Death Dust: The Little-Known Story of U.S. and Soviet Pursuit of Radiological Weapons

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A thin line separates science and science fiction, especially with respect to new kinds of weapons. Who is to say, for example, which is more far-fetched or imaginary: a city dusted with a synthetic "death sand" or a huge, nuclear-propelled torpedo packed with radioactive waste?

More than seventy years separates the first "science fiction" account of radioactive death dust attributable to both Robert Heinlein and his publisher, John W. Campbell, in 1941 and the second, contemporary "doomsday" weapon depicted on slides held by Russian defense officials meeting with President Vladimir Putin.[1] The concept for the latter weapon, some Russian sources maintain, resembles the idea of a giant, nuclear-powered torpedo outlined a half century earlier by Soviet nuclear weapons designer and subsequent human rights and disarmament activist Andrei Sakharov.[2]

These and other U.S. and Soviet/Russian figures envisaged the development of relatively easy to manufacture but devastatingly lethal radiological

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1. See Anson MacDonald, "Solution Unsatisfactory," *Astounding Science Fiction*, Vol. 27, No. 3 (May 1941), pp. 56–86. The story by Robert A. Heinlein was published under the pseudonym "Anson MacDonald." For a discussion of the Russian weapon, see Steve Weintz, "Why Russia's Status-6 Torpedo Is Really a 100–Megaton Cruise Missile," *National Interest*, July 7, 2018, https://nationalinterest.org/blog/buzz/why-russias-status-6-torpedo-really-100-megaton-cruise-missile-25272.
2. The accusation about Sakharov, for which little evidence is presented, is made by Evgeny Krutikov, "Sverkhsekretnyj proekt 'Status-6' napominayut ideyu akademika Sakharova" [Top-secret project "Status-6" recalls an idea of academician Sakharov], *Vzglad*, November 12, 2015, https://vz.ru/society/2015/11/12/777703.html, and is repeated by many commentators.

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weapons (RW) whose use would not discriminate between civilian and military targets. Some viewed their development as horrific but inevitable; others regarded the weapons as necessary, at least until they could be replaced by even more powerful nuclear arms that relied on the effects of heat and pressure, rather than radiation, to do the killing.

The RW imagined by Heinlein and Campbell were pursued in earnest by the United States and the Soviet Union, as well as several other states including Iraq, and possibly Egypt and North Korea. Senior U.S. and British military figures also feared that Nazi Germany was intent upon their development, and they took precautions against their employment during the planning of the invasion of Normandy. The United Kingdom also embarked on a program to develop radiological weapons known only to a small number of British defense officials and scientists—including the Soviet spy Klaus Fuchs. More recently, Israel conducted civil defense exercises, motivated by the fear of possible Iranian possession and use of RW.[3] Notwithstanding this history of research, development, and, in at least three cases, actual testing,[4] there is no evidence that such weapons were ever deployed as an operational military force.

Today, with the exception of the widely discussed but possibly exaggerated Russian "super torpedo," RW appear to have more in common with historical trivia than weapons of the future. Moreover, following the terrorist attacks of September 11, 2001, most expert commentary on radiological weapons has focused almost exclusively on nonstate actors, who are assumed to covet radioactive dispersal devices, or "dirty bombs," as a means to inflict nuclear violence on the cheap. Yet, despite the widespread availability of radiological sources and the relative ease of matching a conventional explosive to a radiological payload, no terrorist has successfully carried out a dirty-bomb attack.

Should one conclude from this record that RW are a thing of the past, more suitable to pulp fiction than serious military procurement or doctrine? Or perhaps an emphasis on nonstate actors has obscured the continuing possibility that states may pursue RW. Why did so many states express interest in RW, sometimes actually develop and test them, but in all instances ultimately

3. Yaakov Katz, "Security and Defense: Preparing for Nuclear Terror," *Jerusalem Post*, December 9, 2011, https://www.jpost.com/features/front-lines/security-and-defense-preparing-for-nuclear-terror.
4. In addition to the U.S. and Soviet programs examined in this article, Iraq also experimented with RW and tested radioactive zirconium-filled gravity bombs before abandoning the program in the 1980s. See United Nations Monitoring, Verification and Inspection Commission, "Compendium of Iraq's Proscribed Weapons Programmes in the Chemical, Biological and Missile Areas," June 2007, pp. 1049–1052, https://web.archive.org/web/20121106170523/http://www.un.org/Depts/unmovic/new/documents/compendium/Chapter_VII.pdf.

prove reluctant to deploy them? Why is so little known about these false starts, especially outside of the United States? Can one draw more general conclusions about the primary drivers and disincentives to acquire radiological weapons? Are such weapons more difficult to manufacture than depicted by science fiction authors and military pundits? Is there a norm or taboo against their use comparable to those regarding nuclear or biological weapons (BW)? Are there military objectives that could usefully be served by RW or are the weapons fundamentally inefficient, easily countered, and dependent on too large an investment to justify their existence? Finally, under what circumstances in the future might states express renewed interest in RW, and what means might be undertaken to reduce the possibility of their production, deployment, and use?

This article attempts to answer these questions by undertaking a comparative analysis of the previously underexplored cases of state-level RW programs in the United States and the Soviet Union.[5] We employ newly available archival material and other primary sources to illuminate the drivers of and limitations on weapons innovation in one specific nuclear sector. Although the study is not principally devoted to theory building, it is informed by relevant theoretical and conceptual approaches in the fields of international relations and public policy, and it benefits especially from the literature on organizational change and weapons innovation. Its focused comparative analysis of RW developments in the United States and the Soviet Union, paired with an examination of the relationship between the rise and demise of RW programs and the fate of parallel chemical and nuclear weapons programs in both countries, also enhances the generalizability of its findings—an important but often overlooked dimension of theory construction.

To preview the study's major findings, the first two countries to develop nuclear weapons—as well as several other nuclear weapons aspirants—initially pursued RW in tandem with both their nuclear weapons and chemical weapons (CW) programs. Technological advances were among the major drivers of initial government interest in RW in both the United States and the Soviet Union, although the countries differed in terms of the processes by which the

5. The research reported in this article is part of a larger project that examines the consideration of and/or pursuit of RW by a number of other countries, including the United Kingdom, Iraq, and Egypt. Although this article represents the first extended comparative analysis of state-level RW programs, there is a large body of scholarship on nonstate actors and radiological dispersal devices. See, for example, Charles D. Ferguson and William C. Potter, *The Four Faces of Nuclear Terrorism* (New York: Routledge, 2005); Michael Levi, *On Nuclear Terrorism* (Cambridge, Mass.: Harvard University Press, 2007); and Brecht Volders and Tom Sauer, eds., *Nuclear Terrorism: Countering the Threat* (London: Routledge, 2016).

idea or invention advanced from conception to military production and testing. Significantly, there was major bureaucratic interplay in both countries involving individual and institutional actors from the traditional chemical weapons establishment, the relatively new but booming nuclear weapons industry, and the fledging RW sector.[6]

The anticipated promise of RW as a weapons innovation never materialized in the United States or the Soviet Union, and RW were not deployed in either country's military arsenals. Among the major factors accounting for their demise were greater than anticipated technical difficulties associated with the production and maintenance of the weapons, diminution in the perceived military utility of RW relative to both CW and nuclear weapon systems, and low threat perceptions about the risks posed by adversary RW programs—due in large part to poor intelligence about adversary RW capabilities. Bureaucratic political infighting and other country-specific factors involving the nature of the military procurement system and the presence or absence of high-level advocates also impeded the transition of RW as a promising scientific possibility to full-fledged weapons innovation.

Notwithstanding the failure to date of any country to incorporate radiological weapons into its military arsenal, this article reveals that pursuit of RW is far more widespread than is commonly known. Although some of the factors that inhibited the adoption of RW in the past may still pertain, one cannot exclude the possibility that some countries today, such as North Korea, may be exploring an RW option or may choose to do so in the near future. This prospect is especially likely if they perceive that path to be less difficult or risky than the pursuit of nuclear weapons. It also is increased by the absence of any international mechanisms to discourage the development or use of RW. Identifying those factors that have historically accounted for the rise (and eventual demise) of radiological weapons is critical to determining how to deter their development without elevating their salience or appeal.

The article opens with a review of scholarship on military innovation, examining the insights from a number of theoretical approaches and conceptual frameworks. We then present our research methodology, which draws heavily on Alexander George's method of structured, focused comparison and Matthew Evangelista's framework for interpreting patterns of military innova-

6. The bureaucratic political dimension of the postwar U.S.-Soviet chemical weapons arms race is discussed by Jonathan B. Tucker in Tucker, *War of Nerves: Chemical Warfare from World War I to Al-Qaeda* (New York: Pantheon, 2006), pp. 122–189. See also Joachim Krause and Charles K. Mallory, *Chemical Weapons in Soviet Military Doctrine: Military and Historical Experience, 1915–1991* (Boulder, Colo.: Westview, 1992), p. 133.

tion in the United States and the Soviet Union. The article then briefly traces the conceptual origins of radiological weapons before undertaking a comparative analysis of the factors responsible for the rise and demise of U.S. and Soviet radiological weapons programs. In conclusion, we identify a number of implications for future, would-be RW proliferators based on the U.S. and Soviet experiences.

