



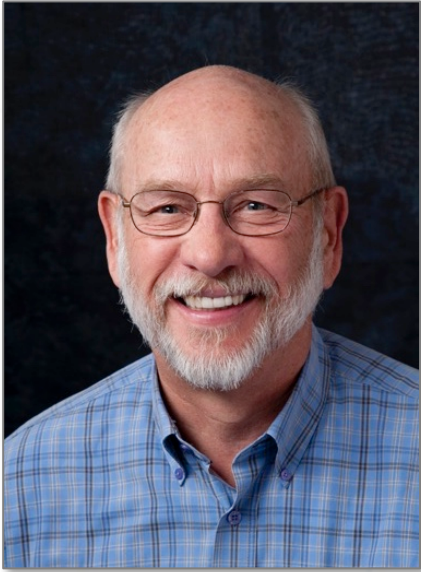
Structure of NRC Regulatory Framework: Historical Licensing Landmarks

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GAIN

Gateway for Accelerated
Innovation in Nuclear



Roger J. Mattson

Summary

- Fifty plus years experience in nuclear safety, licensing and related fields

Education

- Ph.D., Mechanical Engineering, University of Michigan, 1972

Mattson has diversified experience in engineering and management with Sandia Laboratory, Atomic Energy Commission, Nuclear Regulatory Commission and Environmental Protection Agency. He served as president of International Energy Associates Limited and was a founder and chief operating officer of SCIENTECH, Inc., a leading nuclear safety company.

Mattson's technical experience is in heat transfer and fluid flow, nuclear safety, nuclear facility licensing, nuclear policies and standards, readiness reviews, risk management, security of nuclear facilities and materials, quality assurance and emergency preparedness. He conducted and managed safety reviews for more than 110 nuclear power plants and other radiological facilities. He led the development of NRC's new requirements after the accident at Three Mile Island in 1979 (NUREG-0578, 0585 and 0660).

From 1974 to 1984, Mattson advised AEC and NRC commissioners on policy issues such as safety goals, radiological protection, standardization, risk assessment and security. He led NRC's reviews of advanced nuclear power plant designs from 1977 to 1984. He participated in NRC's onsite response to Three Mile Island and several other nuclear incidents. He developed NRC's standards for security, safety, radiation protection and environmental protection of uranium fuel cycle facilities and waste management facilities.

Since leaving NRC in 1984, he has advised managers of NRC licensees, National Laboratories and DOE contractors on policy issues and decision-making in nuclear safety and security. He led readiness reviews for startup of Limerick Nuclear Power Plant Unit 2, Rocky Flats Plant, and K-Reactor at Savannah River. He participated in safety analysis and field reviews of nuclear facilities in the U.S., Europe, the former Soviet Union and the Far East. He co-chaired the International Atomic Energy Agency's development of safety principles for nuclear power plants after the 1986 accident at Chernobyl (INSAG-3). He served on nuclear safety review boards for five operating nuclear power plants, the Rocky Flats decommissioning site, the DynEx Program at Los Alamos, and the Advanced Test Reactor at Idaho National Laboratory. He established and led nuclear safety consultancies in Ukraine and Kazakhstan. He served on the team that responded to lessons learned from the Fukushima Daiichi event for the president of the American Society of Mechanical Engineers.

3 Major “Eras” of Licensing History

Searching for the Regulator’s Role

- 1954 to 1975

Developing the Independent Regulator

- 1975 to 1979

Correcting for Operational Experience

- 1980 to Today

Summary Observations

Searching for the Regulator's Role 1954-1975

AEC's Foundation of Nuclear Safety Regulation

- 1953 – Edward Teller and the Reactor Safeguards Committee suggested nuclear reactors be designed for “worst possible accident.”
- Nuclear power began with a 1954 amendment to the Atomic Energy Act (AEA) allowing commercial nuclear power and requiring Atomic Energy Commission (AEC) to establish standards to provide adequate protection of public health and safety.
- March 1955 – AEC established its first Division of Licensing under Harold Price, a lawyer.
- January 1956 – AEC issued 10 Code of Federal Regulations (CFR) 50 for licensing of production and utilization facilities.
- After political controversy in the Joint Committee on Atomic Energy (JCAE) (Republicans favored industry lead while Democrats preferred government lead) a hybrid arrangement emerged, along with numerous demonstration plants of varying technology, including Shippingport in 1957.



