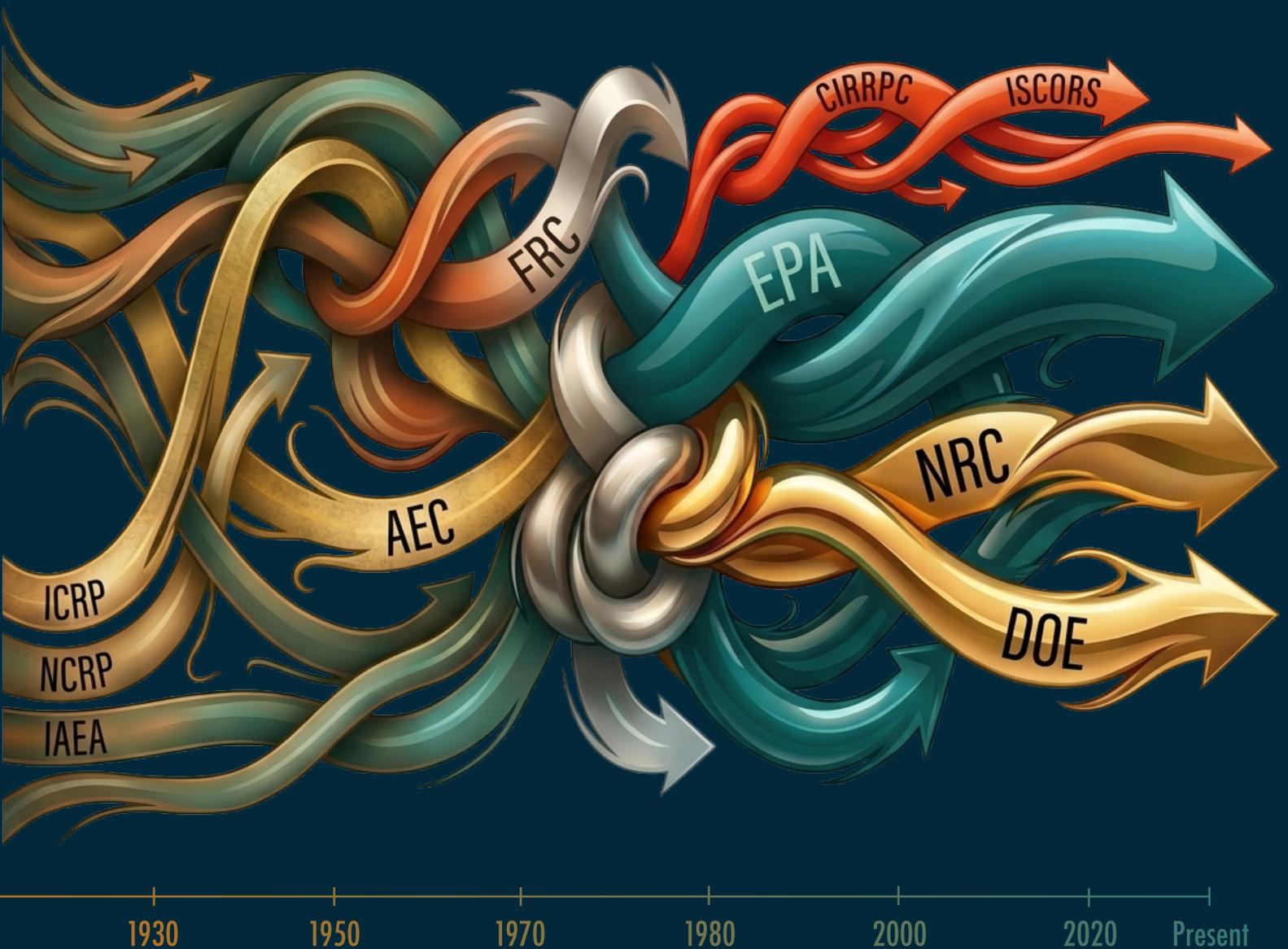


DECAY FRAGMENTS: A HEALTH PHYSICS HISTORY

America's Radiation Protection Regulatory System
and How it Came to Be



AUTHOR: PJ SEEL

I. EXECUTIVE SUMMARY

Debates about radiation protection regulation in the United States often center on scientific risk models or how stringent exposure limits should be. Those debates are real, but they obscure a more consequential fact. The federal government regulates the same physical hazard through multiple statutes administered by different agencies, each operating under distinct mandates, analytical frameworks, and acceptable risk thresholds. The result is a system in which legally acceptable exposure levels can vary dramatically depending on which regulatory program applies rather than the underlying risk being addressed.

This is not a result of regulatory incompetence. Regulations had to be established under genuine scientific uncertainty, and early standard-setters acted with the evidence available to them. The problem is that the system never received a comprehensive reassessment. The closest attempt was the parallel revision of Part 20 and the Clean Air Act (CAA) radionuclide standards during the 1980s and early 1990s. But it only produced negotiated compromises rather than coherent reform, leaving underlying statutory conflicts intact.

Most analyses treat these differences as technical disagreements or as disputes over scientific judgment. That interpretation misses the more important explanation. The structure of the regulatory system itself is the root cause of how certain policies became embedded and why they persist. What appears to be a collection of technical inconsistencies is in fact the accumulated outcome of institutional decisions made across decades. Once embedded in statute and regulatory practice, those decisions created a system that can appear internally rational within individual programs while remaining inconsistent across the federal system as a whole. Each response addressed real problems, but collectively, they produced a system that no one would design from scratch.

The purpose of this report is to examine how the current regulatory structure emerged and to clarify the institutional mechanisms that produced it. Understanding how this system accumulated is necessary for distinguishing reforms that are administratively achievable from those that require legislative change. Without that historical and institutional perspective, reform proposals often target symptoms of fragmentation rather than the conditions that sustain it.

The report draws on historical policy analysis of federal radiation regulation, including the development of regulatory guidance, statutory authorities, and agency responsibilities over time. It examines the institutional evolution of the system through major policy episodes such as fallout regulation in the 1950s, environmental legislation in the 1970s, and the reorganization that created the Nuclear Regulatory Commission. The analysis focuses on how statutory mandates, regulatory objectives, and administrative coordination mechanisms interacted to produce the present system.

Three consistent findings emerge from this analysis:

1. Radiation protection standards have tended to tighten through discrete regulatory actions rather than through comprehensive reassessment of the underlying risk framework. Once lower exposure levels were demonstrated to be technically achievable, regulatory expectations frequently shifted downward. These decisions were rarely revisited even when scientific understanding or policy priorities changed, contributing over time to divergence among regulatory programs.
2. Environmental statutes emphasize population risk and environmental protection, while nuclear regulatory statutes emphasize operational safety and controlled exposures within licensed activities. Agencies implementing these mandates therefore employ different analytical methods, metrics, and acceptable risk thresholds. When applied to similar exposure pathways, these frameworks can produce dramatically different regulatory outcomes.
3. Administrative mechanisms such as memoranda of understanding, interagency working groups, and coordinated rulemakings have repeatedly been used to manage conflicts among agencies. These efforts can align terminology, share technical analysis, and reduce procedural conflict. They cannot reconcile statutory requirements that embed fundamentally different regulatory goals.

These findings have direct implications for reform. Administrative action can improve coherence where agencies have flexibility to harmonize definitions, analytical assumptions, and implementation guidance within existing authority. Such steps can reduce unnecessary inconsistency and procedural conflict. However, the most consequential divergences arise from the interaction between statutes enacted for different purposes, particularly environmental protection statutes and the Atomic Energy Act. Where statutory mandates require agencies to pursue incompatible regulatory objectives, administrative coordination alone cannot resolve the conflict.

To understand why each treatment has failed to solve these issues, and how to approach the future, diagnosing the underlying causes of fragmentation is needed. Reform efforts should begin by recognizing that the current system is the product of institutional accumulation rather than a single flawed policy decision. Distinguishing between administrative inconsistencies and statutory conflicts is a precondition for designing reforms that can succeed. Without that distinction, proposals for harmonization will continue to encounter the same structural barriers that have shaped radiation regulation for decades.

II. INTRODUCTION

Radiation protection regulation has become a central, if often implicit, constraint on nuclear energy deployment in the United States. Recent executive actions calling for a “nuclear renaissance,” accelerating licensing timelines, and reconsidering foundational assumptions such as the linear no-threshold model and ALARA reflect a growing recognition that the regulatory system is not functioning as intended.^{1,2} Yet debates over individual standards or scientific assumptions often obscure a more fundamental issue: the structure of radiation regulation itself.

Today, radiation protection authority is fragmented across multiple agencies operating under distinct statutory mandates and regulatory philosophies. This arrangement has produced widely varying acceptable risk thresholds, prolonged interagency disputes, and repeated delays in regulatory reform. The fragmentation is not the product of deliberate institutional design but of successive reorganizations and rulemakings, each responding to the previous era's credibility crisis, court orders, international recommendations, or public controversy. Each addressed an immediate problem while creating new coordination failures. Yet, because no single institution is clearly accountable for system-level coherence, this structural dysfunction is routinely treated as a technical or coordination challenge rather than an institutional one. Dose limits across federal agencies have varied by as much as 100,000-fold for the same physical hazard, differing by agency and regulatory context rather than by the underlying risk. Without a clear understanding of how this fragmentation became embedded and why it persists, reform efforts tend to target symptoms rather than causes.³

This paper examines how past decisions have shaped the regulatory state that exists today and why that state has proven so resistant to change. It uses historical events to illuminate several recurring mechanisms: statutory incompatibility, coordination without decision authority, reactive rulemaking, and political dynamics that reward caution and delay. These factors

¹ Exec. Order No. 14300, *Ordering the Reform of the Nuclear Regulatory Commission*, 90 Fed. Reg. 22,587 (May 29, 2025).

² Exec. Order No. 14302, *Reinvigorating the Nuclear Industrial Base*, 90 Fed. Reg. 22,595 (May 29, 2025).

³ PJ Seel and Adam Stein, “The Current State of Radiation Protection in the United States: Fragmented, Mission-Specific, and Conflicting without Improving Safety Outcomes,” The Breakthrough Institute, December 2, 2025, <https://thebreakthrough.org/issues/nuclear-energy-innovation/the-current-state-of-radiation-protection-in-the-united-states>.

substantially explain why fragmentation persists even when agencies share technical expertise, operate in good faith, and recognize the need for reform. By clarifying how the current system came to behave as it does, the analysis aims to distinguish between problems that can be addressed through administrative action and those that require structural change.

III. THE CURRENT REGULATORY LANDSCAPE

America's radiation protection system was not designed; it accumulated. Before the government claimed jurisdiction, expert committees (the ICRP internationally, the NCRP domestically) developed workable standards through scientific consensus. The Atomic Energy Commission (AEC) incorporated these recommendations wholesale when it assumed unified authority in 1946, concentrating weapons development, civilian promotion, standard-setting, and safety regulation in a single agency. This arrangement had obvious tensions, but it also had a single point of accountability.

That unity unraveled in stages. The Federal Radiation Council (FRC) was created in 1959 to coordinate across agencies. The 1970 transfer of radiation functions to the newly created EPA split authority between agencies operating under incompatible statutory frameworks: the AEA's qualitative standards and the NRC's deterministic dose-based implementation, versus the CAA's risk-based methodology. The Energy Reorganization Act dissolved the AEC, creating the NRC as an independent regulator and what became the DOE as the successor to the AEC's promotional and weapons functions. This better addressed the innate tensions of the dual role but set each organization on its own regulatory path. Each successive reform responded to the previous era's failures while creating new coordination problems that would surface later.