The Sources of Military Innovation

One way to achieve a better understanding of the life cycle of RW programs in the United States and the Soviet Union is to treat them as instances of the broader phenomenon of the weapons innovation process. In fact, there is an extensive literature on innovation in the military sector, especially with respect to U.S. weapons systems. Regrettably, a much smaller body of research exists about weapons innovation in and diffusion to other states, and even fewer comparative studies have been conducted.[7]

Among the leading explanations that scholars have proposed for the origins and outcomes of weapons programs are those emphasizing international security imperatives, bureaucratic political determinants, scientific and technological breakthroughs, and economic resources and organizational capacity.[8] Several major insights from these categories of explanations relevant to the case of RW are summarized below. Their relative explanatory power also is examined in more detail in the body of this article.

INTERNATIONAL SECURITY IMPERATIVES

Historically, the dominant explanation for military innovation has focused on the international security environment and is heavily influenced by neorealist assumptions. Perceived threats from adversaries, a need to engage in balancing behavior, and the operation of action-reaction dynamics are among the presumed drivers of decisions to acquire new weapons systems. A common el-

7. An important contribution to this underdeveloped literature is Andrea Gilli and Mauro Gilli, "The Diffusion of Drone Warfare? Industrial, Organizational, and Infrastructural Constraints," *Security Studies*, Vol. 25, No. 1 (2016), pp. 50–84, doi.org/10.1080/09636412.2016.1134189.
8. This list is not exhaustive. A recent contribution to the literature on the factors influencing the adoption and retention of different types of weapons of mass destruction (WMD) is "weapons substitution theory." It does not fit neatly into traditional categories of explanations for the pursuit of new weapons, but has a basis in economic theory dealing with the cross elasticity of demand. Most relevant to the authors' work on RW is the article by Michael C. Horowitz and Neil Narang, "Poor Man's Atomic Bomb? Exploring the Relationship between 'Weapons of Mass Destruction'," *Journal of Conflict Resolution*, Vol. 58, No. 3 (April 2014), pp. 509–535, doi.org/10.1177/0022002713509049.

ement among most studies emphasizing external security considerations is the insight that contending states will emulate one another's innovations in what often appears to be an action-reaction process. As Stephen Rosen puts it, "Innovations in one nation will trigger matching or responsive innovations in another." An important subsidiary thesis governing the military innovation diffusion process noted by Rosen is that "the link between the activities in the competing nations is the network of military technical intelligence."[9]

BUREAUCRATIC POLITICAL DETERMINANTS

Many security-oriented explanations of foreign policy decisions, in general, and weapons procurement outcomes, in particular, are vulnerable to criticism about their neglect of internal factors. In response to this perceived shortcoming, a rich literature on domestic sources of foreign policy—and weapons acquisition—developed, drawing heavily on organizational theory and public policy analysis. Especially influential was the early work on bureaucratic politics and organizational processes by Morton Halperin and Graham Allison.[10] They demonstrated convincingly that policy outcomes often are suboptimal from the standpoint of the government as a whole and cannot be explained adequately without reference to the individual and organizational actors involved in what is fundamentally an intra-national political, bargaining process. In other words, while technological breakthroughs and perceptions of external threat may influence an organization's interest in considering new weapons systems, the most important factors determining military innovation (or the lack thereof) are the personal and organizational interests, frames of reference, and influence of the key players involved in the decisionmaking process, including the often-overlooked implementation phase.[11]

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9. Stephen Peter Rosen, *Winning the Next War: Innovation and the Modern Military* (Ithaca, N.Y.: Cornell University Press, 1991), p. 45.
10. See, for example, Morton H. Halperin, "The Gaither Committee and the Policy Process," *World Politics*, Vol. 13, No. 3 (April 1961), pp. 360–384, doi.org/10.2307/2009480; Morton Halperin, Priscilla Clapp, and Arnold Kanter, *Bureaucratic Politics and Foreign Policy* (Washington, D.C.: Brookings Institution Press, 1974); and Graham T. Allison, "Conceptual Models and the Cuban Missile Crisis," *American Political Science Review*, Vol. 63, No. 3 (September 1969), pp. 689–718, doi.org/10.1017/S000305540025853X; and Graham T. Allison, *Essence of Decision: Explaining the Cuban Missile Crisis* (Boston: Little, Brown, 1971).
11. Case studies with a bureaucratic politics focus include Michael H. Armacost, *The Politics of Weapons Innovation: The Thor-Jupiter Controversy* (New York: Columbia University Press, 1969); and Edmund Beard, *Developing the ICBM: A Study in Bureaucratic Politics* (New York: Columbia University Press, 1976). A recent extension of this literature, but with a focus on organizational frames of reference and stereotypes, is Frank L. Smith, *American Biodefense: How Dangerous Ideas about Biological Weapons Shape National Security* (Ithaca, N.Y.: Cornell University Press, 2014). It suggests that the military's preference for "kinetic weapons" is an obstacle to the adoption of systems that do not resemble traditional bullets or bombs—an insight relevant to the fate of RW.

Scientific and Technological Breakthroughs

Another explanation for military innovation (and arms racing), which usually emphasizes domestic considerations, focuses on science, scientists, and technology as catalysts for the development of new weapons. Although far from uniform in perspective, this school of thought often highlights supply-side, "technology push" factors.[12] According to one prominent proponent of this category of explanation, "Ideas for a new weapon system derived in the first place, not from the military, but from different groups of scientists and technologists who are concerned to replace or improve old weapons systems."[13] One can regard such scientists as change agents or "technological entrepreneurs" committed to promoting new weapons technologies in the face of both indifference and bureaucratic resistance to change.[14] One of the most important insights derived from this school of thought is the key roles scientists play in giving rise to new ideas for weapons systems and advocating for their development and adoption.

Economic and Other Organizational Resources

A number of studies of weapons innovation emphasize the impact of economic factors. These explanations range from the financial resources at the disposal of the organization, to the nature of the state's economic system, to the role attributed to the military-industrial complex and defense contractors.[15] They also may focus on other less tangible organizational resources such as the capacity of a military organization to change, a capacity that may be influenced by economic factors but also may reflect the size, age, and culture of an organization.[16] According to one of the most well-developed theo-

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12. See Mary Kaldor, "The Weapons Succession Process," *World Politics*, Vol. 38, No. 4 (July 1986), p. 580, doi.org/10.2307/2010167.
13. Solly Zuckerman, *Nuclear Illusion and Reality* (New York: Viking, 1982), p. 143, quoted in Matthew Evangelista, *Innovation and the Arms Race: How the United States and the Soviet Union Develop New Military Technologies* (Ithaca, N.Y.: Cornell University Press, 1988), p. 13. Another major exponent of technology as a driver of military innovation—and arms races—is Herbert F. York. See York, *Race to Oblivion: A Participant's View of the Arms Race* (New York: Simon & Schuster, 1970). The role of scientists as change agents with respect to nuclear weapons is discussed in Scott D. Sagan, "Why Do States Build Nuclear Weapons? Three Models in Search of a Bomb" *International Security*, Vol. 21, No. 3 (Winter 1996/97), pp. 63–73, doi.org/10.1162/isec.21.3.54.
14. For a discussion of the role of change agents in the innovation and diffusion process, see Everett M. Rogers and F. Floyd Shoemaker, *Communication of Innovations: A Cross-Cultural Approach*, rev. ed. (New York: Free Press, 1971), pp. 233–248.
15. Studies emphasizing the role of economic drivers in the weapons acquisition process include Jacques S. Gansler, *The Defense Industry* (Cambridge, Mass.: MIT Press, 1980); and J. Ronald Fox, *Arming America: How the U.S. Buys Weapons* (Cambridge, Mass.: Harvard University Press, 1974). See also Michael E. Brown, *Flying Blind: The Politics of the U.S. Strategic Bomber Program* (Ithaca, N.Y.: Cornell University Press, 1992), for a review of other economic explanations.
16. The most fully developed explanation for military innovations emphasizing economic re-

ries emphasizing both economic and other organizational resources, military innovators must possess both the financial capital to acquire new technology and the internal capacity to adopt the innovation, which may involve major changes in operating behavior.[17]

Despite the large number and diverse nature of studies undertaken to probe the emergence of and resistance to new weapons, the field still lacks a robust theory of weapons innovation that has broad explanatory and predictive power. Even the most sophisticated theoretical approaches, such as Michael Horowitz's "adoption-capacity" theory, leave a number of variables underspecified, require more information about organizational capacity than is often available, and are better equipped to explain the interstate diffusion process rather than the original decision to adopt a new weapon system. Indeed, although there has been a proliferation of excellent case studies of weapons innovation decisions over the past half century, explanations for the origins and outcomes of weapons decisions often are not cumulative and frequently are contradictory.

Although no single theory explains the rise and demise of radiological weapons programs in the United States and the Soviet Union, collectively they provide numerous insights into the dynamics of policymaking with respect to what once was regarded as a promising new military technology. The comparative framework used to tease out both the similarities and differences in the life spans of the U.S. and Soviet RW programs is described below.

Methodology

The methodology employed in this study is eclectic, but it most closely resembles that of structured, focused comparison, an approach pioneered by Alexander George.[18] Its intent is to hone and refine existing theories and con-

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sources and organizational capacity is Michael C. Horowitz's "adoption-capacity theory." See Horowitz, *The Diffusion of Military Power: Causes and Consequences for International Politics* (Princeton, N.J.: Princeton University Press, 2010). Jon Schmid also develops a related explanatory framework, which he calls "threat-capacity theory." See Schmid, "The Determinants of Military Technology Innovation and Diffusion," Ph.D. dissertation, Georgia Institute of Technology, 2018, pp. 31–36.