AEC's Foundation of Nuclear Safety Regulation, Cont.

- In May 1956, provisional construction permits for Dresden Unit 1 and Indian Point Unit 1 were among the first licensing actions by AEC.
- 1957 – Price Anderson Act provided government indemnity for major accidents. Other AEA amendments required Advisory Committee on Reactor Safeguards (ACRS) review and opportunity for public hearing on construction permit and operating license applications.
- Apr 1958 – National Council on Radiation Protection and Measurements (NCRP) revised maximum permissible dose of radiation.
- Apr 1959 – AEC issued proposed rules on radiation protection (10 CFR 20 effective Jan 1961) and reactor siting (10 CFR 100 effective in Jun 1962).
- Sep 1959 – AEC issued operating license for Dresden 1, first large privately owned plant.
- Nov 1959 – AEC Regulation elevated to Assistant General Manager level.
- Jan 1961 – SL-1 reactor at National Reactor Testing Station (NRTS) in Idaho had power excursion and rod ejection, killing three.

AEC's Foundation of Nuclear Safety Regulation, Cont.

- Striving for commercial viability, designers scaled up plants with little construction, testing, or operating experience.
 - Power scale up: From Shippingport initial criticality in 1957 to Indian Point 2 CP application in 1964, the power went up from 236 MWt to 3000 MWt, more than 10-fold in 7 years.
 - Fuel scale up: 12-foot cores, thousands of fuel elements, little experience in fabrication of fuel, fuel elements, or fuel assemblies. Many leaked. Nuclear Regulatory Commission (NRC) eventually created a Fuels Oversight Branch.
 - Higher operating temperatures than Shippingport but using same basic materials of construction. One result was cracking problems with piping and steam generators, with downstream liabilities and more NRC oversight.
 - Use of boric acid as soluble neutron absorber (chemical shim) for reactivity control in pressure water reactors (PWRs) and as an emergency shutdown system in boiling water reactors (BWRs). Result was greater plant complexity and growing corrosion problems, all with regulatory implications

AEC's Foundation of Nuclear Safety Regulation, Cont.

- Quality concerns emerged everywhere – design, analysis, construction, manufacturing, startup, operations.
- Early push by the JCAE for commercialization of nuclear power plants (NPPs) had consequences. The push owed to a national prerogative to establish and maintain nuclear supremacy (Atoms for Peace) and to meet growing electric power needs as American population and industry grew after WW II.
- Early focus of AEC reactor safety reviews and testing was power control, especially avoidance of power excursions and containment design.
- Jun 1961 – Supreme Court ruled AEC had to provide “reasonable assurance” of adequate protection under §182a of Atomic Energy Act before licensing operation of NPPs. In 1987, DC Court of appeals ruled, “The level of adequate protection need not, and almost certainly will not, be the level of ‘zero risk.’ This court long has held that the adequate-protection standard permits the acceptance of some level of risk.” Decision also addressed costs for safety beyond adequate.

AEC's Foundation of Nuclear Safety Regulation, Cont.

- Dec 1962 – Con Edison proposed two 800 MWe PWRs at Ravenswood site in Brooklyn with double steel-shelled containments, emergency core cooling system (ECCS) for rupture of largest pipe, use of single failure criterion. After much debate, regulatory staff and ACRS were negative; Con Edison withdrew its application. Indian Point site became de facto limit on metropolitan siting, enduring even today.



AEC's Foundation of Nuclear Safety Regulation, Cont.