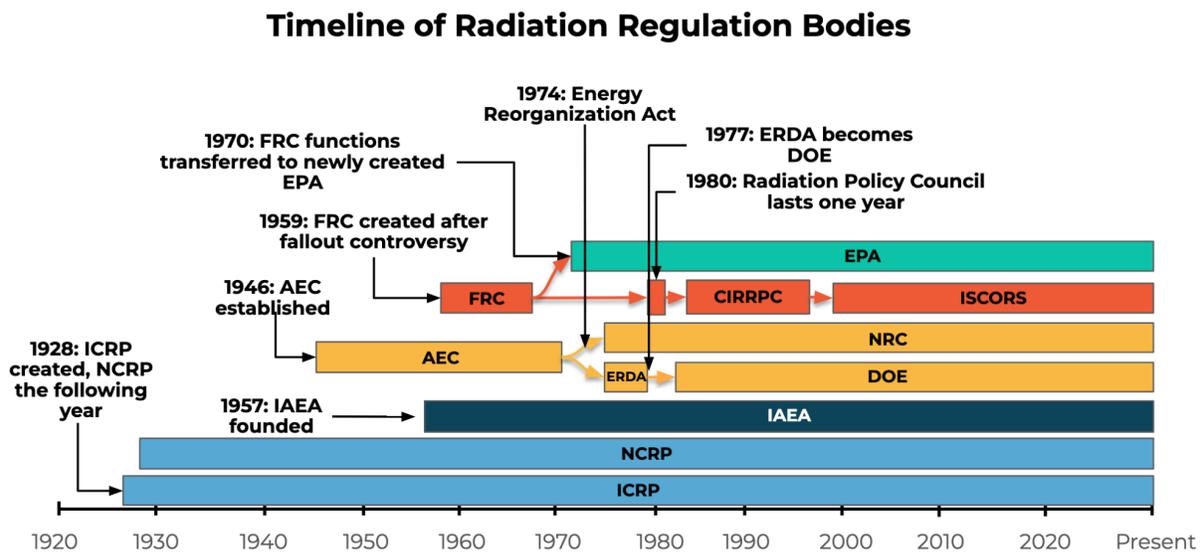


Figure 1. Chronology of Current and Historic Authorities on Radiation Protection in the USA

The slow accumulation of government agencies made distinct silos. Voluntary mechanisms were created to prevent different authorities from infringing on respective domains. However, nuclear technologies are regulated more than most other technical fields and the multi-step devolution of authority has inadvertently made even the underlying physical risks of radiation become a topic of debate across agencies that must work with one another. Later attempts at replicating the FRC solved smaller technical matters but repeatedly showed the limits of voluntary coordination between agencies with diverging priorities and separate mandates.⁴

Current Jurisdictional Distribution

Today, federal radiation protection authority is distributed across multiple agencies, each operating under distinct statutory frameworks.

TABLE 1. SUMMARY OF THE CURRENT JURISDICTIONAL DISTRIBUTION OF FEDERAL RADIATION AUTHORITY.

AGENCY	AUTHORITY	KEY REGULATIONS	FRAMEWORK
NRC	AEA licensees	10 CFR 20	Dose-based
EPA	Environmental standards	40 CFR 61, 190, 197	Risk-based
DOE	Federal facilities, NNSA	10 CFR 835	Dose-based w/ ACLs
OSHA	Non-AEA workers	29 CFR 1910.1096	1971 AEC standards
Agreement States	Delegated materials	Varies	Compatible with NRC
NASA	Astronauts	Internal SPELs, STD-3001	Mission-specific
FAA	Aircrew	Advisory only: AC 120-61B	Guidance, no binding limit
DoD	Military personnel	DoDI 6055.08, defers to NRC/FPG	Adopts existing frameworks

⁴ For a detailed account of this institutional evolution, see Supplement 1 for a deeper historical analysis of US radiation protection and Supplement 2 for the history of coordinating bodies. Focusing on some of the most indicative policy decisions can illustrate this historical trend most clearly.

The vast majority of regulation is held within the primary regulatory triad of the NRC, EPA, and DOE. Some of the fragmentation is functional and rational. NASA establishes mission-specific, risk-based radiation exposure limits for astronauts, reflecting the fundamentally different radiation environment encountered in low-Earth orbit and deep space, where galactic cosmic radiation and solar particle events dominate exposure pathways. Existing standards explicitly recognize that interplanetary missions will require further revision as crews operate beyond the protective influence of Earth's magnetic field.⁵

Some of the fragmentation exists as de facto gaps. The Federal Aviation Administration, by contrast, addresses cosmic radiation exposure to aircrew through advisory guidance rather than enforceable dose limits, leaving one of the most highly exposed occupational groups in the United States governed by nonbinding recommendations.⁶ The European Union has taken a different approach, requiring airlines to assess, monitor, and record aircrew radiation exposure under binding Euratom directives.⁷

The Occupational Safety and Health Administration (OSHA) retains an ionizing radiation standard largely unchanged since 1971, covering residual categories of non-NRC-regulated sources such as medical and dental X-ray equipment, certain industrial radiography activities, and some particle accelerators.⁸ The OSHA regulation continues to permit dose calculation using the age-prorated 5(N–18) formula, an approach abandoned by every other federal radiation protection authority.⁹

Although no single statute or policy document explicitly assigns the Department of Defense (DoD or DoW) to use NRC-derived radiation protection standards rather than DOE/NNSA internal limits, historical practice following the dissolution of the AEC demonstrates that DoD consistently aligned with the regulatory radiation protection framework inherited by the NRC.

⁵ National Aeronautics and Space Administration, *NASA Space Flight Human-System Standard, Volume 1: Crew Health (NASA-STD-3001, Rev. B)*; National Aeronautics and Space Administration, *NASA Procedural Requirements for Limiting Exposure to Ionizing Radiation (NPR 8715.26)*; National Security Presidential Memorandum-20, *National Policy for Nuclear Power Sources in Space*.

⁶ Federal Aviation Administration, *In-Flight Radiation Exposure (Advisory Circular 120-61B)*; Federal Aviation Administration, Office of Aerospace Medicine, *Cosmic Radiation Exposure of Aircrew*.

⁷ Council of the European Union, *Council Directive 2013/59/Euratom of 5 December 2013 Laying Down Basic Safety Standards for Protection Against the Dangers Arising from Exposure to Ionising Radiation*, Official Journal of the European Union L13 (2014).

⁸ Occupational Safety and Health Administration, *Ionizing Radiation*, 29 C.F.R. § 1910.1096 (1971).

⁹ *Ibid.*; National Council on Radiation Protection and Measurements, *Limitation of Exposure to Ionizing Radiation (NCRP Report No. 116)*.

This alignment reflects the NRC's role as the federal government's generally applicable radiation regulator, whereas DOE/NNSA standards were developed for internal self-regulation of weapons and laboratory operations. The fact that the DoD references the 1987 occupational guidance further highlights this habit of deferring to generally applicable civilian regulation, outside of warfare-focused guidance.

IV. THE PATTERN: LAGGING RESPONSE AND COORDINATION FAILURES

Voluntary coordination mechanisms do not resolve fundamental inter-agency disputes on radiation protection. This is the central lesson of seven decades of institutional history. The FRC, the Radiation Policy Council, CIRRPC, and ISCORS each achieved technical alignment on uncontroversial matters (dose conversion factors, survey methodologies, analytical protocols) but failed when agencies' statutory frameworks pointed toward different conclusions. No administration has undertaken an earnest effort to resolve the overlapping authority problem. Instead, the consistent pattern has been to create new coordination bodies on top of existing regulatory structures, without providing the authority necessary to compel resolution. Each body was created as a response to perceived coordination failures, and each reproduced the same limitation: voluntary participation with no consequence for deadlock.

These coordination bodies didn't completely fail at their assigned tasks. The FRC produced useful guidance; CIRRPC coordinated research; ISCORS standardized methodologies. But, none were designed to resolve the underlying authority conflicts. Each was a band-aid applied to symptoms while the structural condition persisted.

Beyond coordination failures, radiation protection standards exhibit a characteristic pattern that compounds fragmentation: they tighten based on operational achievability rather than demonstrated health necessity, and once tightened, they rarely relax regardless of subsequent evidence. It's a regulatory ratchet.

The ratchet also creates a temporal mismatch between rulemaking cycles and coordination efforts. The NRC's revision to Part 20 consumed 11 years. The CAA radionuclide dispute consumed almost 20 years. Coordination bodies operate on political timelines (the Radiation Policy Council lasted eleven months) while major rulemakings extend across multiple administrations. By the time one agency completes a revision, the scientific consensus or international recommendations that informed it may have evolved, and other agencies may be at different points in their own revision cycles.

When the NRC finally revised Part 20 in 1991, it retained the 5 rem/year occupational limit rather than adopting ICRP's 2 rem/year recommendation, reasoning that actual exposures were already "mostly theoretical" relative to the limit. DOE, however, moved toward 2 rem/year as an administrative control level. OSHA's ionizing radiation standard remains fundamentally unchanged since the agency inherited AEC-era limits in 1971, despite subsequent interpretive

guidance and enforcement deference to the NRC and Agreement States. The result: three agencies operating under three different numerical limits, all nominally informed by the same underlying science, with the differences reflecting institutional judgment about implementation rather than disagreement about health effects.¹⁰

Once established, lower limits prove nearly impossible to relax even when evidence might support reconsideration. The political economy is asymmetric: proposing stricter standards can be framed as protective, while proposing relaxation invites accusations of favoring industry over public health. When the NRC considered but declined to further reduce limits after BEIR-V, it acknowledged that "assumptions are necessary because it is generally impossible to determine whether or not there are any increases in the incidence of disease at very low doses and low dose rates."¹¹ The NRC's position was that the absence of observed effects did not justify relaxation; it merely counseled against further tightening.

This asymmetry means effective coordination occurs before standards tighten, not after. Yet the coordination bodies that might achieve such alignment have consistently lacked the authority, longevity, or institutional weight to influence rulemakings that span decades.

¹⁰ J. Samuel Walker, *Permissible Dose: A History of Radiation Protection in the Twentieth Century* (Berkeley: University of California Press, 2000), 134.

¹¹ 56 Fed. Reg. 23,363 (May 21, 1991) ("[A]ssumptions are necessary because it is generally impossible to determine whether or not there are any increases in the incidence of disease at very low doses and low dose rates.").

V. PIVOTAL REGULATIONS AS CASE STUDIES

The preceding institutional history explains how authority fragmented. The following case studies illustrate what fragmentation produces in practice. Each demonstrates a distinct manifestation of the underlying structural problem:

1. The public dose limit changes trace reactive incrementalism: a dozen discrete actions over five decades, each responding to immediate pressures rather than systematic design.
2. The CAA radionuclide dispute reveals a statutory incompatibility so fundamental that neither agency action nor voluntary coordination could resolve it; only Congressional intervention provided an exit.
3. The ALARA study shows how shared vocabulary can mask incompatible implementations, with agencies using identical language to describe fundamentally different regulatory approaches.
4. The Below Regulatory Concern endeavor demonstrates that even explicit Congressional mandates cannot insulate technical policy from political volatility.
5. The continuing debate over Spent Nuclear Fuel and Waste synthesizes these dynamics.