17. Reference here is to Horowitz's "adoption-capacity theory." Horowitz, *Diffusion of Military Power*, pp. 8–12.

18. See Alexander L. George, "Case Studies and Theory Development: The Method of Structured, Focused Comparison," in Paul Gordon Lauren, ed., *Diplomacy: New Approaches ion History, Theory, and Policy* (New York: Free Press, 1979), pp. 48–68; and Alexander L. George and Timothy J. McKeown, "Case Studies and Theories of Organizational Decision Making," in Robert F. Coulam and Richard A. Smith, eds., *Advances in Information Processing in Organizations*, Vol. 2 (Greenwich, Conn: JAI, 1985), pp. 21–58.

ceptual frameworks by assessing their ability to explain the impact of different variables on policy behavior across multiple cases. By asking the same set of specific questions across several cases, one increases the generalizability of findings and the cumulation of knowledge.

Our focused comparative approach to the study of the rise and decline of RW in the United States and the Soviet Union benefited particularly from the conceptual framework proposed by Matthew Evangelista in his comparative analysis of U.S. and Soviet development of new military technologies.[19] It identifies a series of five different stages in the process of weapons innovation peculiar to each country—at least with respect to the cases examined in his focused comparison. In the United States, these stages are "technocratic initiative," "consensus building," "promotion," "open window," and "high-level endorsement." Their counterparts in the Soviet Union are "stifled initiative," "preparatory measures," "high-level response," "mobilization," and "mass production."[20] Although we do not attempt to apply Evangelista's framework explicitly in our analysis, his concepts and generalizations provide a useful point of comparison in interpreting the processes by which the United States and the Soviet Union embarked on, developed, and subsequently abandoned their respective RW programs. Among the major conclusions from his study, whose applicability we explore with respect to the evolution of U.S. and Soviet RW, are (1) the impetus for the introduction of new weapons technology in the United States typically came from the bottom up (i.e., from scientists and military officials with whom they interacted), whereas in the Soviet Union, the impetus for innovation usually came from the top and in response to technological developments abroad; (2) internal factors involving bureaucratic consensus building and policy advocacy usually preceded a formal decision in the United States for advanced research and development (R&D) or production, but they were not present in the Soviet Union until the post-adoption "mobilization"/implementation phase; and (3) perceptions of external threat were more likely to become salient at a relatively late stage in the innovation process in the United States—unlike the Soviet Union—when it became necessary to secure funding for the actual deployment of new weapons.

Given the frequent use of the term "innovation" in this article, it is important to define the concept and to distinguish it from two other terms often referenced in discussions about the adoption of new weapons systems: "invention" and "diffusion." Although there is no standard definition of these terms,

19. See Matthew Evangelista, *Innovation and the Arms Race*.
20. Ibid., p. 52.

even within a military context,[21] we treat "invention" as the process by which a new idea or concept is created; "innovation" as the process by which an invention is translated into a tangible product and adopted by an organization; and "diffusion" as the process by which an idea or product spreads to or is emulated by another organization.[22] Invention thus precedes innovation, but diffusion does not presuppose adoption of the new idea for a weapon system. This distinction is important in understanding the rise and abandonment of RW in the cases under review, as RW as a concept appears to have diffused from the United States to the Soviet Union (and to other countries), although the innovation never really took hold in either country's military in the form of mass production and deployment.

Another important definitional question is "what constitutes a radiological weapon?" During the early years of the nuclear age, RW were often considered a subset of nuclear weapons, but they were never precisely defined.[23] For example, in 1948, the United Nations described "radioactive material weapons," alongside "atomic explosive weapons" and "lethal chemical and biological weapons," as types of weapons of mass destruction, but without further elaboration.[24] Thirty years later, ambiguity associated with the term contributed to the difficulty in gaining international support for the draft U.S.-Soviet convention on the prohibition of radiological weapons.[25]

This article defines a radiological weapon as one designed to disperse radioactive material in the absence of a nuclear detonation. This standard definition encompasses a variety of weapons, which state actors have contemplated, pursued, or in several instances actually tested, including those intended to produce mass casualties and others designed for area denial and sabotage mis-

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21. See, for example, Franklin C. Annis, "Military Innovation and the Tower of Babel," *Small Wars Journal*, June 4, 2019, https://smallwarsjournal.com/jrnl/art/military-innovation-and-tower-babel.
22. The seminal work on diffusion of innovation theory is Rogers and Shoemaker, *Communication of Innovations*.
23. See, for example, the definition of atomic weapon, U.S. Department of State, "Second Report of the United Nations Atomic Energy Commission to the Security Council [extract], September 11, 1947," *Documents on Disarmament, 1945–1959, Vol. I: 1945–1956*, doc. 19 (Washington, D.C.: U.S. Government Printing Office [GPO], 1960), pg. 149, http://unoda-web.s3-accelerate.amazonaws.com/wp-content/uploads/assets/publications/documents_on_disarmament/1945-1956/DoD_1945-1959_VOL_I.pdf.
24. U.S. Department of State, "Resolution of the Commission for Conventional Armaments: Definition of Armaments, August 12, 1948," *Documents on Disarmament, 1945–1959*, Vol. 1, doc. 26, p. 176.
25. See Lesley Kucharski, Sarah Bidgood, and Paul Warnke, "Negotiating the draft Radiological Weapons Convention," in William C. Potter and Sarah Bidgood, eds., *Once and Future Partners: The United States, Russia, and Nuclear Non-proliferation* (London: International Institute for Strategic Studies, 2018), pp. 187–216. This initiative is discussed in more detail below.

sions.[26] Although we focus on state-level RW programs, the definition is consistent with devices and techniques usually associated with nonstate actors, including radiological dispersal and exposure devices, often misleadingly referred to as "dirty bombs." In all instances, the weapons make use of fission products or irradiated isotopes.

The one instance in which we depart from the standard definition of RW is in our discussion of some nuclear bomb designs, which involve nuclear fission but whose purpose is primarily to release radioactive fallout. These include enhanced radiation weapons ("neutron bombs") and "salted bombs," which jacket the nuclear material with neutron-absorbing metal to increase fallout.

A final methodological consideration concerns sources. In the U.S. case study, we relied heavily on unclassified and declassified government documents. An especially valuable resource was the final report of the Advisory Committee on Human Radiation Experiments, released by President Bill Clinton in October 1995 under Executive Order 12958. Other important primary-source materials included correspondence and analyses by early U.S. enthusiasts for RW. Much of this material was obtained during visits to the U.S. National Archives in College Park, Maryland, the Library of Congress, the University of California Berkeley's Bancroft Library, and the New York Public Library.

We faced greater challenges in securing comparable information about the Soviet radiological weapons program given a dearth of accessible primary-source material. Nevertheless, a great deal of important information on the program's origins and structure was distilled from declassified Russian-language documents on the "USSR Atomic History" section of Rosatom's digital library. We also benefited from the investigative reports on the Soviet RW program published in Russian by the Bellona Foundation, as well as retrospectives written by Soviet participants in the testing of radiological weapons.

Origins of the Concept of Radiological Weapons

Writers of fiction often are the first to anticipate major innovations in warfare, and this is the case with respect to radiological warfare. The concept of radio-

26. Col. John Hinds, "Desirable Characteristics of Radiological Warfare Weapons," National Military Establishment Military Liaison Committee to the Atomic Energy Commission, May 24, 1948, U.S. Department of Energy Office of Scientific and Technical Information [DOE OSTI] OpenNet, https://www.osti.gov/opennet/detail?osti-id=16007062.

logical weapons appears to have been the literary brainchild of John W. Campbell, a prolific science fiction writer and editor.[27] In November 1940, he encouraged Robert Heinlein to write a story about the use of radioactive dust as a weapon, leading to the publication in May 1941 of "Solution Unsatisfactory" in *Astounding Science Fiction*, a magazine that Campbell edited. Both Campbell and Heinlein were aware of developments in nuclear physics and radiochemistry through their contacts within the scientific community, which included members of Ernest Lawrence's research team at the University of California, Berkeley.[28] The story, set in the midst of World War II, depicts the development by a team of U.S. scientists engaged by the War Department of uranium-derivative "deadly artificial radioactives," research that was pursued after work on nuclear explosives utilizing U-235 was discontinued.[29] In the story, production of this "radioactive dust" was seen by some as a means by which the United States could put an end to the war and declare a Pax Americana. Others, however, foresaw a radioactive-dust arms race in which the whole world would resemble "a room full of men, each armed with a loaded .45."[30]

In July 1941, Campbell also published a nonfiction, if sensationalist, cover story entitled "Is Death Dust America's Secret Weapon?" in the entertainment magazine *PIC*, which he also edited.[31] The article presciently noted that the world war (in which neither the Soviet Union nor the United States was yet directly involved) would be dramatically impacted by discoveries in the laboratory, and would entail a race for uranium ore. The article's main message, however, was to highlight the potential for development of a synthetic, radioactive "death dust," whose dispersal would paralyze cities. Beneath an artist's conception of a city sprayed with the dust, is the caption: "Even rats wouldn't