- Ergen Report of 1966 led to requirement for ECCS on all light water reactor (LWR) nuclear power plants. Proposed plants had grown so large containments could not cope with core melt and meet the siting criteria.
- By this time, industry and AEC had settled on LWR technology but for a small unsuccessful effort by General Atomics with high temperature gas reactors (HTGRs) at Peach Bottom and Fort St. Vrain and the Clinch River Breeder Reactor which was cancelled during the Reagan administration.

Dawn of Environmental Activism

- In the early days, AEC envisioned industry leading the way to reliable and safe nuclear power with government following behind to codify good practices.
- But industry fell short. Unsatisfactory engineering performance by vendors and architectural engineers (AEs) was countered by growing AEC question lists in licensing reviews. (ECCS, containments, dynamic load combinations, metallurgy, analysis, seismic forcing functions, chemistry, etc.)
- AEC could have told industry to stop and get it right, but AEC was conflicted by promoting and regulating at the same time. AEC Regulatory Staff studiously avoided being critical path.
- Then along came the environmental movement: Union of Concerned Scientists (UCS) 1969, National Environmental Policy Act (NEPA) 1970, Natural Resources Defense Council (NRDC) 1970.
- May 1969 – Minnesota proposed effluent radiation standards << AEC's Gofman, Tamplin, and Sternglass joined the fray. DPOs erupted inside AEC and the regulators won out.
- Licensing hearings became contentious. By 1971 UCS had stalled more than a dozen hearings on the ECCS issue.

Developing the Independent Regulator 1975-1979

Environmental Activism, Cont.

- 1971 Roisman intervention on licensing of Calvert Cliffs led to Environmental Impact Statement (EISs) for all plants.
- 1972 BEIR Committee, National Academy of Science – linear no-threshold dose effects.
- 1972-74 AEC Rulemaking Hearing on ECCS. DPOs split staff and Labs. 50.46/App. K.
- 1974 – As Low as Practical/As Low as Reasonably Achievable (ALAP/ALARA) Rulemaking Hearing. 60 environmental groups intervened. AEC introduced ALARA for limiting exposure to radiation in 10 CFR 50 Appendix I in 1975.
- 1974 Arab Oil Embargo led to Nixon's and AEC's Project Independence – 1000 NPPs by 2000. There was a push to streamline licensing requirements and procedures.
- Public concern for safety and AEC's internal conflicts of interest led to Energy Reorganization Act of 1974, creating NRC in January 1975.

NRC Establishes its Independence

- As NRC issued more detailed licensing requirements in Regulatory Guides, Standard Review Plans and Branch Technical Positions, industry capitulated, “just tell us what you want.”
- NRC didn't have a corner on talent, but the pressure to get licensing done and off the critical path was strong, and NRC staff had greater success resolving issues in contested hearings.
- This deferral to NRC, a reversal of original intentions, persisted until Three Mile Island (TMI) and then it accelerated. It reduced uncertainty for license applicants and sped things up, but it let license reviewers decide engineering issues, rather than reviewing industry's solutions for engineering issues.

NRC Establishes its Independence, Cont.

- Various other initiatives were undertaken to reduce licensing and financial uncertainty, including standard designs and the NRC/American National Standards Institute (ANSI) national nuclear standards program.
 - American Society of Mechanical Engineering (ASME)
 - Institute of Electrical and Electronics Engineers (IEEE)
 - American Nuclear Society (ANS)
 - American Welding Society (AWS)
- This program helped to limit the power of individual license reviewers.
- To reach agreements in this period, NRC staff tended to deal with designers rather than through owner/operators. This mistake persisted until it was revealed by events at TMI in 1979.