Case Study Timelines

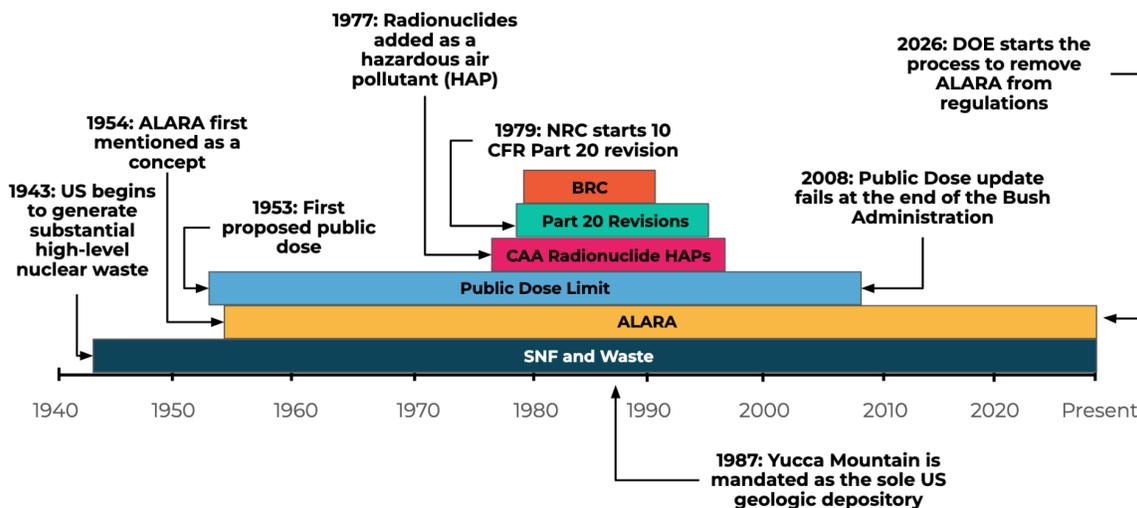


Figure 2. Timeline Showing the Overlap of Important Case Studies in Radiation Protection. Note that while the Part 20 revisions aren't themselves case study, they overlapped and influenced all of the others.

Together, these cases reveal patterns invisible in abstract institutional description: multi-decade disputes, memoranda of understanding that defer rather than resolve disagreements, and ongoing coordination failures.

1. The Public Dose Limit: From One-Tenth to 10

The public dose limit in the United States is not a single number. NRC licensees operate under a 100 mrem/year limit from all licensed activities. EPA's fuel cycle standard imposes 25 mrem/year for the uranium fuel cycle. The 1992 EPA-NRC memorandum established a 10 mrem/year goal for non-reactor licensees. DOE facilities operate under 100 mrem/year but with distinct administrative control levels. A member of the public living near multiple regulated facilities could theoretically be subject to different dose accounting depending on which agency regulates which source.

This patchwork creates compliance complexity without demonstrated health benefits and creates regulatory uncertainty for new technologies. Advanced reactors, fuel cycle facilities, and medical isotope production must navigate overlapping requirements that were designed for a different industrial landscape. When agencies' numerical limits diverge, licensees face the practical challenge of determining which standard governs which pathway.

The EPA's fuel cycle standard and the NRC's Part 20 limit created a situation where nuclear facilities effectively operated under EPA's stricter standard while the NRC maintained the higher limit for its regulatory framework.

The variation in background radiation in the U.S. (approximately 3.6 mSv (360 mrem)) is five times greater than the difference between the NRC public dose limit and the higher EPA limits (100 vs 75 mrem). Denver residents receive approximately 0.5 mSv (50 mrem) more cosmic radiation per year than coastal residents.¹² Yet facilities must demonstrate compliance with each applicable limit separately, and the limits themselves reflect different eras of rulemaking rather than a unified assessment of acceptable risk.

How We Got Here: Public Dose Limits

The public dose limit evolved through nine discrete actions over five decades, each responding to immediate pressures rather than systematic design.

¹² National Council on Radiation Protection and Measurements. 2009. *Report No. 160 - Ionizing Radiation Exposure of the Population of the United States* (2009). <https://ncrponline.org/shop/reports/report-no-160-ionizing-radiation-exposure-of-the-population-ofthe-united-states/>.

1953: The ICRP first proposes that doses to the public be kept to one-tenth of the occupational dose. The NCRP resisted this to prevent "the appearance of a double standard."¹³

1957: With the first promulgation of 10 CFR 20, the AEC included the one-tenth standard, thus 500 mrem became a de facto value with the 5 rem occupational limit.¹⁴

1960: The Federal Radiation Council established a 500 mrem/year individual limit and 170 mrem/year population average.¹⁵

1977: EPA issued 40 CFR 190 with a 25 mrem/year fuel cycle standard, creating a de facto stricter limit for nuclear facilities. This was EPA's first major exercise of its transferred radiation authority, establishing a precedent for source-specific standards below the general limit.¹⁶

1979: The NRC launched a major review of Part 20, its basic radiation protection regulations, finding the 1960-era rules "badly outdated."¹⁷

1987: NCRP Report No. 91 recommended 100 mrem/year as the public dose limit—a four-fold reduction from the FRC's 1960 guidance.¹⁸

1990: BEIR-V published. NRC staff considered but declined to further reduce exposure limits, noting that doses were far below permissible levels with ALARA.¹⁹

1991: The NRC finalized Part 20 revisions, adopting 100 mrem/year as the public dose limit from all licensed activities, with compliance required by January 1994. The revision consumed more than eleven years from the first serious review to final rule.²⁰

¹³ ICRP, *Recommendations of the International Commission on Radiological Protection*, Publication 1 (Oxford: Pergamon Press, 1959).

¹⁴ 10 C.F.R. § 20 (1957).

¹⁵ FRC Report No. 1 (1960).

¹⁶ 40 C.F.R. § 190.10 (1977).

¹⁷ U.S. Nuclear Regulatory Commission, *Proposed Revision of 10 CFR Part 20*, SECY-79-139, (May 1979).

¹⁸ NCRP Report No. 91, *Recommendations on Limits for Exposure to Ionizing Radiation* (Bethesda, MD: NCRP, 1987).

¹⁹ Walker, *Permissible Dose*, 121.

²⁰ 56 Fed. Reg. 23,360 (May 21, 1991).

2002—2008: The EPA, once again, considered revising the FRC guidance, but internal conflict about whether an overall public limit should be removed and a source-specific 25 mrem limit retained, or just committing to 100 mrem from all sources, stalled the conversation and the effort died at the end of the second Bush presidency.

2. Clean Air Act: Radionuclide Standards and NESHAPs

NRC licensees today operate under a 1992 memorandum of understanding between the EPA and NRC that proved sufficient to end the nearly two decade dispute over CAA regulation of radioactive emissions. However, that created a system where any future rulemaking affecting NRC licensees' airborne emissions must navigate both frameworks simultaneously. Even when both agencies agree on appropriate protection levels, they may reach different numerical conclusions because their statutes require different approaches.

The MOU remains in effect, but it rests on EPA's discretionary forbearance rather than statutory reconciliation. EPA agreed not to enforce its CAA standards for NRC licensees, contingent on the NRC maintaining regulations that provide an "ample margin of safety." The underlying statutory conflict between the AEA's dose-based framework and the CAA's risk-based framework remains unresolved.

This arrangement creates latent regulatory risk. The MOU could theoretically be rescinded by either party, reopening disputes over standards that differ by factors of two to eight. More practically, the arrangement's stability depends on NRC's implementation of ALARA. Any NRC decision that could be characterized as relaxing that standard invites challenge under the MOU's "ample margin of safety" condition, potentially reopening the statutory conflict the arrangement was designed to avoid.

Why Congressional Intervention Was Required

Neither the EPA's radiation protection staff nor the NRC viewed CAA regulation as a scientifically useful or necessary approach to radiation protection, even as EPA lawyers concluded that the statute and court decisions compelled regulatory action. An EPA official commented, "Dose is really what counts, and from a scientific standpoint, is logical. There is really nothing to be accomplished by setting emissions standards."²¹ Both agencies considered the dose-based approach superior to ambient air standards.

²¹ Walker, *Permissible Dose*, 121.

Court decisions drove policy in directions neither agency preferred. The benzene rule precedent required the EPA to consider only health effects in setting initial risk levels, compelling the agency to propose standards inconsistent with its own technical judgment about appropriate regulatory approaches. The agencies could not resolve the dispute through voluntary coordination because their statutory frameworks pointed toward incompatible conclusions.

Almost 20 years elapsed from the 1977 CAA amendments until the EPA rescinded its 1985 NESHAP standards in 1996 to formalize MOU. The agreement required Congressional intervention (1990 CAA amendments) before the agencies could reach an accommodation. For years prior to resolution, the EPA and the NRC disputed whether the appropriate standard should be 25 mrem or 15 mrem (a dose difference achievable in a single transatlantic flight). The dispute consumed substantial agency resources while producing no improvement in public health protection.

How We Got Here: NESHAPs

1977: Congress added radionuclides to the list of hazardous air pollutants in the CAA amendments. This provision, a late addition to the legislation, caught the nuclear industry and federal agencies off-guard. The Act required the EPA to regulate radioactive air pollutants if they could "reasonably be anticipated to endanger public health."²²

1979: EPA made the endangerment determination, triggering an obligation to issue standards for radioactive pollutants by June 1980.²³

1981: The EPA delayed action, arguing existing dose limits fulfilled the Act's requirements. The Sierra Club filed suit.²⁴

1982: Court ordered the EPA to issue standards within 180 days.

1983: The EPA proposed air quality standards for radionuclides, including a 10 mrem/year limit for NRC licensees.²⁵

1984: EPA Administrator William Ruckelshaus, persuaded that the originally proposed levels were unnecessarily strict, announced withdrawal of the proposed regulations. He indicated preparedness to "de-list" radionuclides from hazardous

²² Clean Air Act Amendments of 1977, Pub. L. No. 95-95, § 112, 91 Stat. 685.

²³ 44 Fed. Reg. 76,738 (Dec. 27, 1979).

²⁴ Sierra Club v. Ruckelshaus, No. C-81-2436 (N.D. Cal. Sept. 30, 1982).

²⁵ 48 Fed. Reg. 15,076 (Apr. 6, 1983).

air pollutants if found in contempt of court.²⁶ Judge William Orrick found Ruckelshaus and the EPA in contempt of court.

1985: Faced with the contempt citation and lacking a statutory basis for de-listing, the EPA issued new standards: 25 mrem/year whole-body and 75 mrem/year single-organ for NRC and DOE facilities.²⁷

1987: *Natural Resources Defense Council v. EPA* (the vinyl chloride/benzene decision) ruled that EPA could consider only health effects in setting initial risk levels. The EPA interpreted this as requiring reassessment of its radionuclide standards.²⁸

1989: The EPA proposed new standards ranging from 10 mrem/year to 0.3 mrem/year for NRC licensees.²⁹

1990: Congress amended the CAA to allow the EPA discretion to refrain from regulating NRC licensees if the NRC limits provided "ample margin of safety."³⁰

1992: The EPA and the NRC signed two memoranda of understanding, a larger structural one and a technical one on ALARA. The EPA agreed to rescind its CAA standards once the NRC issued regulatory guidance setting a 10 mrem/year goal for public exposure from non-reactor licensees.³¹

1996: The EPA officially rescinds Subpart I for both energy and non-energy uses of nuclear technology regulated by the NRC.³²

3. ALARA: A Debate as Contentious as Possibly Achievable

"As Low As Reasonably Achievable" appears throughout federal radiation regulations, creating an impression of coherence. The principle is invoked by the NRC, DOE, and in federal guidance documents. Yet each agency interprets ALARA through its own statutory framework, producing

²⁶ Walker, *Permissible Dose*, 124.