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27. H. Bruce Franklin notes that there were several earlier works of fiction to imagine radioactivity as a weapon of war, including Roy Norton, *The Vanishing Fleets* (serialized in the *Associated Sunday Magazines* in 1907) and Hollis Godfrey, *The Man Who Ended War* (Boston: Little, Brown, 1908). These writings, however, bore little resemblance to radiological weapons as we have come to know them. See Franklin, "Fatal Fiction: A Weapon to End All Wars," *Bulletin of the Atomic Scientists*, Vol. 45, No. 9 (November 1989), p. 20, doi.org/10.1080/00963402.1989.11459745.
28. References to both Campbell's and Heinlein's familiarity with the activities of nuclear scientists occur throughout their frequent correspondence. See, for example, "John W. Campbell to Robert Heinlein, October 29, 1940," Robert A. and Virginia G. Heinlein Papers, MS95, box 27:5, University of California, Santa Cruz.
29. MacDonald, "Solution Unsatisfactory," pp. 63–64.
30. Ibid., p. 65.
31. John W. Campbell Jr., "Is Death Dust America's Secret Weapon?" *PIC*, July 22, 1941, pp. 6–8, pdf accessed via Alex Wellerstein, "Death Dust, 1941," *Restricted Data: The Nuclear Secrecy Blog*, http://blog.nuclearsecrecy.com/wp-content/uploads/2014/03/PIC-magazine-1941-Campbell-Death-Dust-via-Gene-Dannen.pdf.

survive the blue, luminescent radioactive dust. Vultures would be poisoned by their own appetites."[32]

Early speculation about radiological warfare in literature and the popular press arose in the context of fears that Nazi Germany would incorporate the products of atomic science into its war machine, a not-unrealistic prospect given the pioneering work on nuclear fission played by Otto Hahn and other German scientists. Germany also possessed at least one laboratory engaged in work on isotope separation and a cadre of scientists with expertise in radiobiology.[33] As Campbell notes, Germany, like other belligerents in the war, had access to the necessary raw materials to produce "death dust."

The evidence that Adolf Hitler's Germany pursued radiological warfare, however, is problematic and at best fragmentary. It includes Joseph Goebbels' propaganda about *Wunderwaffen* (wonder weapons) turning the tide of the war and Hitler's reported bragging to the Romanian fascist dictator Ion Antonescu that German scientists had devised a long-range V-Weapon "of such potent effect that all human life is exterminated within a radius of three to four kilometers from the point of impact."[34] Scholarship on the topic is also underdeveloped, and more often than not is the province of fabulists.[35] At most, a circumstantial case can be made that Hitler's V-rockets were not intended exclusively for delivery of conventional explosives, an argument advanced by Philip Henshall, who asserts that German rocket schematics and layouts of rocket sites are suggestive of a radiological payload.[36]

The U.S. Experience with Radiological Weapons

The first reference to RW in a government document appears in May 1941, the same month and year as the publication date of the Heinlein story in *Astounding Science Fiction* and seven months before Japan's attack on Pearl

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32. Campbell, "Is Death Dust America's Secret Weapon?" pp. 6–7.
33. Pavel V. Oleynikov, "German Scientists in the Soviet Atomic Project," *Nonproliferation Review*, Vol. 7, No. 2 (Summer 2000), pp. 1–30, https://www.nonproliferation.org/wp-content/uploads/npr/72pavel.pdf.
34. Heinrich Bodensieck, "Die Atombombe in der Kriegspropaganda. Presseberichte ueber Massenvernichtungswaffen 1941 und 1944," [The atom bomb in war propaganda. Press reports on weapons of mass destruction 1941 and 1944], in Michael Salewski, ed., *Das nukleare Jahrhundert* [The nuclear century] (Stuttgart, Ger.: Franz Steiner, 1998), p. 58.
35. See, for example, Geoffrey Brooks, *Hitler's Nuclear Weapons: The Development and Attempted Deployment of Radiological Armaments by Nazi Germany* (London: Pen and Sword, 1992); and Rainer Karlsch, *Hitlers Bombe* [Hitler's bomb] (Munich: Deutsche, 2005).
36. Philip Henshall, *Vengeance: Hitler's Nuclear Weapon Fact or Fiction*? (London: Allan Sutton, 1995).

Harbor. The document identified three possible military aspects of atomic fission, the first of which was "production of violently radioactive materials . . . carried by airplanes to be scattered as bombs over enemy territory."[37] The report estimated that "radioactive dust would need a year's preparation after 'the first successful production of a chain reaction,' which meant 'not earlier than 1943.'"[38]

While there is no indication that any immediate action followed the report's release, by 1942, scientists at the University of Chicago's newly established Metallurgical Laboratory (Met Lab) had become worried that Nazi Germany might be ahead of the United States in developing a nuclear reactor. Fearful that Germany might use it to breed radioactive isotopes that could be mixed with dust or liquid particles for dispersal in a bomb, the United States decided to initiate a study of its military uses and possible defenses against them.[39]

Although the precise chronology of events related to the serious consideration of RW in 1943 is unclear, the assignment fell to a subcommittee of the S-1 Committee, the successor to the Advisory Committee on Uranium. The subcommittee produced a short memo titled "Use of Radioactive Material As a Military Weapon," which foresaw two principal military applications: (1) "as a terrain contaminating material," and (2) "as a gas warfare instrument."[40] In the first case, the subcommittee estimated that spreading radioactive products on the ground might provide area denial for weeks or months. In the second case, it anticipated that radioactive material might be ground into microscopic particles to form dust and smoke, which could be "distributed by a

37. Report of the Uranium Committee. Arthur H. Compton, National Academy of Sciences Committee on Atomic Fission, to Frank Jewett, President, National Academy of Sciences, May 17, 1941, p. 2, https://www.documentcloud.org/documents/3913457-Report-of-the-Uranium-Committee-Arthur-H-Compton.html. The other two possible applications were "a power source on submarines and other ships" and "violently explosive bombs."
38. Ibid. The report indicated that it would take at least three years after a chain reaction to produce a nuclear power source, whereas a bomb based on U-235 or plutonium would unlikely be available before 1945.
39. Richard Rhodes, *The Making of the Atomic Bomb* (New York: Simon & Schuster, 1986), p. 510. Barton J. Bernstein cites a communication from Arthur Compton to James Conant in July 1942 expressing the view that there was a real danger that Germany might attack the United States with bombs designed to disperse radioactive material. See Bernstein, "Radiological Warfare: The Path Not Taken," *Bulletin of the Atomic Scientists*, Vol. 41, No. 7 (August 1985), p. 45, doi.org/10.1080/00963402.1985.11455998.
40. "Use of Radioactive Material As a Military Weapon," ACH1.000003.006.e, DOE OSTI OpenNet, p. 1, https://www.osti.gov/opennet/servlets/purl/16384400.pdf. The memo has no date, but it appears to have been prepared during the summer of 1943. See "Foreign Intelligence Supplement No. 2," *Manhattan District History*, Bk. 1: *General*, Vol. 14: *Intelligence and Security*, DOE OSTI OpenNet, July 31, 1952, p. 3, https://www.osti.gov/includes/opennet/includes/MED_scans/Book%20I%20-%20General%20-%20Volume%2014%20-%20Intelligence%20-%20Foreign%20Intell.pdf.

ground-fired projectile, land vehicles, or aerial bombs."[41] The subcommittee, however, pointed to several factors that might offset the effectiveness of radioactive dust or smoke: the potential for rapid dissipation due to wind and the "shielding effects of buildings." Although the subcommittee was divided over the likelihood of German use against allied forces in the fall of 1943, all members thought it unlikely that a radioactive weapon would be used against the continental United States. Nevertheless, the subcommittee was sufficiently concerned about the use of radioactive material as a weapon in Europe to recommend creation of a special committee to prepare a report on defensive measures.[42] Interestingly, the subcommittee itself did not directly advocate development of RW by the United States but suggested that, if military authorities wished to be ready to employ radiological weapons in response to enemy first use, then "studies on the topic should be started immediately."[43]

In contrast to this cautious assessment of RW, Manhattan Project physicists Enrico Fermi and Robert Oppenheimer were enthusiastic about its offensive potential. In April 1943, Fermi privately suggested to Oppenheimer that fission products—most likely strontium-90—be used to poison the German food supply. Oppenheimer swore Fermi to silence and even kept the idea from subcommittee member Arthur Compton, but he discussed the concept with fellow physicist Edward Teller, as well as with Gen. Leslie Groves, director of the Manhattan Project.[44] In Oppenheimer's view, the plan made sense only if it were able to poison a half million men.[45] There is no indication if he had in mind only combatants.