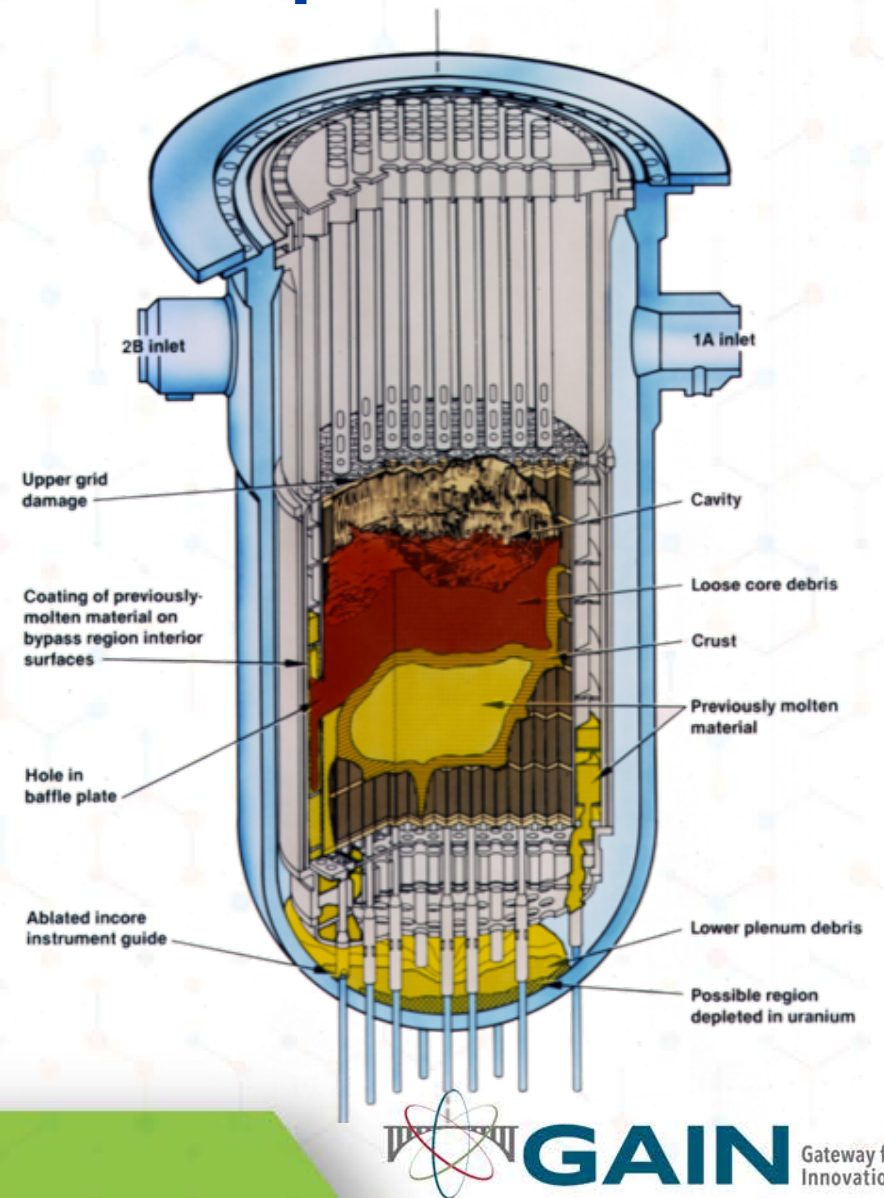
The Reactor Safety Study, NUREG 1400, October 1975

- Study met ACRS resistance. Probabilities and uncertainties were novel concepts.
- Regulatory staff began to apply the study in limited areas, e.g., anticipated transient without scram (ATWS) and sabotage.
- Congress mirrored ACRS concerns and forced NRC to not rely on Probabilistic Risk Assessment (PRA) in licensing.
- The 1979 TMI event resembled key aspects of WASH-1400 – high pressure core melt.
- Overnight, PRA was in vogue – risk-informed development of TMI requirements and oversight of operating reactors, use of PRA in Limerick 1 environmental hearing, PRA standards, seismic PRAs, plant-specific PRAs, risk monitors in the control rooms.
- But operating license conformance was and is still required because of tie between licenses and safety bases. However, risk-based technical specifications have been allowed since mid-1990s.
- And even today, deterministic methods are favored by some, including ACRS.