²⁷ 50 Fed. Reg. 5,190 (Feb. 6, 1985).

²⁸ *Natural Resources Defense Council v. EPA*, 824 F.2d 1146 (D.C. Cir. 1987).

²⁹ 54 Fed. Reg. 9,612 (Mar. 7, 1989).

³⁰ Clean Air Act Amendments of 1990, Pub. L. No. 101-549, § 112(d)(9), 104 Stat. 2399.

³¹ Memorandum of Understanding Between EPA and NRC, 57 Fed. Reg. 56,832 (Dec. 1, 1992).

³² 60 Fed. Reg. 46206 (Sept. 5, 1995), 61 Fed. Reg. 68972 (Dec. 30, 1996).

implementations so different that the shared vocabulary obscures rather than reflects common practice.

This divergence creates practical problems. A worker moving between NRC-licensed facilities, DOE sites, and OSHA-regulated workplaces encounters different ALARA expectations at each. A facility seeking to demonstrate ALARA compliance may satisfy one agency's interpretation while failing another's. The principle that was supposed to provide a common framework for continuous improvement instead functions as vocabulary permitting agencies to describe incompatible activities in compatible-sounding terms.

ALARA's operational success creates a paradoxical coordination problem. Achieved exposure reductions become evidence of what is "reasonably achievable," establishing new baselines that agencies adopt at different times, or that the ICRP incorporates into recommendations, citing achievability rather than health necessity. The asymmetric political economy compounds this ratchet: tightening appears protective while relaxation invites accusations of trading lives for dollars.

The NRC transformed ALARA from a philosophical aspiration into a binding legal obligation with detailed implementation requirements. Between 1973 and 2022, average measurable dose per individual at commercial reactors decreased more than ninefold.³³ The EPA's approach under the CAA translates "reasonably achievable" into MACT technological feasibility rather than dose optimization as used by other agencies and internationally. DOE's administrative control level of 20 mSv (2 rem) per year creates categorical distinctions that ALARA's continuous optimization logic does not recognize.

How We Got Here: ALARA

1954: The National Bureau of Standards Handbook 59 recommends that exposure "be kept at the lowest practicable level," the first American articulation of dose minimization beyond limit compliance.³⁴

³³ U.S. Nuclear Regulatory Commission. *Occupational Radiation Exposure at Commercial Nuclear Power Reactors and Other Facilities 2023: Fifty-Sixth Annual Report*. NUREG-0713, vol. 45. Washington, DC: U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, July 2025. <https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0713/v45/index>

³⁴ National Bureau of Standards, *Permissible Dose from External Sources of Ionizing Radiation*, Handbook 59 (Washington, D.C.: NBS, 1954).

1960: The FRC issues its first Radiation Protection Guides. The FRC guidance focuses on numerical limits but does not articulate an optimization principle.³⁵

1966: ICRP Publication 9 formally states that "any unnecessary exposure be avoided and that all doses be kept as low as is readily achievable, economic and social considerations being taken into account."³⁶

1970: The AEC proposes that radioactive releases from nuclear facilities be kept "as low as practicable" (ALAP). Industry paradoxically requests numeric targets, concerned that vague language would create licensing uncertainty.³⁷

1971: The AEC adds explicit numerical design objectives (Appendix I to 10 CFR 50), quantifying what "as low as practicable" meant for reactor effluents.³⁸

1973: ICRP Publication 22 replaces "readily" with "reasonably" and introduces a formal cost-benefit framework for optimization.³⁹

1977: ICRP Publication 26 establishes the modern radiation protection framework: justification, optimization, and limitation.⁴⁰

1981: The EPA's draft occupational guidance adopts "as low as reasonably achievable" terminology.⁴¹

1983: ICRP Publication 37 provides detailed methodology for quantifying the alpha-value (monetary cost per unit collective dose) to guide optimization decisions.⁴²

1987: The FRC Guidance for Occupational Exposure makes ALARA explicit federal policy.⁴³

1990: The ICRP announces Publication 60, reducing its recommended occupational dose limit from 5 rem to 2 rem per year.⁴⁴

³⁵ FRC Report No. 1 (1960).

³⁶ ICRP Publication 9 (1966).

³⁷ 35 Fed. Reg. 5414 (April 2, 1970).

³⁸ 36 Fed. Reg. 11,113 (June 9, 1971).

³⁹ ICRP Publication 22 (1973).

⁴⁰ ICRP Publication 26 (1977).

⁴¹ 46 Fed. Reg. 7836 (Jan. 23, 1981).

⁴² ICRP Publication 37 (1983).

⁴³ 52 Fed. Reg. 2822 (Feb. 27, 1987).

⁴⁴ ICRP Publication 60 (1991).

1991: The NRC's Part 20 revision codifies ALARA as a regulatory requirement, not merely a goal. The NRC retained the 5 rem/year limit rather than adopting ICRP's 2 rem recommendation.⁴⁵

1992: The EPA-NRC memorandum invokes both agencies' ALARA commitments, but neither agency's interpretation is reconciled with the other's.⁴⁶ The 1992 EPA-NRC memorandum succeeded because it deferred the ALARA question rather than resolving it. EPA surveys showed 95 percent of reviewed facilities already had emissions below 1 millirem per year.⁴⁷ The agencies could agree on an endpoint without agreeing on what "reasonable" meant in their respective regulatory contexts.

2007: The DOE revises 10 CFR 835, establishing an administrative control level of 2 rem/year, effectively operationalizing ALARA as "stay below the administrative level" rather than continuous optimization.⁴⁸

2021: The NRC upholds the use of LNT in part due to its support to the ongoing use of ALARA.⁴⁹

2026: The DOE starts the process to remove ALARA from their guidance and issue new rulemaking removing references to it in statute.⁵⁰

4. Below Regulatory Concern: A Congressional Seesaw

The United States has no dose-based de minimis threshold: a level below which exposures are categorically exempt from regulatory concern, regardless of source. Every other major nuclear nation has established such thresholds, following IAEA guidance (whether even the international standard of 10 μ Sv/year is reasonable is a separate question we have addressed).⁵¹ The absence of a de minimis standard means that trivial exposures receive the same regulatory

⁴⁵56 Fed. Reg. 23,360 (May 21, 1991).

⁴⁶Memorandum of Understanding Between EPA and NRC, 57 Fed. Reg. 56,832 (Dec. 1, 1992).

⁴⁷James L. Blaha to Commissioner Assistants, May 24, 1993, NRC Records.

⁴⁸72 Fed. Reg. 31,904 (June 8, 2007).

⁴⁹U.S. Nuclear Regulatory Commission, *Linear No-Threshold Model and Standards for Protection Against Radiation*, Federal Register 86, no. 157 (August 17, 2021): 45923–45948.

⁵⁰Geoff Brumfiel, *The Trump Administration Has Secretly Rewritten Nuclear Safety Rules*, NPR, January 28, 2026.

⁵¹Seel and Stein, *Drawing the Line*.

treatment as significant ones, forcing agencies to expend resources on oversight that produces no measurable health benefit.

This gap exists because the NRC's 1990 attempt to establish a "Below Regulatory Concern" policy was revoked by Congress in 1992. The episode demonstrated that even explicit Congressional mandates cannot insulate technical policy from political volatility. Three decades later, the political toxicity of BRC continues to discourage any agency from revisiting de minimis thresholds, even though the technical case for them remains sound.

Why Technical Merit Was Irrelevant

Congress mandated the policy, then Congress revoked it. The technical merits of BRC were obscured by public furor. The policy was quite modest: the proposed 10 mrem threshold was one-tenth of the public dose limit. The nuclear industry itself was "wary" of BRC, sensing "an impending public relations disaster."⁵² The driving force was NRC Chairman Kenneth Carr, committed to the policy because of the congressional mandate and his conviction that it was technically sound.

The controversy unfolded while the CAA radionuclide dispute remained unresolved, and public hostility toward the NRC was already elevated. The timing compounded the political difficulty: an agency perceived as captured by industry was proposing to exempt certain radioactive materials from regulation at precisely the moment courts were finding it in contempt for failing to regulate radioactive air emissions strictly enough. Twelve states and more than one hundred local governments passed laws prohibiting BRC practices or announcing opposition.⁵³ As with many environmental regulations, fragmentation extends below the federal level.

How We Got Here: BRC

1981–1990: NRC staff debated appropriate dose levels as part of Part 20 revisions. Internal disagreements arose between a 1 mrem individual limit and 10 mrem. The Advisory Committee on Reactor Safeguards recommended 3 to 10 mrem. EPA arrived at 4 mrem.

1985: The Low-Level Radioactive Waste Policy Amendments Act mandated that the NRC establish criteria for which radioactive waste materials posed enough risk to require specially constructed landfills and which could be disposed of in ordinary

⁵²Walker, *Permissible Dose*, 119.

⁵³Walker, *Permissible Dose*, 120.

landfills. The statutory language made "Below Regulatory Concern" the phrase of choice, overtaking the less politically charged "de minimis."⁵⁴

1990: The NRC issued its BRC policy statement, establishing 10 mrem as an interim individual limit and 1,000 person-rem as the collective dose limit.⁵⁵ Public meetings generated intense opposition. Anti-nuclear groups characterized BRC as "a trade-off of people's lives in favor of the financial interests of the nuclear industry." Audiences called for commissioner resignations or criminal indictments.⁵⁶

1991: The NRC declared a moratorium on implementation after a consensus-building process failed.

1992: The Energy Policy Act formally revoked the BRC policy statement.⁵⁷

1993: The NRC officially withdrew the policy and terminated staff action.

5. Spent Nuclear Fuel and Waste: Where Problems Converge

More than 95,000 metric tons of commercial spent nuclear fuel sit at reactor sites nationwide.⁵⁸ The United States has no licensed permanent repository and no operating consolidated interim storage facility. The Yucca Mountain project, after absorbing billions of dollars and decades of effort, remains in licensing limbo. DOE's consent-based siting process has not identified a leading candidate site. DOE has recently introduced the Nuclear Lifecycle Innovation Campus program.⁵⁹

The regulatory landscape for any future repository remains fragmented. EPA's generic repository standards (40 CFR Part 191), now four decades old, apply to any non-Yucca facility. Site-specific standards developed for Yucca Mountain (40 CFR Part 197) established different dose limits and compliance periods. If a new repository is proposed, it will face overlapping EPA and NRC jurisdiction, with standards that may or may not be reconciled depending on how Congress and the agencies choose to proceed.

⁵⁴Low-Level Radioactive Waste Policy Amendments Act of 1985, Pub. L. No. 99-240, 99 Stat. 1842.

⁵⁵55 Fed. Reg. 27,522 (July 3, 1990).

⁵⁶Walker, *Permissible Dose*, 119-120.

⁵⁷Energy Policy Act of 1992, Pub. L. No. 102-486, § 2901, 106 Stat. 2776.

⁵⁸NRC, *Spent Fuel Storage in the United States* (2024).