There is no evidence that anything ever came of Fermi's plan directly. Although Groves was persuaded of the need to study the potential of radiological weapons, he disclaimed interest in its offensive use.[46] There also is no indication that President Franklin Roosevelt or Secretary of War Henry Stimson was apprised of or was interested in the military applications of

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41. Ibid., p. 2.
42. Ibid., p. 3.
43. Ibid., p. 2.
44. See "J. Robert Oppenheimer to Enrico Fermi (inviting to Los Alamos)," March 11, 1943, *Restricted Data: Nuclear Secrecy Blog*, http://blog.nuclearsecrecy.com/wp-content/uploads/2013/09/1943-Oppenheimer-to-Fermi.pdf. See also Rhodes, *Making of the Atomic Bomb*, p. 511.
45. "J. Robert Oppenheimer to Enrico Fermi (inviting to Los Alamos)," March 11, 1943. See also Alex Wellerstein, "Fears of a German Dirty Bomb," *Restricted Data: Nuclear Secrecy Blog*, September 6, 2013, http://blog.nuclearsecrecy.com/2013/09/06/fears-of-a-german-dirty-bomb/.
46. See Sean L. Malloy, "'A Very Pleasant Way to Die': Radiation Effects and the Decision to Use the Atomic Bomb against Japan," *Diplomatic History*, Vol. 36, No. 3 (June 2012), p. 527, doi.org/10.1111/j.1467-7709.2012.01042.x. He suggests that Groves, as well as Conant, Compton, and Urey, were reluctant to support radiological warfare because of its resemblance to chemical warfare.

radioactive material, although they may have been aware of Operation Peppermint—an Allied plan to counter possible German use of radioactive fission products to defend against the Normandy invasion.[47]

Although most of the limited U.S. research on RW during the war was defense oriented, the ideas for offensive use broached by Fermi resonated with one individual with whom Oppenheimer interacted—Joseph Gilbert Hamilton. He was an assistant professor of medicine at the University of California's Berkeley Radiation Laboratory, who, since 1942, had been investigating the biological effects of uranium fission products.[48] In the same letter to Fermi in which Oppenheimer cautions against pursuing the food poison plan unless it could be done on a huge scale, he mentions his plans to pursue the matter "a little more deeply with Hamilton, although of course only on the psychological side."[49]

Hamilton and Oppenheimer exchanged correspondence, but it is unclear if they ever discussed in person Fermi's plan for radiological poisoning.[50] What is known is that Hamilton, who at the time was conducting radiological experiments on both humans and animals, was excited about the possibilities for offensive use of radiological poisons and communicated his ideas to other scientists, including Robert Stone at the Met Lab. As early as May 27, 1943, in a letter to Stone, Hamilton outlined the purported military virtues of using radioactive material to contaminate the air and poison food stocks. Stone, for his part, requested more detailed information from Hamilton about the effects of the material and their optimal concentrations.[51]

The Met Lab included both defensive and offensive radiological warfare on its list of research objectives as late as December 1943,[52] and it is possible that a few scientists working on the Manhattan Project at other facilities also explored different facets of radiological weapons. For all practical purposes, however, research on the subject in the United States was put on hold during the last years of the war. The pause, however, was short.

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47. See "Foreign Intelligence Supplement No. 2," July 31, 1952, *Manhattan District History*, pp. 7–10. See also Wellerstein, "Fears of a German Dirty Bomb."
48. Joseph G. Hamilton, letter to Col. E.B. Kelly, Research Program for Contract W-7405-eng-48-A, August 28, 1946, DOE OSTI OpenNet, https://www.osti.gov/opennet/servlets/purl/16004198.pdf.
49. "J. Robert Oppenheimer to Enrico Fermi (inviting to Los Alamos)," March 11, 1943.
50. Barton Bernstein notes that there are no references to such a discussion in the papers of either Hamilton or Oppenheimer. See Bernstein, "Radiological Warfare," p. 46
51. Ibid.
52. Glenn T. Seaborg, "Wednesday, December 8, 1943," in *Journal of Glenn T. Seaborg: Chief, Section C-1, Metallurgical Laboratory, Manhattan Engineer District, 1942–46*, Vol. 1 (Berkeley, Calif.: Lawrence Berkeley National Laboratory, 1992), https://escholarship.org/content/qt8t99r79q/qt8t99r79q.pdf.

THE RISE OF U.S. RW

The process by which RW gained traction in the United States is largely consistent with the first two phases of the U.S. weapons innovation process described by Evangelista. In the first, "technocratic initiative" phase, scientists discover new technical possibilities and advocate their military applications; in the second, "consensus building" phase, they collaborate with military associates to build broader bureaucratic support and secure R&D funding.[53] In fact, many of the key early proponents of RW were scientists who had been engaged in radiochemistry and radiological defense during World War II. Hamilton and Stone, for example, pressed for more work on RW; Teller was enamored by its possibilities; and Lawrence was an ardent supporter. The circle of proponents grew to include military figures who had previously not been directly involved in discussions about RW. These included Gen. Curtis LeMay, who, in August 1946, reportedly "urged consideration of the use of radioactive fission products from atomic piles," going so far as to suggest that they might be more effective weapons than atomic bombs.[54]

On December 31, 1946, the day before the Manhattan Project became the responsibility of the civilian Atomic Energy Commission (AEC), Hamilton sent a long memo to Col. K.D. Nichols of the Army Corps of Engineers. The memo enumerated "the major differences between chemical and radioactive poisons," and made a forceful case for the military advantages of RW. These were alleged to include effective and persistent means of area denial, the difficulty of neutralizing the agents, and the unique suitability of the weapons to spread "consternation, as well as fear and apprehension" among a targeted civilian population.[55]

Hamilton's memo spurred the AEC to appoint a panel of civilian and military experts to explore the merits of an offensive RW weapons program. The panel, chaired by the chemist Albert Noyes, first met in May 1948. The assembled decisionmakers, including AEC Director David Lilienthal, Ernest Lawrence, AEC Chief of Military Applications Gen. James McCormack, and several scientist veterans of the Manhattan Project, concluded that RW was worthy of further study to determine its military usefulness. Lawrence was a particularly staunch advocate, urging his fellow panel members to avoid drawing unfavorable comparisons between the nascent category of RW and

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53. Evangelista, *Innovation and the Arms Race*, pp. 52–59.
54. Bernstein, "Radiological Warfare," p. 48.
55. "Memorandum from Joseph G. Hamilton, M.D., to Colonel K.D. Nichols, Radioactive Warfare," Radiation Laboratory, Berkeley, California, December 31, 1946, DOE OSTI OpenNet, https://www.osti.gov/opennet/servlets/purl/16367341.pdf.

established weapons such as chemical and biological weapons.[56] During the subsequent summer, researchers at Oak Ridge National Laboratory conducted field tests addressing the problems of dispersal, diffusion, and dosimetry.[57]

In August 1948, after accumulating data from the Oak Ridge tests, the Noyes Committee released a report to the Department of Defense in which it laid out its recommendations for an RW program. The report did not fully reflect the enthusiasm of Hamilton's earlier memo regarding the effectiveness and feasibility of RW.[58] It did, however, acknowledge that initial experiments were encouraging enough to recommend that the Defense Department pursue a full-fledged program to design and build radiological weapons. The panel examined various means of delivery and concluded that the most promising path was the use of munitions similar to those employed in the then-active U.S. chemical weapons program. As such, the Defense Department assigned responsibility for the design and testing of radiological dispersal devices to the Army Chemical Corps (ACC).

Proponents of RW found an enthusiastic military partner in the ACC (formerly the Chemical Warfare Service), an organization that had been marginalized by the nonuse of chemical weapons during World War II and the emergence of the atomic bomb as a decisive weapon. Just days after atomic bombs were dropped on Hiroshima and Nagasaki, a high-ranking officer in the Chemical Warfare Service recommended to the CWS commander, Gen. Alden Waitt, that their unit should "move into the atomic business."[59]

Responsibility for the RW mission offered the ACC a new bureaucratic raison d'être at a time when the atomic bomb posed a challenge to the organization's existence as a separate entity.[60] The new mission also provided the ACC with a greater profile and increased funding, albeit temporarily. In fiscal years

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56. D.F. Carpenter, "Minutes of the 1st Meeting of an Ad Hoc Panel on RW," May 23, 1948, DOE Information Center, Oak Ridge, Tennessee, DOE OSTI OpenNet, p. 5, https://www.osti.gov/opennet/detail?osti-id=16142313.
57. Karl Z. Morgan, "Uniformly Distributed Source, ARUU Program," Oak Ridge National Laboratory, Health Physics Division, August 25, 1948, DOE OSTI OpenNet, https://www.osti.gov/opennet/servlets/purl/16125584.pdf.
58. Joint NME-AEC Panel on Radiological Warfare, "Radiological Warfare Staff Study, June–August 1948," August 29, 1948, DOE OSTI OpenNet, https://www.osti.gov/opennet/servlets/purl/16359248.pdf.
59. "Memorandum from John C. MacArthur to General Alden H. Waitt, Post-hostilities Organization," August 13, 1945, record group [RG] 373, Department of Defense, Department of the Army, U.S. Army Chemical Corps Research and Development Command, National Archives at College Park, Maryland.
60. See the commentary by William Porter, a subordinate officer to the chief of the Chemical Weapons Service, in "William Porter to Commanding General, Army Service Forces, Post-War Research and Development Activities of the Chemical Warfare Service," August 22, 1945, RG 373, National Archives at College Park, Maryland.