Correcting for Operational Experience 1980 to Today

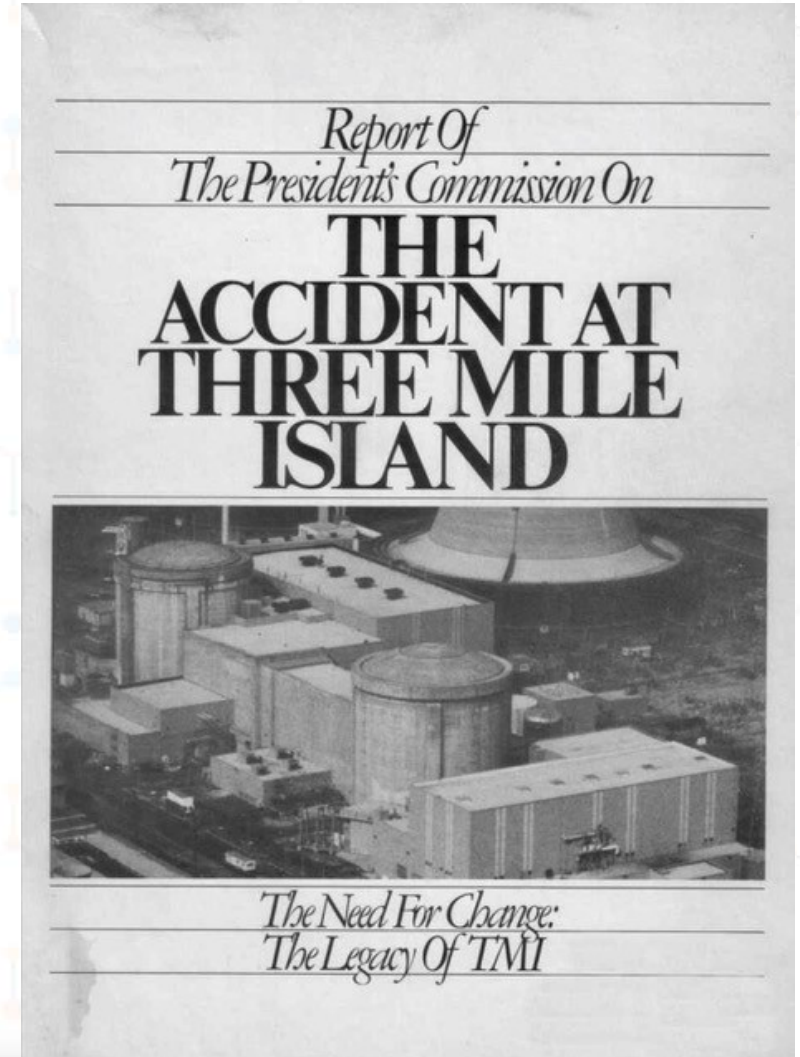
Events Shaped Regulatory Landscape

- **1975 Browns Ferry Fire** – Candle-induced fire in electric cabling of Unit 1 while running at full power led to simultaneous failures in several plant safety systems. (BTP & 50.48 resulted)
- **1979 Three Mile Island Core Melt** – Resin blockage in condensate polisher led to water hammer, feedwater transient, turbine trip, reactor trip, stuck open pilot-operated relief valve (PORV). Operator error converted the upset to a high-pressure core melt sequence. They turned off the ECCS.
- TMI revealed inadequacies in operator training, emergency operating procedures, human machine interface, simulators, reactor instrumentation, reactor vents, emergency preparedness.



Events Shaped Regulatory Landscape, Cont.