⁵⁹<https://www.energy.gov/articles/department-energy-seeks-hosts-nuclear-lifecycle-innovation-campuses>

The “nuclear waste problem”, in part, persists because it currently is in a stable equilibrium.⁶⁰ Spent fuel in dry cask storage at reactor sites is functionally inert, safe, and contained. The lack of pressing safety concern has repeatedly sapped political energy to solve the disposal question. But the unresolved status creates ongoing costs: ratepayer-funded storage, liability exposure for the federal government, and regulatory uncertainty for new reactor projects that must account for eventual waste disposition.

How Waste Policy Shaped Other Disputes

Nuclear waste policy is both indicative and causal of the political context in which the other radiation regulation disputes unfolded during the late 1980s and early 1990s. The selection of Yucca Mountain as the sole repository candidate in 1987 transformed what had been technical debates about dose limits into proxy battles over the legitimacy of nuclear power itself.

The sequence of events in 1990–1992 reveals how multiple regulatory disputes reinforced each other. The NRC was simultaneously finalizing Part 20 (adopting 100 mrem/year), defending BRC (at 10 mrem/year), and negotiating with EPA over CAA standards (ranging from 10 mrem to 0.3 mrem). Each proceeding cited the others. When public furor over BRC peaked, it strengthened EPA's bargaining position while undermining NRC credibility. Congressional intervention in both the CAA amendments and the Energy Policy Act reflected not technical judgment but political calculation. By directing EPA to base Yucca Mountain standards on a National Academy of Sciences study, Congress effectively created another parallel regulatory universe.⁶¹

Any future attempt to site a repository will reactivate the same political dynamics that shaped the 1987–1992 period. The 2012 Blue Ribbon Commission recommended a consent-based approach to future siting, but implementing that approach requires navigating the same fragmented regulatory landscape.⁶²

How We Got Here: Spent Nuclear Fuel and Waste

1943: The first reactor to undergo fission, Chicago Pile 1 is repurposed into two other reactors.⁶³ The X-10 Reactor, meant to produce plutonium, becomes operational at

⁶⁰Adam Stein, "Nuclear Waste Is a Wicked Problem: DOE Is Testing a Different Way Through It," The Breakthrough Institute, March 9, 2026, <https://thebreakthrough.org/issues/nuclear-energy-innovation/nuclear-waste-is-a-wicked-problem>.

⁶¹Energy Policy Act of 1992, § 801.

⁶²Blue Ribbon Commission on America's Nuclear Future, *Report to the Secretary of Energy* (2012).

⁶³Fermi, Enrico, *Experimental Production of a Divergent Chain Reaction*, Tech. Rep. CP-413 (AECD-3269), Metallurgical Laboratory, 1943.

Oak Ridge and construction begins at the Hanford site in Washington state. General Leslie Groves noted that the industrial scale production of nuclear material presented challenges "nothing like" anything that had "ever been attempted before."⁶⁴

1957: The National Academy of Sciences publishes *The Disposal of Radioactive Waste on Land*, identifying deep geologic disposal as the most promising option.⁶⁵

1970: The AEC selects an abandoned salt mine in Lyons, Kansas, as the first national repository.⁶⁶

1972: The Lyons repository effort is abandoned due to technical uncertainties and public opposition.⁶⁷

1982: The Nuclear Waste Policy Act establishes a framework for permanent geologic disposal. EPA receives authority to promulgate generally applicable environmental standards; NRC must issue licensing criteria consistent with EPA's standards.⁶⁸

1985: The EPA issues 40 CFR Part 191 standards for management and disposal of spent nuclear fuel and high-level waste.⁶⁹

1987: The Nuclear Waste Policy Amendments Act directs DOE to investigate only Yucca Mountain, Nevada (or as local politicians called it, the "Screw Nevada Bill").⁷⁰

1992: The Energy Policy Act directs the EPA to contract with the NAS to recommend site-specific standards for Yucca Mountain.⁷¹

2004: The D.C. Circuit vacates portions of EPA's Yucca Mountain draft standards, finding a 10,000-year compliance period contradicts NAS recommendations.⁷²

⁶⁴Groves, Leslie R., *Now It Can Be Told: The Story of the Manhattan Project* (New York: Harper & Brothers, 1962); Gephart, Roy E., *Hanford: A Conversation about Nuclear Waste and Cleanup* (Columbus: Battelle Press, 2003).

⁶⁵National Academy of Sciences, *The Disposal of Radioactive Waste on Land* (1957).

⁶⁶J. Samuel Walker, *Containing the Atom: Nuclear Regulation in a Changing Environment, 1963–1971* (Berkeley: University of California Press, 1992), 389-392.

⁶⁷Walker, *Containing the Atom*, 392-395.

⁶⁸Nuclear Waste Policy Act of 1982, Pub. L. No. 97-425, 96 Stat. 2201.

⁶⁹50 Fed. Reg. 38,066 (Sept. 19, 1985).

⁷⁰Nuclear Waste Policy Amendments Act of 1987, Pub. L. No. 100-203, 101 Stat. 1330.

⁷¹Energy Policy Act of 1992, Pub. L. No. 102-486, § 801, 106 Stat. 2776.

⁷²*Nuclear Energy Institute v. EPA*, 373 F.3d 1251 (D.C. Cir. 2004).

2008: EPA finally promulgates Yucca Mountain-specific standards, establishing a 15 mrem/year limit for the first 10,000 years and 100 mrem/year thereafter.⁷³

2010—present: DOE terminates support for Yucca Mountain licensing; Congress ceases appropriations. Consent-based (now collaboration-based) siting efforts continue without leading candidates.⁷⁴

⁷³40 C.F.R. Part 197.

⁷⁴U.S. Department of Energy, *Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste* (2013).

VI. POLICY IMPLICATIONS AND THE COMMON THREAD

The case studies are not five separate regulatory histories. They are five manifestations of a single, unresolved, structural problem: the absence of binding institutional authority for radiation protection decisions. Each case study reveals that voluntary coordination mechanisms prove insufficient for contested policy questions, statutory frameworks create irreconcilable obligations, and individual regulatory proceedings become proxy battles for structural tensions that no single agency can resolve. Some of the resulting inconsistencies are technical like legacy definitions and modeling conventions that diverged through independent rulemaking rather than deliberate choice. Most are fundamental, rooted in statutory frameworks that require agencies to pursue incompatible objectives when regulating the same physical phenomenon.

The costs of continued inaction are diffuse but cumulative. They appear in duplicative compliance requirements, in regulatory proceedings that relitigate settled science, in public confusion about safety standards that vary by agency rather than by risk, and in planning horizons that cannot accommodate multi-decade nuclear projects within five-year regulatory cycles. Recent Supreme Court decisions limiting agency deference add urgency: statutory ambiguities that agencies once resolved through interpretation now invite litigation.⁷⁵

Radiation protection is not the primary barrier to nuclear deployment, and the benefits of any individual reform are modest in isolation. But the aggregate effect of a coherent framework would be substantial: reduced administrative burden, clearer public communication, more predictable licensing, and regulations whose stringency reflects deliberate policy choice rather than historical accident. The recommendations that follow are organized by the level of institutional change required—beginning with technical harmonization achievable through coordinated administrative action, proceeding to reforms requiring binding enforcement authority, and concluding with statutory changes that only Congress can accomplish.

What Administrative Action Can Achieve

Within existing statutory frameworks, agencies can achieve substantial improvements through coordinated administrative action:

⁷⁵Loper Bright Enterprises v. Raimondo, 603 U.S. ____ (2024) (overruling Chevron U.S.A. Inc. v. Natural Resources Defense Council, 467 U.S. 837 (1984)).

- **Unified definitions:** Dose, risk, optimization, dose modeling conventions, and de minimis thresholds can be harmonized across agencies through coordinated rulemaking and joint guidance documents.
- **Graded approach clarification:** A clear distinction between dose limits (legal caps), action levels (administrative triggers), and de minimis thresholds (exposures too small for meaningful regulatory concern) would align with international frameworks and reduce compliance complexity.
- **Coordinated rulemaking:** Synchronized timelines for major regulatory revisions would prevent the situation where one agency's standards become outdated while another's proceed through multi-year revision processes. This works within agencies too; imperfect rules can be promulgated first and then harmonized with other in-process rulemakings if objectives change.
- **Enhanced international participation:** Active participation by U.S. government agencies in NCRP and ICRP proceedings would improve coherence between domestic regulations and international recommendations. Changes in US systems don't have to shock partners, they can be points of discussion on the evolution of standards.
- **Consolidated scientific authority:** Fully designating the NCRP as the standing body responsible for continuous radiation risk interpretation and technical guidance would provide agencies with a common scientific reference point.

What Requires Enforcement Authority

Voluntary coordination has a consistent track record of failure on controversial questions. Historical precedent suggests that effective coordination requires:

- **Final decision authority:** Either one agency must have final authority on cross-cutting radiation protection questions, or Congress must establish decision-making procedures for when agencies disagree. When agencies deadlock, the current system permits indefinite impasse. Options include a designated lead agency, White House coordination with binding authority, or statutory dispute resolution mechanisms.
- **Binding timelines:** Agencies face no penalty for indefinite delay in coordinating regulatory revisions. Binding timelines for harmonization efforts would create accountability currently absent from voluntary coordination.

What Requires Congressional Action

The deepest source of fragmentation is statutory incompatibility that administrative action cannot overcome:

- **Permanent reconciliation of definitions:** The AEA's dose-based approach and the CAA's risk-based approach impose fundamentally different analytical requirements. This would eliminate the situation where agencies operating in good faith reach incompatible conclusions because their governing statutes require different approaches. Reconciliation would require Congressional action to establish consistent objectives for radiation protection across regulatory frameworks.
- **Jurisdictional clarification:** The current system produces situations where the same facility faces different analytical requirements from the NRC and EPA for the same release. Congressional clarification of jurisdictional boundaries would reduce compliance complexity and regulatory uncertainty.
- **Set appropriate statutory boundaries:** With recent Supreme Court decisions like *Loper-Bright*, there is less deference to agencies. Clear signals, like opening up waste options and clear designation agencies based on purview or better clarifying societal risk valuation would decrease issues with litigation of agency actions.
- **Consider Larger Legislative Changes:** Part of the jurisdictional overlap happened because of the designation of radionuclides as HAPs. Numerous secondary effects would need to be considered, but delisting radionuclides, other modifications to the CAA, and/or giving the NRC greater sole authority would also be options for simplifying the system.

VII. CONCLUSION

The regulatory architecture governing American radiation protection reflects 70 years of accumulated responses to specific problems, not coherent design. The fallout controversy prompted the FRC. The environmental movement transferred radiation authority, somewhat inadvertently, to the EPA. The dual-role problem drove the 1974 reorganization of the AEC. Unintended outcomes of legislation deepened agency divides. Each response addressed real concerns in its historical moment. Collectively, they produced the current system of overlapping jurisdictions and incompatible frameworks.

Expert standard-setting through bodies like the NCRP and ICRP continues to function reasonably well. The problem is not the development of radiation protection recommendations but rather what happens when those recommendations reach a fragmented federal implementation structure where multiple agencies translate the same underlying science through incompatible regulatory philosophies. Voluntary coordination mechanisms achieve technical alignment on matters like dose coefficients and survey methodologies but fail to resolve fundamental disagreements between agencies with different statutory mandates.

Synchronization requires recognizing what historical experience teaches. Administrative action can narrow the gap between agency approaches through unified definitions, coordinated rulemaking, and enhanced international participation. But a binding coordination authority is necessary to resolve inter-agency disputes, and only Congress can address the statutory incompatibility that constitutes the deepest source of fragmentation. Without structural reform, the current pattern will persist: agencies will continue operating under different numerical limits for the same phenomenon, coordination bodies will continue producing technical outputs while avoiding contested questions, and the 100,000-fold variation in acceptable risk levels will remain embedded in federal regulation.