1950–53, "RW Agents" and "RW Munitions" were among the most generously funded ACC research and development projects.[61] These projects produced a series of prototype radiological munitions and generated dozens of open-air tests at the Dugway Proving Ground, a U.S. Army facility in Utah, from 1949 to 1953.[62] These field tests were successful in the sense that the devices detonated and dispersed radioactive material over a large area. The results, however, were insufficient to counter the diminution of institutional support during this period for the Army RW program. As such, in 1954, the Weapons System Evaluation Group, a technical committee that appraised the effectiveness of weapons systems for the Department of Defense and Joint Chiefs of Staff, recommended a significant downgrade in the RW program given complications related to the "U.S. capability to produce RW agent material."[63] The program also was stripped of its mandate to produce radiological weapons for aircraft and guided missile delivery. Subsequent budget cuts further squeezed the program, and by 1956 the Army Chemical Corps' Estimate of the CBR (Chemical, Biological, and Radiological) Situation declared that "the sole United States ability in radiological warfare as presently defined is to produce contamination by the use of nuclear weapons."[64]

THE DEMISE OF U.S. RW

Although technocratic advocates of RW were able to build a consensus among key military-technical stakeholders to pursue RW, they were stymied in their efforts to promote broader support for the new weapons technology among the military services, Congress, and the executive branch—the "promotion" phase in Evangelista's model of the U.S. weapons innovation process. They also failed to exploit external threats to justify the new weapon's adoption or to secure high-level endorsement for the novel RW technology.[65] These failures resulted in the RW program losing out in the competition for both financial re-

61. For example, in fiscal year 1950, $4.3 million was earmarked for "Radiological Research and Development," representing almost one quarter of the Army Chemical Corps R&D budget. See "Director of Logistics, GSUSA, ATTN: Deputy Dir for R&D, 'Breakdown of Chemical Corps Research & Development Funds, FY1950 in Basic Fields,'" August 16, 1948, RG 373, National Archives at College Park, Maryland.
62. See, for example, "Static Test of Full-Diameter Sectional Munitions, E83," U.S. Army Chemical Corps, May 7, 1953, Defense Technical Information Center, https://archive.org/details/DTIC_AD0596085.
63. Command Historical Office, CBDCOM, "Disposition Form, Radiological Warfare," June 30, 1954, DOE OSTI OpenNet, https://www.osti.gov/opennet/servlets/purl/16007717.pdf.
64. Office, Chief Chemical Officer, "Estimate of the CBR Situation," October 1, 1956, DOE OSTI OpenNet, https://www.osti.gov/opennet/servlets/purl/16007341.pdf. Bernstein asserts that the U.S. "radiological warfare program seems to have died officially in 1954, under the Eisenhower Administration's budget cutbacks." Bernstein, "Radiological Warfare," p. 48.
65. Matthew Evangelista refers to the last two phases of the weapons innovation process in the

sources and attention within the military-industrial establishment. It is worth examining how competing military priorities and bureaucratic politics combined with technical obstacles to doom a program that had once enjoyed considerable support in some sectors of the military and scientific establishment and also had been heralded in the popular press as foreshadowing "a way of waging *humane* warfare."[66]

RESOURCE CONSTRAINTS. The fate of the U.S. RW program turned in part on the decision to pursue a supply chain involving one specific radioisotope. When Hamilton first delineated his vision of radiological warfare in his 1946 memo, he described in lurid detail the dosages and effects of radiation poisoning, informed by his field of expertise as a radiobiologist. He neglected to mention what the source of the radiation might be. Thus, although he noted that the most appropriate isotopes for a weapon would be those "whose half-lives range from several weeks to the order of a year," he did not identify specific isotopes or explain how they would be produced.[67] The more cautious estimation of RW in the Noyes Committee report of August 1948 is largely the result of a thorough inquiry into how the radioactive material would be generated. The nuclear engineers on the panel indicated that although nuclear reactors produced a multitude of radioactive isotopes as waste material, few possessed the required characteristics for an effective area-denial weapon: gamma-emitters with a half-life no shorter than several weeks and no longer than a year or so.[68] In fact, they identified only one fission product as being useful for RW: zirconium-columbium.[69] Although this isotope was available in abundance in the nuclear waste generated by the plutonium production reactor at Hanford, Washington, extracting it was prohibitively difficult and expensive, and priority was given to employing plutonium separation for the production of material for nuclear explosives. Processing the nuclear waste would have required specialized facilities dealing with dangerous levels of contamination and, as environmental surveys of the nuclear weapons program in the early Cold War era attest, the U.S. nuclear establishment of the time did not pay particular attention to the disposition of the waste produced by the program.[70]

An alternative means to obtain material for a radiological weapon was to ir-

United States as "Open Windows" and "High Level Endorsement," in Evangelista, *Innovation and the Arms Race*, p. 52.

66. Lt. Col. David B. Parker, "War Without Death," *Coronet*, July 1950 (italics in the original).

67. "Memorandum from Joseph G. Hamilton, M.D., to Colonel K.D. Nichols, Radioactive Warfare," December 31, 1946, p. 3.

68. "Radiological Warfare Staff Study," August 29, 1948, pp. 22–23.

69. Ibid., p. 27.

70. See, for example, Stephen I. Schwartz, *Atomic Audit: The Costs and Consequences of U.S. Nuclear Weapons since 1940* (Washington, D.C.: Brookings Institution Press, 1998), p. 361.

radiate an inert metal inside a nuclear reactor through neutron capture. The engineers on the Noyes Committee recommended irradiating tantalum to produce its radioactive isotope, tantalum-182. Although not available in quite the abundance of the zirconium-columbium extracted from nuclear waste, this material had substantial advantages: its half-life is about 114 days, about the perfect "goldilocks zone" for tactical area denial—not too long, not too short. Moreover, it did not require a heavy investment in specialized facilities. In principle, the Hanford plutonium reactor could have been used to irradiate the tantalum during its normal operation. For these reasons, all the prototype radiological weapons produced over the course of the program used tantalum-182 as their radioactive payload.

The material needs of the RW program conflicted, however, with the requirements of the rapidly expanding atomic weapons program. In 1948, the United States possessed only one nuclear reactor capable of large-scale isotope irradiation, the B reactor at the Hanford site. The Hanford pile was devoted to the production not only of plutonium-239, the fissile material for most of the nuclear weapons then being built, but also of polonium, a necessary component of the neutron initiators in early bombs. As RW components are constantly decaying, they have a short shelf life. This means that maintaining stockpile equilibrium requires constant production of radioactive isotopes. With the Hanford pile running at full capacity to furnish the materials for the nuclear weapons program, it was not obvious how one could also sustain an RW arsenal.[71]

By early 1948, the primary U.S. advocates of radiological warfare realized that a meaningful RW program would require a devoted production infrastructure and could not indefinitely piggy-back on the nuclear weapon production complex. In the first meeting of the ad hoc panel investigating RW, Lawrence floated the idea of having reactors run in standby mode around the country in order to be ready for RW production at a moment of military necessity. He estimated that "twenty or thirty reactors would not be fantastic to contemplate."[72] Albert Holland at Oak Ridge issued a directive in 1949 that, in all future nuclear reactor construction, provisions must be made to include "space for irradiation of materials and sufficient excess reactivity to cover possible use of this space" to serve the RW program.[73] Yet, Lawrence's grand plan for a

71. "Radiological Warfare Staff Study," August 29, 1948, p. 49.
72. "Minutes of the 1st Meeting of an Ad Hoc Panel on RW," May 23, 1948, p. 5. One can imagine the dollar signs in Lawrence's eyes.
73. Holland, A.H., Production of Materials for Radiological Warfare, January 25, 1949, p. 2: Box 49-1-239, Central Files, Nuclear Testing Archive, Las Vegas, Nevada. Approved for public release April 1, 2016.

fleet of reactors devoted to RW agent production never came to fruition, and there is no evidence that Holland's directive resulted in any reactor being redesigned to accommodate the RW program.

Nonetheless, sufficient material was accumulated to undertake dozens of field tests at the Dugway Proving Ground.[74] These tests focused on the potential of RW for relatively short-term area-denial effects, and were not designed to examine other possible uses of RW.[75]

Reports on the field tests do not provide a qualitative assessment of their success or failure. They do indicate, however, that most of the munitions types functioned, and that they dispersed radiation over a considerable area.[76] This modest achievement was nevertheless insufficient to persuade the Weapons System Evaluation Group to recommend continued funding for an active RW program. Although the factors responsible for this outcome are unclear, it is likely that, in addition to the issue of competing resources, two considerations played a significant role: (1) the lack of a compelling military rationale for RW in an era dominated by nuclear arms, and (2) bureaucratic politics.

MILITARY RATIONALE AND EFFECTIVENESS. A number of U.S. military figures were intrigued by radiological weapons in the immediate postwar period, but none of them viewed RW as essential to their service's military mission. General LeMay's early interest in the potential of RW already has been noted, and General McCormack, the director of Military Applications of the AEC, encouraged investigation of a number of alternative ways to use RW.[77] Gen. Douglas MacArthur reportedly proposed creating a belt of radioactive cobalt dust "five miles deep and 100 miles wide" to cut off Chinese supply lines during the Korean War.[78] Although most proponents of RW during this

74. From 1949 to 1952, the Chemical Corps conducted sixty-five field tests at Dugway, releasing 13,000 curies of tantalum-182 into the atmosphere. Advisory Committee on Human Radiation Experiments [ACHRE], "Chapter 11—Intentional Releases: Lifting the Veil of Secrecy: What We Now Know," Final Report of the Advisory Committee on Human Radiation Experiments, *DOE Openness: Human Radiation Experiements*, https://ehss.energy.gov/ohre/roadmap/achre/chap11_2.html.

75. A very different picture of the scope and duration is depicted in Lisa Martino-Taylor, *Behind the Fog: How the U.S. Cold War Radiological Weapons Program Exposed Innocent Americans* (New York: Routledge, 2018).