- Presidential commission: Myopia and hubris led to mindsets and complacency.
- Improvements were mandated in procedures, operations, equipment, instruments, simulators, analysis of operating experience, control rooms, and preparedness—multi-billion-dollar backfits and delays and dozens of cancelled plants. (TMI Action Plan, NUREGs 0660 and 0737)
- Creation of Institute of Nuclear Power Operations (INPO) – peer pressure, self-insurance through Nuclear Electric Insurance Limited (NEIL)/INPO tie, training, inspections.
- The most far-reaching changes in operational reliability occurred over next several years.



Events Shaped Regulatory Landscape, Cont.

- **1983 Salem (ATWS precursor)** – During startup following refueling, low water level in steam generator on Unit 1 sent a scram signal to two reactor trip breakers which failed to function. The last straw in operational reliability leading to 1991 Maintenance Rule (10 CFR 50.65)
- **1985 Davis Besse (loss of feedwater)** – Multiple common cause failures owed to design, operation, and maintenance inadequacies with far-reaching implications for nuclear industry. Led to risk-oriented criteria for auxiliary feedwater (AFW) systems in PWRs.
- **1987 Peach Bottom (sleeping operators)** – NRC ordered both operating reactors at Peach Bottom to shut down. Control room operators had been routinely sleeping in control room. Inspections revealed thousands of nonconformances with design. Dozens of other plants found to have similar issues with design basis conformance.
- **Late 1980s-1990s Troubled Plants** – Many operating plants experienced extended shutdowns because of operational performance problems or events, including 14 of 27 plants in NRC Region III.

Events Shaped Regulatory Landscape, Cont.

- **1989 Chernobyl Disaster** – Suppression of design flaws and lax operational discipline led to a catastrophic event that spread radiation over much of Northern Europe. Dozens died early, many later. Huge socio-political-economic consequences.
- **2002 Davis Besse hole in reactor head** – Undermined licensing presumption that reactor vessels don't fail. Other heads replaced.
- **2011 Fukushima Daiichi** – Historic earthquake and tsunami led to loss of four plants and widespread contamination. Few deaths. Huge socio-political-economic consequences.



Summary Observations

Summary Observations

- Regulation provides a framework within which minimum standards are established and safety is reviewed on each license application.
- The NRC has depended on professional standards organizations to develop technical consensus for reliance by NRC and nuclear industry in meeting licensing requirements.
- Industry experience gained at TMI led to the formation of the INPO, which promotes excellence in operation of licensed plants.
- Fulfilling regulatory requirements and obtaining a certification or license does not make a reactor safe.
- Adequate design for nuclear safety is responsibility of developer/designer with oversight by owner/operator, not NRC.
- Ultimate responsibility for safe design and operations rests with license holder, not NRC.
- Liability for protection of public and environment belongs to the license holder.

Summary Observations, Cont.

- Dichotomy: New reactor developers want NRC to define what constitutes reasonable assurance of adequate safety in performance terms, but without as much detail as in the past on how to get there.
- That approach failed when AEC entrusted early LWR developers and licensees to define and achieve adequate safety. The future holds an opportunity to get it right the second time.
- Industry failed to fulfill its role, especially in public hearings (e.g., ECCS and ALARA) and operational performance (e.g., TMI, human reliability and maintenance).
- Faced with no alternative for getting and keeping plants licensed, AEC/NRC became more prescriptive, changing requirements in response to emerging events.
- Prescriptiveness reduced business risk for investors in future plants but shifted burden of responsibility.

Summary Observations, Cont.

- By late 1980s, nearly everyone concluded NRC had overdone prescriptiveness, and by 1995 NRC moved towards performance-based, risk-informed regulation.
- Safety has improved. Design and operating features have improved to reflect changes in technology, socio-political factors, and operating experience.
- Significant improvements have been made in operational reliability, including plant availability.
- Nuclear energy is important in attaining domestic goals for decarbonization and power system diversity, reliability, and resilience.
- Innovative and advanced reactor technologies may offer greater assurance in demonstrating that adequate levels of safety are achieved.
- Nuclear energy is viable if socio-political-economic consequences like those of TMI, Chernobyl, and Fukushima are prevented in the future.