Supplement I

HOW FRAGMENTATION EMERGED: HISTORICAL ANALYSIS FROM FISSION TO FRACTURE

The Start of Radiation Regulation (1928–1946)

Before any government agency claimed jurisdiction over atomic energy, radiation protection evolved through expert committees operating outside governmental structures. The International X-Ray and Radium Protection Committee (later the ICRP) was established in 1928, and its American counterpart, the Advisory Committee on X-Ray and Radium Protection (later the NCRP), formed the following year. Neither body had statutory authority; their influence derived from scientific credibility.⁷⁶

The model produced results. In 1934, both committees recommended the first quantitative "tolerance doses." These values were acknowledged as rough estimates, but they were workable criteria that government agencies later adopted wholesale.

The Manhattan Project fundamentally transformed radiation protection from an occupational concern into a government enterprise. The Project's Health Division adopted conservative standards and pioneered practices: remote handling, shielding, continuous monitoring, and systematic dose tracking. They achieved a remarkable safety record given wartime urgency and scientific uncertainty. When Congress created the AEC in 1946, it inherited the Manhattan Project's contractor system, its trained personnel, and its safety culture. The AEC also inherited the assumption that radiation protection was inseparable from nuclear operations: that the agency promoting atomic energy should and could regulate its hazards.

The Unified System (1946–1970)

The AEC's monopoly from 1946 to 1974 concentrated authority over weapons development, civilian reactor promotion, radiation protection standards, and safety regulation in a single

⁷⁶George T. Mazuzan and J. Samuel Walker, *Controlling the Atom: The Beginnings of Nuclear Regulation 1946–1962* (Berkeley: University of California Press, 1984), 38–42.

agency. The AEC incorporated NCRP recommendations into its regulations, adopting standards developed by experts with no institutional stake in nuclear expansion or contraction.

Combined military and civilian oversight meant that a problem in one sphere would inevitably undermine trust in the other. As fallout from weapons testing generated ever greater public concern, confidence in AEC assessments eroded, especially after the Castle Bravo test led to significant unintended exposure. The National Academy's Biological Effects of Atomic Radiation (BEAR) study and the 1957 Joint Committee on Atomic Energy hearings on fallout started the conversations that would lead to the eventual breakup of the AEC.⁷⁷ Delegating the BEAR study to the National Academy of Sciences reflected a Cold War pattern: when a technical question threatened public confidence in government assessments, credibility was sought by placing the inquiry with an institution perceived as independent of the agencies whose judgment was in doubt.⁷⁸

Recognizing that declining public confidence in AEC assessments required a response, President Dwight D. Eisenhower directed the Bureau of the Budget to study federal agencies' roles in radiation protection. After the Bureau completed its report, Eisenhower created the Federal Radiation Council by executive order in August 1959. The FRC was established to advise the President on radiation safety and provide guidance to federal agencies. Its membership reflected dispersed federal interests: the secretaries of Defense, Commerce, Labor, Agriculture, and Health, Education, and Welfare (HEW), along with the AEC Chairman. The Secretary of HEW was designated as chairman to explicitly reassure the public about objectivity.⁷⁹

The FRC's 1960 Radiation Protection Guides established the 5 rem/year occupational and 0.5 rem/year public limits that shaped American radiation policy for decades. But the FRC's advisory nature became apparent when agencies deadlocked. Throughout the 1960s, the FRC attempted to establish radon standards for uranium mines. When the Departments of Labor, Interior, and HEW supported stricter limits while the AEC, Defense, and Agriculture favored more permissive standards, the Council could only postpone action with a 3-3 vote. The day after the FRC failed to reach an agreement on May 4, 1967, Labor Secretary Willard Wirtz imposed his own standard unilaterally, revealing the fundamental weakness of voluntary coordination. Since the DOL had

⁷⁷Mazuzan and Walker, *Controlling the Atom*, 304–305.

⁷⁸Jessica Wang, *American Science in an Age of Anxiety: Scientists, Anticommunism, and the Cold War* (Chapel Hill: University of North Carolina Press, 1999).

⁷⁹Federal Radiation Council, *Background Material for the Development of Radiation Protection Standards*, Report No. 1 (Washington, D.C.: FRC, 1960).

broad authority over federal contractors—which included nearly every uranium mine—it became a practical national rule.⁸⁰

The federal-state dimension of fragmentation traces to Section 274 of the Atomic Energy Act, added by the 1959 amendments. The provision authorized the AEC to enter formal agreements with states that demonstrated adequate radiation protection programs, transferring to those states regulatory authority over source materials, byproduct materials, and small quantities of special nuclear material.⁸¹ The AEC retained exclusive jurisdiction over reactor licensing, ocean disposal, and activities involving quantities sufficient to sustain a chain reaction. Kentucky became the first agreement state in February 1962.

The program was designed as an orderly transfer of limited functions, but it created a durable structural asymmetry. Agreement states regulate many of the same materials and activities that the NRC regulates in non-agreement states, under programs that must be “compatible” with but need not be identical to NRC standards. The compatibility requirement has been a persistent source of tension. The AEC’s original draft criteria called for state standards “no more and no less” than federal limits, but state resistance forced deletion of that language before the first agreements were signed.⁸² States insisted on the authority to impose stricter requirements to address local conditions, a position that introduced variability into what was supposed to be a uniform national framework.

By 1970, multiple overlapping forms of radiation oversight had already developed without long-term vision. The National Academy of Sciences’ separate committees continued to synthesize scientific evidence on biological effects, a function formalized with the BEAR study and continuing through the Biological Effects of Ionizing Radiation (BEIR) series (1972, 1977, 1980, 1988, 1990, 1999, 2006). The Federal Radiation Council provided interagency coordination and presidential guidance. The AEC maintained internal standards for its licensees and contractors. State radiation control programs operated with varying degrees of independence. The reorganizations that followed would codify rather than rationalize this duplication.

⁸⁰Walker, *Permissible Dose*, 31–33.

⁸¹Atomic Energy Act of 1954, § 274, as added by Pub. L. No. 86-373, 73 Stat. 688 (1959); Mazuzan and Walker, *Controlling the Atom*, 286–302.

⁸²Mazuzan and Walker, *Controlling the Atom*, 297–298. The AEC deleted the “no more and no less” language from its draft criteria in response to state objections before the first agreements were signed.

The EPA's 1970 Creation: Parallel Authorities

Following recommendations from the President's Advisory Council on Executive Organization, commonly known as the Ash Council, President Richard Nixon diagnosed environmental protection as structurally fragmented. Federal programs had "grown up piecemeal over the years," leaving the government unable to mount "a coordinated attack on the pollutants which debase the air we breathe, the water we drink, and the land that grows our food."⁸³ The administration identified a critical coordination failure: "some pollutants—chemicals, radiation, pesticides—appear in all media. Successful control of them at present requires the coordinated efforts of a variety of separate agencies and departments."⁸⁴ Reorganization Plan No. 3 consolidated these scattered programs into a single Environmental Protection Agency in December 1970.⁸⁵ While the consolidation strengthened environmental protections, it created new challenges for nuclear regulatory coordination.

The consolidation transferred the Federal Water Quality Administration from Interior, the National Air Pollution Control Administration from Health, Education, and Welfare, pesticide registration authority from Agriculture, and portions of the Public Health Service's Bureau of Radiological Health. The plan also abolished the FRC, and transferred its environmental standard-setting functions to EPA.⁸⁶ The rationale for including radiation protection was never explicitly articulated: radiation qualified as an environmental pollutant that appeared across multiple media, and both the FRC and Bureau of Radiological Health performed environmental protection functions rather than operational regulation.

The Bureau of Radiological Health transfer proved consequential. Public Health Service epidemiologists had documented elevated lung cancer rates among uranium miners throughout the 1960s while the AEC and state regulators resisted stronger standards. When EPA absorbed these programs, it inherited institutional memory shaped by two decades of disputes with the AEC over fallout from weapons testing, uranium mine ventilation, and state regulatory

⁸³Richard Nixon, "Message to the Congress About Reorganization Plans to Establish the Environmental Protection Agency and the National Oceanic and Atmospheric Administration," July 9, 1970, <https://www.epa.gov/archive/epa/aboutepa/reorganization-plan-no-3-1970.html>.

⁸⁴Ibid.

⁸⁵Reorganization Plan No. 3 of 1970, 35 Fed. Reg. 15,623, 84 Stat. 2086 (Dec. 2, 1970).

⁸⁶Walker, *Permissible Dose*, 68.

capacity.⁸⁷ This history informed EPA's skepticism toward industry assurances and its preference for stringent environmental limits.

The consolidation created lasting jurisdictional problems. EPA inherited the FRC's authority to set environmental radiation standards for public protection, but the AEC retained operational authority over nuclear facilities under the AEA. No mechanism reconciled these parallel authorities or resolved conflicts between EPA's emerging risk-based framework under the CAA and the AEC's dose-based approach. When EPA established its 25 millirem per year fuel cycle standard in 1977, it formalized a regulatory boundary that has never been systematically rationalized.

OSHA and the Workplace Dose Split

The Occupational Safety and Health Act of 1970, signed the same month EPA began operations, created yet another jurisdictional boundary for radiation protection.⁸⁸ OSHA assumed general authority over workplace safety across American industry, but the AEC's exclusive jurisdiction over occupational radiation exposures at licensed facilities under the Atomic Energy Act remained undisturbed. This carve-out was neither accidental nor contested at the time; the AEC's technical capacity in radiation protection far exceeded what any new general-purpose safety agency could replicate.

But as the AEC dissolved and its functions dispersed, the occupational split calcified. The NRC retained authority over worker doses at licensed civilian facilities under 10 CFR 20. DOE set its own occupational standards for its facilities and contractors under separate orders, eventually codified in 10 CFR 835.⁸⁹ The EPA issued federal guidance on occupational exposure applicable across all sectors but enforceable only through other agencies' adoption.⁹⁰ OSHA's general industry standards nominally covered radiation workers outside NRC and DOE jurisdiction, but in practice OSHA deferred to the specialized agencies. The result was that a single physical hazard, occupational radiation exposure, fell under at least three distinct regulatory regimes,

⁸⁷Occupational Safety and Health Act of 1970, Pub. L. No. 91-596, 84 Stat. 1590 (Dec. 29, 1970). The AEC's exclusive jurisdiction over radiation hazards at licensed facilities derived from the preemption provision of the Atomic Energy Act.

⁸⁸John C. Wagner et al., *Reevaluation of Radiation Protection Standards for Workers and the Public Based on Current Scientific Evidence*, INL-RPT-25-85463, Rev. 0 (Idaho National Laboratory, July 2025), Table 1 and accompanying discussion.

⁸⁹52 Fed. Reg. 2822–34 (Jan. 27, 1987); Walker, *Permissible Dose*, 106–107.

⁹⁰Walker, *Containing the Atom*, 360.

each operating under different statutory authority, using different dose calculation methodologies, and applying different administrative controls. OSHA's creation formalized rather than resolved this fragmentation.