76. See "Static Test of Full-Diameter Sectional Munitions, E83," May 7, 1953.

77. General McCormack was insistent that RW activities fall under the purview of the AEC. See Atomic Energy Commission, "Decision on AEC 28/1, Application of Certain Materials for Military Use: Report by the Director of Military Application in Collaboration with the Director of Biology and Medicine," March 18, 1948, DOE OSTI OpenNet, https://www.osti.gov/opennet/servlets/purl/16359831.pdf.

78. "Texts of Accounts by Lucas and Considine on Interviews with MacArthur in 1954," *New York*

period viewed the weapons as best suited for purposes of area denial, some advocates envisioned their potential as strategic weapons. In June 1947, Col. M.E. Barker, commandant at the Chemical Corps School, expressed special interest in toxic radioactive gas, which he believed might "be even more effective against strategic targets than atomic bombs."[79] At about the same time, one also could find arguments that RW might be attractive as a "relatively benign from of warfare," the idea being that they could be used in dosages that disrupted an adversary's economy and spread fear without killing people.[80] This view is reflected in a 1949 article on RW in the Department of the Army's monthly publication, *Officers' Call*, in which an entire section is devoted to the topic "RW as a Humane Weapon."[81] A darker variant of this view, articulated by Lawrence, suggested that because of the absence of a clear norm or taboo against their employment, RW might be more usable than atomic bombs, especially with regard to first use.[82]

None of these arguments, however, generated strong support among key institutional players in the U.S. defense establishment, and by 1956, radiological weapons were no longer regarded by any of the military services as effective in fulfilling priority military missions. To some extent, this view of the diminished value of RW was justified by technical considerations and relative cost effectiveness. The devaluation of RW, however, also was affected by competing organizational interests and bureaucratic political infighting.

BUREAUCRATIC POLITICS. Consistent with the logic of bureaucratic politics, the fate of the RW program in the United States was intrinsically linked to competition with its primary competitors—nuclear and chemical weapons. To be sure, some Army officials regarded RW as a possible complement to or

Times, April 9, 1964, https://www.nytimes.com/1964/04/09/archives/texts-of-accounts-by-lucas-and-considine-on-interviews-with.html.

79. Colonel M.E. Barker, "Chemical Weapons of the Future," *Military Review*, Vol. 27, No. 3 (June 1947). Adri De la Bruheze also cites this source but refers to the author as "Baker." De La Bruheze, "Radiological Weapons and Radioactive Waste in the United States: Insiders' and Outsiders' Views, 1941–55," *British Journal for the History of Science*, Vol. 25, No. 2 (June 1992), pp. 212–213, doi.org/10.1017/S0007087400028776.

80. Bernstein attributes this view to a group of physicists at Berkeley, including Luis Alvarez. Bernstein, "Radiological Warfare," p. 48. Edward Teller, Bernstein notes, continued to advocate the use of a cobalt-based RW as late as 1968, also ostensibly on grounds that it would be more humane. Ibid., pp. 48–49.

81. "Radiological Warfare," *Officers' Call*, Vol. 2, No. 6 (1949), pp. 1–12. The precise month of the publication is difficult to discern as it does not appear on the journal. No author is credited.

82. See statement by Lawrence in 1948, as relayed by Oak Ridge engineer William Becker and cited in John Shilling Jr., "Meeting Notes on Radiological Warfare Conferences, June 28 and 29, 1948," Oak Ridge Operations Office, Records Holding Task Group, Classified Documents, RHTG #26,040, box 51, DOE OSTI OpenNet, www.osti.gov/opennet/servlets/purl/906491.pdf.

even substitute for chemical weapons as a means to defend Europe from Soviet aggression, and Air Force figures such as LeMay were intrigued by the military applications of RW in general. Neither the Air Force nor the Navy, however, was ever a strong institutional RW advocate. By the mid-1950s, both services were far more interested in securing "their fair share" of the rapidly growing defense budget for nuclear explosives of all shapes and sizes. For the Air Force, this initially meant nuclear gravity bombs and, subsequently, nuclear-tipped intercontinental ballistic missiles.[83] The Navy, for its part, was never invested in the concept of RW, but had established an office to develop nuclear weapons for deployment on surface ships, submarines, and naval-based aircraft only months after the end of World War II. More importantly, since the early 1950s, Adm. Hyman Rickover had focused naval efforts in the nuclear sector on designing, manufacturing, and deploying nuclear-powered submarines, the first of which was commissioned in 1954.

In terms of intranational bureaucratic political bargaining, RW were always at a disadvantage in comparison to the sprawling and rapidly expanding nuclear weapons complex. As already noted, production of RW agents depended on the Hanford breeder reactor, whose chief mission was plutonium production for nuclear weapons pits.[84] The devastating effect of nuclear weapons also had been proven on the battlefield, and after the first Soviet nuclear test in 1949, arms-racing logic drove the quantitative and qualitative expansion of the nuclear arsenal at the expense of other systems.

RW development also was constrained ultimately by the more established chemical weapons program. The Army Chemical Corps, which initially embraced RW as a means to restore funding and relevance during an institutional nadir immediately after World War II, benefited from the Department of Defense's reevaluation of the role of chemical and biological weapons. In June 1950, a committee tasked by the secretary of defense to undertake a full examination of CW, BW, and RW returned a report recommending a significant upgrade and reinvestment in CW. Most importantly, the report urged the military to abandon its "for retaliation only" policy toward chemical weapons, and to be prepared to employ chemical weapons immediately upon the onset of

83. For a discussion of the bureaucratic and organizational politics associated with the development of these systems, see Edmund Beard, *Developing the ICBM: A Study in Bureaucratic Politics* (New York: Columbia University Press, 1976); and Brown, *Flying Blind*. See also Jacob Neufeld, *The Development of Ballistic Missiles in the United States Air Force, 1945–1960* (Washington, D.C.: GPO, 1990), http://www.dtic.mil/dtic/tr/fulltext/u2/a439957.pdf.
84. See discussion of RW agent acquisition in John Shilling Jr., "Meeting Notes on Radiological Warfare Conferences, June 28 and 29, 1948," p. 2.

war.[85] The report included a brief analysis of RW advantages and disadvantages and urged continued study to evaluate their feasibility and desirability, but afforded RW a much lower priority than CW and, to a lesser extent, BW.[86] While the enhanced status of the ACC accelerated RW development by reauthorizing open-air testing of chemical (and radiological) munitions at Dugway Proving Ground, it also forced the RW program to compete simultaneously for funds and high-level attention with both the nuclear and chemical weapons programs—a competition for which RW advocates were ill-prepared to wage and destined to lose.

An additional bureaucratic factor that may have vitiated against U.S. adoption of RW as a weapons innovation is the military's dominant frame of reference and preference for kinetic warfare—what Frank Smith refers to as the "kinetic frame." According to this thesis, military bureaucracies have a preference for innovations that resemble traditional bullets and bombs.[87] Weapons that propagate radiation, an invisible and frequently misunderstood physical phenomenon, would be particularly disadvantaged by this bias in military thinking.

NORMATIVE CONSIDERATIONS. Conceivably, normative considerations also may have diminished bureaucratic support within the U.S. government for radiological weapons. RW frequently were depicted as an analogue to or variant of chemical weapons by their proponents, and an aversion to chemical weapons could have made some policymakers less receptive to RW. In any case, the potential pitfalls of conflating the two weapons categories were ignored by some of their military and scientific advocates. Hamilton, for instance, promoted the concept of RW to U.S. military authorities as a superior chemical weapon with both potential tactical and strategic capabilities whose use could be as effective in making a city uninhabitable as those of an atomic bomb.[88] Although the Armed Forces Special Weapons Program steered research away from the strategic mission envisioned by Hamilton, the RW program after 1948 did focus its efforts on a device that resembled a chemical bomb in its design

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85. "Report of the Secretary of Defense's Ad Hoc Committee on Chemical, Biological and Radiological Warfare," June 30, 1950, DOE OSTI OpenNet, https://www.osti.gov/opennet/servlets/purl/16008529.pdf. The outbreak of the Korean War on June 25, 1950 lent additional weight to the Committee's recommendations. See Tucker, *War of Nerves*, p. 126.
86. "Report of the Secretary of Defense's Ad Hoc Committee on Chemical, Biological and Radiological Warfare," June 30, 1950, pp. 18–20.
87. Smith, *American Biodefense*, pp. 3–4. Smith discusses the applicability of his kinetic frame thesis to neutron bombs, a non-RW example of weaponized radiation. See, in particular, pp. 33–34.
88. "Memorandum from Joseph G. Hamilton, M.D., to Colonel K.D. Nichols, Radioactive Warfare," December 31, 1946, p. 7.

and attributes, and, as noted above, the U.S. Army Chemical Corps was tasked with its development and testing.

