in recent nuclear power plant operational events, and asked them to coordinate with their management team and provide me personally with specific actions and response.

Every CEO also participates personally in the INPO annual conference, which focuses on nuclear safety, and during which operational events and nuclear power plant ratings assigned by INPO are discussed candidly with them.

The second key factor is maintaining a **Nuclear Safety Focus**.

INPO's mission, which has not wavered since its founding, is to promote the highest levels of safety and reliability – to promote excellence – in the operation of commercial nuclear power plants. The distinction of promoting excellence, rather than regulatory compliance, is fundamental to INPO's role in raising nuclear power safety performance.

Over the years, there have been many suggestions and requests for INPO to become involved in a variety of new issues, or with different stakeholders. And although each such endeavor may have provided some benefit to the nuclear power industry, they also would have diluted the attention and resources placed on our mission of excellence in nuclear power safety.

In the end, nuclear power safety is why we exist, and it is always through the lens of improving nuclear power safety that we examine any potential new activities or changes in the scope of current efforts.

The third key factor in effective self-regulation and improving nuclear power safety has been the **Support from the Industry**.

The nuclear power industry understands and has accepted that a key part of self-regulation is subjecting its plants to on-site peer reviews, which we call plant evaluations. The evaluations are intrusive, comprehensive, and performance-based, and their importance cannot be overstated. Since 1980, we have conducted nearly 1,200

plant evaluations, an average of more than 16 at every nuclear power plant, inspecting them, on average, once every two years.

The nuclear power industry participated in developing standards of excellence, and then committed to meeting the standards. The strong industry participation has continued, and it has played a key role in the numerous advanced standards and guidelines developed over the years, but the leadership of INPO, supported by our Board of Directors, makes the final decision on expected levels of performance.

Although INPO programs today are part of the fabric of the nuclear power industry, gaining wide acceptance in the early years was not easy! Some nuclear power plants questioned the technical credibility of the plant evaluation teams and were skeptical about the value of INPO evaluations. We addressed these issues and overcame the challenges by continuing to hire competent and operationally experienced staff, many of whom had valuable experience as managers in commercial or Navy nuclear power plants. And we continued to deliver plant evaluation reports that identified important safety and reliability issues that – when corrected – improved safety and reliability, thereby improving performance.

In addition to its acceptance and welcoming of INPO activities and programs, the nuclear power industry supports and participates in self-regulation through INPO with involvement in advisory groups, industry task forces and working groups, and by loaning employees to INPO to serve in a variety of functions, including as peer evaluators.

The support provides benefits to the individual organizations, as well as to the entire nuclear power industry. By serving as peer evaluators for example, professionals from individual utilities not only provide added and current experience to the INPO evaluation team, they also gain insight into nuclear power industry best practices and take that knowledge back to their own companies.

Through their participation peer evaluators also acquire a first-hand understanding of INPO's role and the importance of industry self-regulation. Over the years, more than 13,000 industry peer evaluators have served on INPO teams.

The fourth key factor is **Accountability**.

Self-regulation cannot be effective without an effective means of enforcement. During INPO's first five years, we completed a few rounds of evaluations at every nuclear power plant, and it was clear that not all members were responsive to INPO's findings.

To improve our effectiveness, we had a group of senior industry executives – led by Lee Sillin, former chairman of Northeast Utilities – do a broad self-assessment of INPO activities. Their recommendations included toughening the language in INPO evaluation reports, establishing a formal process for assessing the evaluation results, and assigning a numerical performance rating based on the assessment.

Doing that enabled us to exert more authority and demand more accountability. It also helped build our credibility with the nuclear power industry and with the national regulator.

In addition, we changed our policy for distributing INPO evaluation reports. We made the evaluation reports confidential, distributed only to the utility whose nuclear power plant was evaluated. This change – from our initial policy of distributing all evaluation reports industry-wide – provided for more open and candid interactions and discussions of problems or areas for improvement. The confidentiality of reports has proven to be an important aspect of performance improvement and nuclear safety.

Sanctions can come in various forms. Although INPO does not have the statutory standing to shut down an operating plant, we, on several occasions over our first 15 years, exerted pressure that influenced nuclear power plant operators to shut down or delay starting up until specific safety issues we raised were properly addressed.

We also take formal follow-up actions when a plant exhibits a lack of responsiveness or chronically poor performance. In one notable case, a company's board of directors made changes in its executive leadership in response to our escalating concerns about their corporate management's lack of responsiveness. There have been other situations where companies have been unsuccessful in improving chronic low performance at their nuclear power plants, and – through INPO escalation and pressure – changes were made from the top down. In all these cases, our actions were taken with the full support of the INPO Board and the broader industry. It is this peer pressure that is perhaps INPO's most effective tool for driving real change.

Another incentive for nuclear power plants to perform well comes from the industry's collective insurance company, also known as Nuclear Electric Insurance Limited, or NEIL. After the TMI accident, all nuclear power plants were required to carry insurance through NEIL. NEIL, in turn, requires INPO membership as a condition of insurability, and it uses INPO plant evaluation ratings as a factor in setting insurance premiums.

The fifth key factor is **Independence**.

For INPO to be successful in its self-regulation role, we must be a part of the nuclear power industry and a useful resource. But at the same time, we must remain independent and work to high standards.

In particular, we need to be independent from any one company or nuclear power plant. We accomplish this in the institutionalized ways in which we select team members and distinguish clearly between our evaluative role and the many other collaborative interactions and activities with our members.