The Lead-up to Separation and the 1974–1977 Reorganization

Whether the AEC's unified structure represented a necessary compromise or an inherent conflict of interest became a recurring question throughout the 1960s. The AEC and industry officials argued that nuclear power technology remained too immature to divorce regulation from research and development; safety assessments still depended on access to design expertise and operational data that only integration could provide.⁹¹ Commissioner James T. Ramey predicted in 1963 that an independent regulatory agency might be appropriate within ten years. When Seaborg and Director of Regulation Harold Price reflected on this timeline in 1970, they noted the AEC had been saying separation might occur “in five or ten years” since 1955.⁹² Even General Counsel Joseph F. Hennessey, reviewing the question in October 1968, acknowledged that a separate agency would offer “maximum objectivity and impartiality in reactor safety evaluation,” but concluded the disadvantages outweighed the benefits—in particular “obstacles to informal consultation” between regulators and technical staff.⁹³

The AEC responded not with full structural separation but with incremental measures designed to insulate regulatory decisions from promotional pressures. In 1962, at the urging of the Joint Committee, the AEC established the Atomic Safety and Licensing Boards: panels composed of a hearing examiner serving as chairman alongside two technical experts drawn from outside the agency.⁹⁴ Commissioner Ramey emphasized that the boards would provide “a combination of legal due process and technical judgment,” offering public evaluation of the regulatory staff's conclusions with at least two of three members drawn from outside the agency.⁹⁵ The AEC also imposed “separated staff” requirements prohibiting regulatory personnel who had worked on a particular licensing case from discussing it with the Commission or licensing board except on

⁹¹Walker, *Containing the Atom*, 51.

⁹²Walker, *Containing the Atom*, 51.

⁹³Walker, *Containing the Atom*, 52–53.

⁹⁴Walker, *Containing the Atom*, 44–45.

⁹⁵Mazuzan and Walker, *Controlling the Atom*, 399–400.

the public record.⁹⁶ In 1969, the Commission established the Atomic Safety and Licensing Board Appeal Panel, interposing an intermediate appellate body between the licensing boards and the Commission in an effort to defuse the longstanding conflict-of-interest criticism without conceding full structural separation. The Commission retained authority to review any appeal panel decision on its own motion.⁹⁷ These measures addressed procedural concerns but left the fundamental dual-role structural question unresolved. The view of the Director of Regulation Harold Price, lamented in January 1971 that the changes had not resolved the issue, stating, “as far as the public is concerned there is no distinction between actions by the regulatory [staff], [the] ACRS, the Commission or the ASLB’s.” All were “considered a part of the nuclear power promotional effort.”⁹⁸

The Energy Reorganization Act of 1974 dissolved the AEC effective January 19, 1975.⁹⁹ The NRC inherited licensing and related regulatory authority over civilian uses of nuclear energy as an independent commission; the Energy Research and Development Administration assumed research, development, and weapons responsibilities that would later pass to the Department of Energy. The division was not, however, the clean separation of “promotional” and “safety” functions that subsequent shorthand suggests. The ERA transferred specific operational and R&D programs to ERDA but did not strip the NRC of the AEA’s foundational policy mandate which included that the control of atomic energy be directed to maximize the general welfare ERDA proved entirely transitional. On August 4, 1977, President Carter signed the Department of Energy Organization Act, creating a cabinet-level department that absorbed ERDA, the Federal Energy Administration, and energy functions scattered across other agencies.¹⁰⁰ But the DOE consolidation provided no remedy for fragmentation in radiation protection. DOE inherited ERDA’s promotional and weapons functions; the NRC retained independent regulatory authority over civilian facilities; and the EPA continued setting environmental standards under its own statutory frameworks. Cabinet-level status did not confer authority over other agencies’ radiation protection activities.

The jurisdictional tensions that had marked AEC-EPA relations persisted into the new arrangement. As early as May 1973, AEC Commissioner William O. Doub had concluded it was “unlikely that the two agencies will be able to reconcile their differences” on radiation standards,

⁹⁶Walker, *Containing the Atom*, 45.

⁹⁷Walker, *Containing the Atom*, 53.

⁹⁸Walker, *Containing the Atom*, 53–54.

⁹⁹Energy Reorganization Act of 1974, Pub. L. No. 93-438, 88 Stat. 1233.

¹⁰⁰Department of Energy Organization Act, Pub. L. No. 95-91, 91 Stat. 565 (1977).

and the Commission had requested Office of Management and Budget mediation.¹⁰¹ The reorganization changed the institutional names but not the underlying conflict. When EPA issued its final 40 CFR 190 regulations in January 1977 after extended interagency negotiation, the NRC was “generally satisfied” with the outcome. It still characterized the standards in June 1977 as “an unnecessary and costly overlay” to existing NRC programs.¹⁰² The agencies could resolve individual rules through ad hoc diplomacy, but the underlying structural problem remained: two agencies operating under different statutory frameworks, with different institutional cultures, regulating what was fundamentally a single physical hazard. These institutional tensions reflected deeper philosophical divergences. NRC officials generally viewed nuclear power as “an important, if not essential, part of the nation’s energy future,” a position consistent with the energy policies of Presidents Nixon and Ford. EPA’s institutional orientation was markedly different. Russell Train, who served as EPA Administrator under both Nixon and Ford, declared shortly after leaving office in January 1977: “We need to develop a very firm commitment to the elimination of nuclear power as a source of energy.”¹⁰³ This was not an outlier position. EPA’s statutory mandate oriented it toward precaution and risk elimination in ways that produced systematically different regulatory conclusions, even when the underlying technical assumptions were shared with the NRC. Both agencies adopted linear no-threshold models; both relied on NCRP and ICRP guidance. But the NRC operated under the Atomic Energy Act’s dose-based framework while EPA operated under risk-based statutes that required a fundamentally different regulatory logic. The 1977 Clean Air Act Amendments gave EPA independent statutory authority to regulate radionuclides under an “endanger public health” standard entirely outside the Atomic Energy Act framework, creating a second regulatory track from which further jurisdictional conflict was structurally inevitable.¹⁰⁴

1990s Convergence

The case studies examined how, between 1989 and 1992, the Part 20 revisions, NESHAP mandates, BRC discussions, repository standards, and ALARA implementation all collided at once. They were a single institutional crisis experienced simultaneously by the same agencies, the same Congressional committees, and in many cases the same individual officials.

¹⁰¹Walker, *Permissible Dose*, 71.

¹⁰²Walker, *Permissible Dose*, 78.

¹⁰³“Russell Train Gives Views on the Environment,” *Conservation Foundation Newsletter*, January 1977, 3.

¹⁰⁴Clean Air Act Amendments of 1977, Pub. L. No. 95-95, § 122, 91 Stat. 685, 724 (1977).

The NRC's position during this period illustrates what simultaneous fragmentation looks like in practice. The Commission was finalizing its Part 20 revision after more than a decade of rulemaking, defending BRC against Congressional and public backlash, negotiating with EPA over NESHAPs authority, and positioning for Yucca Mountain repository licensing, all while BEIR V was revising risk estimates upward and ICRP 60 was recommending tighter limits. Each front constrained the others. The NRC staff warned that EPA's proposed NESHAPs rule "represents the entry of EPA into a field of regulation that it has heretofore declined to enter," raising "the possibility that there could be, in addition to NRC regulation of licensed facilities, an overlay of more stringent EPA regulation and perhaps a further overlay of still more stringent regulation by states."¹⁰⁵ The Commission could not concede ground on NESHAPs without undermining its own Part 20 framework, but it could not defend BRC's 10 mrem threshold while EPA was proposing airborne limits as low as 0.3 mrem for the same licensees.

The political dynamics were equally entangled. The BRC backlash did not merely kill the de minimis policy; it weakened the NRC's bargaining position on every other front. An agency perceived as captured by industry was in no position to resist EPA's assertion of CAA authority. The 1992 MOU's requirement that the NRC commit to a 10 mrem per year goal for non-reactor licensees was driven not by the NRC's own risk assessment but by the need to satisfy EPA's statutory framework at a moment when the NRC had little political capital to negotiate otherwise.¹⁰⁶ EPA's leverage derived in part from the contempt findings over NESHAPs delays and in part from the NRC's self-inflicted credibility damage over BRC. The 1992 EPA-NRC memorandum of understanding on Clean Air Act radionuclides explicitly required the NRC to work with agreement states to promote adoption of compatible standards, acknowledging that the NRC could not deliver on its commitments to EPA without securing cooperation from independent state regulatory programs.¹⁰⁷ Any reform of radiation protection standards, whether harmonizing dose limits, implementing de minimis thresholds, or rationalizing ALARA requirements, must navigate this federal-state implementation gap. The agreement state program multiplied the number of regulatory actors whose coordination is required for policy change, adding a horizontal axis of fragmentation to the vertical fragmentation among federal agencies.

¹⁰⁵SECY-89-230 (May 8, 1989), NRC Records; Walker, Permissible Dose, 123–124. See also 54 Fed. Reg. 9612–54 (Mar. 7, 1989).

¹⁰⁶Walker, Permissible Dose, 119–120, 127.

¹⁰⁷Walker, Permissible Dose, 127.

The same underlying fragmentation that distributed radiation protection authority across multiple agencies with different statutory frameworks ensured that any period of scientific revision or political attention would produce simultaneous crises across every jurisdictional boundary. The outcomes were never going to be independent, as the threads were always tied together.

Supplement II

THE HISTORY OF COORDINATION AND ADVISORY BODIES

Table S1. Summary Of Radiation Coordination Bodies.

BODY	YEARS ACTIVE	NOTABLE OUTPUTS	POLICY DISPUTES RESOLVED
Federal Radiation Council	1959–1970	4 Federal Guidance documents	None (uranium mines deadlocked)
Radiation Policy Council	1980–1981	None	None (defunded before action)
CIRRPC	1984–1995	Technical reports, fact sheets, workshops	None brought before committee
ISCORS	1994–Present	MARSSIM, MARLAP, technical guidance	None (Federal Guidance stalled 2002–08)

Federal Radiation Council (1959–1970)

The FRC's structural features established the template that every subsequent coordination body would reproduce. It was designed as an overlay rather than a consolidation with the AEC retaining its regulatory authority and the FRC providing advisory guidance to the President. Its cabinet-level membership guaranteed parity among agencies with divergent interests but provided no mechanism for breaking deadlocks. As detailed in Supplement 1, the uranium mine standards dispute demonstrated this limitation directly: a 3-3 split that could only be resolved when a single agency acted unilaterally.¹⁰⁸

The FRC produced four Presidential Federal Guidance documents on relatively uncontroversial matters: basic radiation protection guidance (1960), guidance on fallout from weapons testing (1961), guidance on X-ray examinations (1962 draft, never finalized), and revised basic guidance (1965). These addressed questions where agencies could agree. On contested questions, the FRC failed. The uranium mine standards dispute illustrated the structural problem: with Labor,

¹⁰⁸Exec. Order No. 10,831, 24 Fed. Reg. 6,749 (Aug. 14, 1959).

Interior, and HEW favoring stricter limits while AEC, Defense, and Agriculture favored permissive standards, the Council split 3-3 and could only postpone action. When the FRC's functions transferred to EPA in 1970, the underlying problem (multiple agencies with incompatible mandates) remained unaddressed.¹⁰⁹

Radiation Policy Council (February 1980–1981)

The Libassi Task Force, convened in 1979 to assess federal radiation protection in the wake of Three Mile Island and growing controversy over low-level radiation effects, found institutional arrangements "confusing, overlapping, and sometimes contradictory" and recommended reestablishing FRC-like coordination functions.¹¹⁰ President Carter responded by creating the Radiation Policy Council in February 1980.¹¹¹

The Council survived eleven months. When the Reagan administration took office, OMB declined to fund it. The RPC never completed a single significant initiative. Its demise demonstrated a vulnerability inherent in any coordination body dependent on annual appropriations and lacking a statutory mandate. Political transitions happen faster than regulatory disputes can be resolved under normal rulemaking and interagency collaboration.