Our mission is largely independent from the regulator – the **Nuclear Regulatory Commission** – but it is also complementary in that both organizations focus on nuclear safety. Over the years, the NRC has formally endorsed selected INPO programs as a satisfactory means for nuclear power plant operators to meet certain regulatory requirements. And INPO has provided the NRC with regular updates and communications on topics of mutual interest related to improving performance in the industry.

Results

Through its 30-plus-year history, INPO has continued to raise the bar for nuclear power plant safety and performance and has been a catalyst for action on important issues. Since the founding of INPO and the start of self-regulation in the nuclear power industry, there have been significant performance improvements in essentially every measure of safety and reliability.

For example, in the early 1980s, the typical nuclear power plant had a capacity factor of 63 percent. **Capacity factor** is the actual amount of electricity generated by a plant divided by the amount it could have generated if it was operating continually at full capacity.

The typical plant also experienced seven automatic shutdowns per year. Also it had a collective radiation exposure that – although it met regulatory and health requirements – we felt could be significantly reduced. Today, and throughout this past decade, the typical nuclear power plant now has a capacity factor above 91 percent, with zero automatic shutdowns per year, and occupational radiation exposure about six times lower than in the 1980s. In addition, the number and severity of operational events at nuclear power plants has dramatically improved since then.

Self-regulation, however, is not a perfect process. Over the last thirty years we occasionally find that – even with high industry standards, regulatory oversight, self-regulation and INPO – a series of errors or omissions can align to produce an unexpected major operational event or declining trend in industry performance. This reality demands constant vigilance.

In response to these issues, INPO, with industry support, conducts periodic critical self-assessments of our own performance, and we have, as a result, implemented many changes to our practices. As an example, in recent years we have significantly expanded our approach to dealing with organizational safety culture.

As industry programs have matured over the decades, the nature of issues often has become more subtle, making it more challenging to observe and quantify. So in order to maintain effectiveness, our evaluation process and other cornerstone activities must continue to evolve and improve.

Today, we often engage plants in discussing difficult issues such as risk assessment and risk management, operational decision-making, long-term equipment strategies, leadership capability and development, safety culture, and corporate governance and oversight.

In summary, INPO and self-regulation in the US nuclear power industry represent a substantial and successful effort undertaken by a high-technology industry to raise its safety standards and performance levels. We believe self-regulation has proven to work effectively in the nuclear power industry. And we also believe the key factors to successful self regulation have been and continue to be CEO engagement, a nuclear power safety focus, industry support, accountability, and independence.

These lessons have been applied internationally, and in particular post-Chernobyl accident, to east-west collaboration through peer review evaluations. The World Association of Nuclear Operators (WANO) story owes much to INPO.

WORLD ASSOCIATION OF NUCLEAR OPERATORS (WANO)

WANO is the most significant means of safety-related cooperation internationally among reactor operators. It was formed following the Chernobyl accident to maximise the safety and reliability of nuclear plant operation, with its inaugural meeting in Moscow in 1989. With Regional Centres in Atlanta, Moscow, Paris and Tokyo and a coordinating centre in London, WANO links all 115 operators of nuclear power plants in 34 countries. Today it also involves reactor designers and vendors, so that there is better feedback of experience.

WANO has four major programs:

- ▶ peer reviews;
- ▶ operating experience;
- ▶ technical support and exchange; and
- ▶ professional and technical development.

WANO peer reviews are the main proactive way of sharing experience and expertise. They are focused on operations, not the design (or siting) of power plants.

The exchange of information on operating experience is the basis of WANO's various programs. Information and event reports are submitted by each operating organisation to its regional centre where they are reviewed for clarity and completeness and then distributed to all WANO members using an international electronic information exchange system. If particular trends or concerns become evident a SOER (special operating event report) may be drawn up and circulated, and this has the force of a recommendation arising from peer review. For instance one was issued six days after the Fukushima accident, with detailed responses then received in the London office from every nuclear plant in the world (other than Fukushima) within two months.

One of WANO's first objectives was for operating staff from every nuclear plant in the former Soviet Union to visit plants in the West for technical exchange, and for personnel from the West to visit every plant in the former Soviet Union. This was accomplished in the first two years of WANO's existence. A great deal of ongoing plant-to-plant cooperation (twinning) grew out of these original exchange visits.

Since then WANO has fostered a voluntary peer review program, and by the end of 2009 a significant milestone had been reached, with every one of the world's commercial nuclear power plants having been peer-reviewed at least once. A key goal was to establish a system whereby every plant hosts an outside review of its performance every three years, and a full WANO peer review at least every six years, and preferably more often. These mainly focus on how a plant is operated but their scope is likely to widen to include severe accident management/ mitigation (SAM) guidelines and also some design matters. Peer reviews result in reports to the operator, and if these are not acted on, follow-up visits ensue with special reports, and ultimately if necessary confrontation with the utility's board.

In recent years WANO has introduced pre-startup reviews as part of its peer review program, particularly to address the situation of new plants in countries and organisations without previous nuclear power experience. As of early 2011 it had undertaken 12 such reviews and with the great increase in construction happening, had 62 scheduled for the next five years. WANO's goal is to do a pre-startup review on every new nuclear power plant worldwide. The reviews seek to evaluate how each operating organization is prepared for startup and make recommendations for improvements based on the collective experience of the world industry. The transition between construction and operation at a nuclear power plant is a delicate period, and many incidents occur during the early months of plant operation - both Three Mile Island 2 and Greifswald 5 were almost new units when accidents destroyed them.



World Nuclear Association

Carlton House • 22a St. James's Square • London SW1Y 4JH • UK

t: +44 (0)20 7451 1520 • f:+44 (0)20 7839 1501

www.world-nuclear.org • wna@world-nuclear.org