CIRRPC (1984–1995)

Reagan established the Committee on Interagency Radiation Research and Policy Coordination in April 1984, combining the functions of Carter's defunct Radiation Policy Council with the Interagency Radiation Research Committee.¹¹² CIRRPC was chartered under the Federal Coordinating Council for Science, Engineering, and Technology and reported to the Office of Science and Technology Policy.

Over eleven years, CIRRPC produced technical reports and coordination documents: annual reports, a study on health effects of extremely low-frequency electromagnetic fields, analysis of uncertainties in the NAS BEIR report's application to federal risk assessment, updates to radiation protection fact sheets, a report on SI metric radiation units, a workshop on internal

¹⁰⁹Walker, *Permissible Dose*, 31–33.

¹¹⁰Interagency Task Force on the Health Effects of Ionizing Radiation (Libassi Task Force), *Report to the President* (Washington, D.C.: HEW, 1979).

¹¹¹Exec. Order No. 12,194, 45 Fed. Reg. 12,769 (Feb. 26, 1980).

¹¹²Exec. Order No. 12,456, 49 Fed. Reg. 29,783 (Apr. 10, 1984).

dosimetry, and a 1994 report titled "Balancing Radiation Benefits and Risks: The Needs of an Informed Public."

What CIRRPC did not produce was policy resolution. An Institute of Medicine review noted that "no disputes between agencies were brought before the CIRRPC before its demise in 1995. Neither the RPC nor the CIRRPC had regulatory or enforcement authority, and their power as executive agencies was severely limited."¹¹³ The CAA radionuclide controversy, the BRC debacle, and EPA-NRC tensions over cleanup standards all occurred during CIRRPC's existence, with no resolution.

ISCORS (1994–Present)

The Interagency Steering Committee on Radiation Standards formed in response to Congressional pressure. Senator John Glenn of Ohio wrote to the NRC, EPA, and OSTP in October 1994 expressing concern about inconsistent radiation standards; ISCORS emerged as the institutional response.¹¹⁴ Unlike its predecessors, ISCORS has survived multiple administrations, suggesting that a sufficiently modest coordination body can persist if it avoids contested questions.

ISCORS has produced genuinely useful technical outputs. The Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) provides standardized survey methodologies across EPA, NRC, DOE, and DoD.¹¹⁵ The Multi-Agency Radiological Laboratory Analytical Protocols Manual (MARLAP) harmonizes laboratory procedures.

Yet ISCORS has not resolved the fundamental policy disputes that generate regulatory fragmentation. When EPA undertook to revise Federal Guidance between 2002 and 2008, internal conflict about whether to establish an overall public limit or rely on source-specific standards stalled the effort across an entire presidential administration. ISCORS had no mechanism to force resolution, and the guidance revision died without completion. Agencies can agree on how to measure radiation while disagreeing on what levels are acceptable. ISCORS facilitates interagency discussion but has no independent scientific function and no binding authority;

¹¹³Institute of Medicine, *Radiation Dose Reconstruction for Epidemiologic Uses* (Washington, D.C.: National Academy Press, 1995), 109.

¹¹⁴Letter from Sen. John Glenn to NRC Chairman Ivan Selin (Oct. 18, 1994).

¹¹⁵EPA, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*, NUREG-1575 (2000).

experts briefing the National Academy of Sciences observed that it "does not provide a centralized radiation science and policy leadership."¹¹⁶

Advisory Bodies

Table S2. Summary Of Radiation Advisory Bodies.

BODY	YEARS ACTIVE	SCOPE	PURPOSE
International Commission on Radiological Protection (ICRP)	1928-Present	International recommendations on dose limits, optimization, and risk framework	Sets international foundational framework; national agencies adopt selectively
National Council on Radiation Protection and Measurement (NCRP)	1929-Present (Congressional Charter in 1964)	Domestic recommendations on exposure limits, measurement, and operational guidance	Congressional charter to develop and disseminate recommendations; no mechanism to compel adoption; AEC originally incorporated NCRP recommendations wholesale
Nuclear Safety Review Board (NSRB) for the National Academies of Science, Engineering, and Medicine (NASEM or NAS)	1956-Present*	Commissioned consensus studies on radiation health effects and policy questions	No standing advisory role; produces episodic studies (BEAR/BEIR series, Yucca Mountain standards) when commissioned by Congress or agencies

**The first study of the Biological Effects of Atomic Radiation was produced in 1956 but committees and boards have been episodic and undergone numerous name and authority changes*

The coordination bodies examined above shared a common design: they were interagency mechanisms meant to align federal regulators with one another. But the coordination problem has a second dimension. Agencies do not develop radiation protection standards in isolation from the broader scientific community; they draw on recommendations from external advisory bodies whose influence operates through scientific credibility rather than authority.

¹¹⁶National Academies of Sciences, Engineering, and Medicine, *Leveraging Advances in Modern Science to Revitalize Low-Dose Radiation Research in the United States* (Washington, DC: The National Academies Press, 2022), 48.

The pathway from scientific recommendation to enforceable regulation depends on both. The NCRP functions as an advisory body that was officially congressionally chartered in 1964, but has operated in essentially the same capacity since 1929.¹¹⁷ Much of the science in ICRP publications reflects work by NCRP-affiliated researchers. But the NCRP's output tends toward operational guidance, measurement protocols, and applied assessments (background exposure, emergency response, and medical radiation, etc.) rather than the comprehensive protection frameworks that ICRP publications provide.

The NCRP contextualizes international recommendations for U.S. conditions; it does not independently generate the dose limit architecture that agencies adopt or reject. NCRP could develop recommendations but not compel their adoption, and agencies increasingly looked to ICRP publication numbers (ICRP 26, 60, 103) as the common reference points around which to selectively organize their regulations. UNSCEAR, established by the UN General Assembly in 1955, operates one step further upstream: it assesses global evidence on radiation levels and effects, producing the scientific synthesis that the ICRP then translates into protection recommendations, but it issues no standards itself and has no direct role in U.S. rulemaking.

The AEC adopted NCRP's 1948 recommendations directly into its 1957 regulations, and its revised standards in 1960 tracked NCRP's 1958 reduction of the occupational limit.¹¹⁸ After the 1974 reorganization dispersed regulatory authority, the adoption pathway fractured. When the ICRP issued Publication 26 in 1977, introducing effective dose equivalent and revised organ weighting factors, these were included in the lengthy Part 20 revisions.¹¹⁹ Right as the revisions were officially adopted, ICRP 60 recommendations were published, including the 20 mSv (2 rem) averaged annual limit as compared to a straight 50 mSv annual limit. The NRC staff concluded that BEIR V findings were "still inconclusive" and that actual worker doses were already well below the limit, making further reduction unnecessary. DOE, by contrast, adopted ICRP 60/66 principles in its 10 CFR 835, creating a situation in which federal workers at DOE facilities operated under different dose calculation methods and different de facto limits than workers at NRC-licensed facilities performing comparable work.¹²⁰

¹¹⁷The NCRP was congressionally chartered by Pub. L. No. 88-376, 78 Stat. 320 (1964). Mazuzan and Walker, *Controlling the Atom*, 38–42.

¹¹⁸Mazuzan and Walker, *Controlling the Atom*, 55–56; Gilbert F. Whittemore, "The National Committee on Radiation Protection, 1928–1960: From Professional Guidelines to Government Regulation" (Ph.D. diss., Harvard University, 1986).

¹¹⁹Walker, *Permissible Dose*, 108–115.

¹²⁰Walker, *Permissible Dose*, 115; SECY-90-387 (Nov. 26, 1990), NRC Records.

DOE retained the 50 mSv (5 rem) regulatory ceiling while using 20 mSv (2 rem) as an administrative control level, rather than adopting ICRP 60's 20 mSv 5-year average limit outright, and the NRC has selectively updated individual technical elements without revising its underlying dosimetric framework. The NRC spent eight years exploring alignment with ICRP 103, issuing an advance notice of proposed rulemaking in 2014, before formally discontinuing the effort in 2016; its regulatory guidance now acknowledges that updated dose coefficients use different weighting factors than those codified in Part 20, but permits their use only through case-by-case exemptions rather than systematic adoption.¹²¹ The practical result is that the two agencies calculate dose to the same worker using different tissue weighting factors, different internal dosimetry models, and different dose quantities, producing numerically different answers from identical exposure conditions.

The EPA follows a third pathway entirely. It inherited the FRC's authority to issue Federal Guidance Reports and it contributes scientific staff to NCRP committees and funds the dosimetric infrastructure (the Federal Guidance Report series developed at Oak Ridge National Laboratory) on which all agencies' dose calculations ultimately depend. But EPA also sets independently enforceable standards under its own statutory authorities: the Clean Air Act (10 mrem/yr for airborne emissions under 40 CFR 61), the Safe Drinking Water Act (4 mrem/yr for beta/photon emitters in drinking water under 40 CFR 141), and CERCLA (cleanup to risk-equivalent doses of 1-25 mrem/yr). These standards derive from the same ICRP science that informs NRC and DOE regulations, but they are processed through risk-based statutory frameworks that consistently produce more restrictive numerical outcomes. The EPA is simultaneously inside the advisory pipeline and outside it: contributing to the science, issuing the guidance, and then setting enforceable standards under different statutory logic that can contradict the guidance it helped develop.

The National Academies' Nuclear and Radiation Studies Board (NRSB) occupies a distinct position in this landscape. The NRSB functions as a standing board within the National Academies of Sciences, Engineering, and Medicine, convened under the Academies' general charter to advise the federal government on scientific matters. Its influence derives not from a statutory mandate but from the National Academies' institutional prestige and from specific Congressional or

¹²¹SECY-08-0197, "Options to Revise Radiation Protection Regulations and Guidance with Respect to the 2007 Recommendations of the International Commission on Radiological Protection," December 18, 2008 (ADAMS Accession No. ML091310193); "Radiation Protection," 79 Fed. Reg. 43,284 (July 25, 2014); "Rulemaking Activities Being Discontinued by the NRC," 81 Fed. Reg. 96,340 (Dec. 28, 2016). On the case-by-case exemption pathway for updated weighting factors, see NRC Regulatory Guide 8.34, Rev. 1.

agency commissions (the Energy Policy Act of 1992 directed EPA to contract with the NAS for Yucca Mountain dose standards). The NRSB produced landmark consensus studies (the BEIR series being the most consequential for radiation policy), but it acts when asked rather than maintaining a continuous advisory role. Where the NCRP offers standing recommendations that agencies may adopt or ignore, the NRSB delivers commissioned findings that are responsive to specific policy questions.

This selective adoption of recommendations across the federal government reflects each agency's distinct statutory framework, institutional culture, and stakeholder pressures. The NCRP's 1964 congressional charter authorizes it to develop and disseminate recommendations, but gives it no mechanism to compel agency adoption, like the other coordination bodies. The NCRP has scientific credibility without regulatory leverage; ISCORS has interagency representation without scientific independence. Neither fills the gap that the FRC was created to fill. And neither can, absent either binding authority or sustained presidential engagement. The succession of failed coordination bodies is itself evidence that voluntary mechanisms cannot overcome the structural incentives for agencies to maintain independent standards under their own statutory frameworks.