It would be reasonable to assume that a number of policymakers shared the view of AEC Chairman Lilienthal that RW were part of a category of weapons that were both undesirable and beyond the pale.[89] After all, in 1948, the United Nations had already defined radiological weapons as a weapon of mass destruction in the context of developing disarmament and nonproliferation initiatives.[90] The issue of RW also began to receive more attention in the public domain in both scientific publications and the mass media. Especially noteworthy was the 1948 book by Austrian physicist Hans Thirring in which he described the humanitarian horror of radiological weapons, or fine-grained "death sand," as he called it.[91] Perhaps the most striking passage in his book refers to the potential of this fearsome new weapon to exterminate frontline soldiers "like vermin in a space that's being gassed with hydrogen cyanide"—a clear allusion to the Nazi's use of gas in the death camps.[92]

Although there exist hints of moral opposition to RW sprinkled throughout the documentary history of the program, it is not apparent that the views of Thirring or like-minded scientists and bureaucrats inside or outside the U.S. government had much impact on building a norm against RW development or use. Instead, the preponderance of evidence suggests that RW proponents believed them to be a legitimate method of warfare whose development was justified by the actions of U.S. adversaries. This perspective is clearly articulated by General McCormack in the early period of the Cold War in a communication to Carroll Wilson, the first general manager of the AEC. McCormack acknowledges that "the subject is not a pleasant one to contemplate, but it must be subjected to a critical examination in the United States, especially as regards the possibility of an enemy waging radiological war against us."[93]

Even Thirring's work, when popularized in the United States, was inter-

89. See David Lilienthal quoted in Bernstein, "Radiological Warfare," p. 48.
90. W. Seth Carus, "Defining 'Weapons of Mass Destruction,'" Center for the Study of Weapons of Mass Destruction Occasional Paper, No. 8 (Washington, D.C.: National Defense University Press, 2012).
91. Hans Thirring, *Atomkrieg und Weltpolitik* [Atomic war and world politics] (Vienna: Danubia-Verlag, 1948). Thirring also made reference to the dangers of radioactive dust in his lectures and in an influential article "Ueber das moegliche Ausmass einer radioacktiven Verseuching durch die Spaltprodukte des U-235" [On the possible extent of radioactive contamination through fission products of U-235] *Acta Physica Austriaca*, Vol. 2, (1948), pp. 379–400.
92. The German word "Blausäuere" is hydrogen cyanide, the "B" in Zyklon-B gas.
93. Brig. Gen. James McCormack, "Memo to Carroll Wilson, Subject: Radiological Warfare," April 16, 1947, National Archives and Records Division, Atomic Energy Commission, DOE OSTI OpenNet, https://www.osti.gov/opennet/servlets/purl/16359294.pdf.

preted in a way that downplayed the ethical component. This is apparent in a 1950 article in the *Bulletin of the Atomic Scientists* by Louis Ridenour, who had been a special assistant to the U.S. secretary of the Air Force.[94] Ridenour accurately portrays the science behind Thirring's work but chooses not to mention the Austrian scientist's moral concerns. Instead, he observes that while the "novel thing" can be viewed "as a horrid and insidious weapon," it also "can be regarded as a remarkably humane one," because "it gives each member of the target population a choice of whether he will live or die."[95] Contrasting RW to the horrific weapons of the last war, which deprived citizens of a choice in the matter of life or death, Ridenour even suggests that there is an excellent chance of survival for a person exposed to the radioactivity of this new weapon if the individual "flees at once with a folded, dampened, handkerchief over his nose and mouth."[96]

At almost the same time that Ridenour's article appeared in print, a report by the aforementioned secretary of defense's Ad Hoc Committee on Chemical, Biological and Radiological Warfare was released, recommending further research and development of RW—in addition to an expansion of CW and BW capabilities.[97] This remarkable document, likely meant to steel U.S. officials' resolve to use any weapon necessary to defeat states that attempted to challenge the United States, repeated Lawrence's argument that "the target populace can detect [RW's] presence and move out of the danger area."[98] It uses this argument to question the relevance of the concept of "weapons of mass destruction" (introduced by the Commission for Conventional Armaments of the United Nations in 1948) when applied to RW, and it advocates strongly for their continued development with intention to use whenever they would offer a military advantage. In short, the report of the secretary of defense's Ad Hoc Committee represents a stark repudiation of any emerging norm against the development, and even the use, of radiological weapons.

INTELLIGENCE FAILURE AND LACK OF "EXTERNAL THREAT." Had policymakers been aware of its magnitude, the Soviet RW program may have constituted an external threat to justify greater investment in the U.S. program. As it was, however, U.S. intelligence about Soviet RW activities was practically nonexis-

94. Louis N. Ridenour, "How Effective Are Radioactive Poisons in Warfare?" *Bulletin of the Atomic Scientists*, Vol. 6, No. 7 (July 1950), pp. 199–202, 224, doi.org/10.1080/00963402.1950.11461264.
95. Ibid., p. 200.
96. Ibid.
97. "Report of the Secretary of Defense's Ad Hoc Committee on Chemical, Biological and Radiological Warfare," June 30, 1950.
98. Ibid., p. 8.

tent, and certainly was much less robust than the Kremlin's knowledge of U.S. RW developments. A Central Intelligence Agency (CIA) Intelligence Memorandum from September 20, 1949, concluded that no foreign country was engaged in the production of radiological warfare agents;[99] a February 1950 CIA working paper likewise reported "no information on Soviet national policy with respect to the employment of radiological warfare materials either openly or subversively."[100] The same paper observes that the United States was unaware of any reports in the Soviet media about defensive measures having been undertaken specifically with respect to RW.[101] The working paper's conclusion underscores just how severely U.S. intelligence agencies underestimated Soviet RW pursuits:

> The USSR does not have available at the present time a sufficient quantity of radiological warfare materials to be useful in a military sense, but they do have the capability of disseminating small quantities of radioactive poisons within the U.S. through the employment of subversive individuals and organizations, if they should so desire.
>
> It is our opinion, however, that from a practical standpoint, as compared to BW and CW, the production of a significant quantity of RW materials requires an extensive plant installation, and would interfere with atomic bomb production. In addition [RW materials] are difficult to handle and disseminate, and their use is relatively ineffective. For these reasons their employment by the USSR is considered to be unlikely.[102]

The CIA assessment of Soviet RW capabilities, and particularly the obstacles in their path, may well have been a product of "mirror-imaging," and the presumption that if Soviet Union embarked on a RW program, it would follow a course similar to the one pursued by the United States.[103]

The Soviet RW Experience

Contrary to U.S. intelligence, Moscow actively pursued radiological weapons for approximately ten years beginning in 1947. Ironically, Soviet interest in RW

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99. "Intelligence Memorandum No. 225," included as an annex to Central Intelligence Agency, "Soviet Potentialities to Conduct Radiological Warfare," February 23, 1950, DOE OSTI OpenNet, https://www.osti.gov/opennet/servlets/purl/16384715.pdf.
100. Ibid., pp. 1–2.
101. Ibid., p. 3.
102. Ibid., p. 4. "They" (in italics) is crossed out by hand and "RW materials" is inserted in the original. A handwritten note at the bottom of the page indicates that the inserts were made after the presentation to the Committee on February 24, 1950.
103. See Army Emergency War Planning, "Chemical Warfare—Biological Warfare—Radiological Warfare," Vol. 2, Annex PP, August 4, 1952, RG 373, National Archives at College Park, Maryland.

appears to have been spurred by what military planners thought to be a significant U.S. investment in RW during this period. Although the contours of the U.S. and Soviet RW programs did not follow identical paths, both eventually suffered the same fate. Changes in perceived threats, the departure of key RW advocates, competition from chemical and nuclear weapons, systemic barriers to weapons innovation within the Soviet military industrial complex, and possibly health and safety considerations all contributed to the gradual demise of the Soviet pursuit of RW.

Although the highly compartmentalized nature of the Soviet RW program makes it challenging to knit its various facets together, the documentary record shows that Soviet scientists were aware of the possible military applications of radioactive material by 1940.[104] In mid-October of that year, two doctors of physical mathematics—V. Maslov and V. Shpinel—submitted a proposal to the Bureau of Inventions of the People's Commissariat of the USSR on the "use of uranium as an explosive and poisoning substance."[105] Their proposal highlights the persistence of fission products, which the authors describe as "thousands of times stronger than the strongest poisons," leading them to wonder whether "the colossal explosive power or the poisoning properties" of uranium fission "is the most attractive from a military standpoint."[106] The authors also underscore the similarities between radiological and chemical weapons, noting that the effects of radioactive agents "do not manifest immediately, and in their character resemble mustard."[107] This comparison was later codified in the term *radioacktivnye otravlyayiuschie veshchestva*—or "radioactive poisoning agents"—which became one of the preferred phraseologies for radiological weapons among Soviet military planners.

Although Maslov and Shpinel's early interest in radiological weapons appears prescient today, their proposal gained no traction with Soviet defense officials at the time. Two reviewers from the Scientific Research Chemical Institute of the People's Commissariat for Defense dismissed it as unreason-

104. Although there are only a few published accounts by actual participants in the Soviet RW program, a significant number of interviews with participants were conducted by Victor Tereshkin for the Bellona Foundation. Many of these interviews, in Russian, are summarized in Tereshkin, "'Gryaznaya bomba' Leningrada" ["Dirty bomb" of Leningrad], *Bellona*, December 27, 2006, https://bellona.ru/2006/12/27/gryaznaya-bomba-leningrada/.
105. See "Claim for an Invention from V. Maslov and V. Shpinel, 'About Using of Uranium as an Explosive and Toxic Agent,'" October 17, 1940, doc. no. 75, *Atomic Project of USSR: Documents and Materials*, Vol. 1, Part 1: History and Public Policy Program Digital Archive, pp. 193–196, https://digitalarchive.wilsoncenter.org/document/121631. Obtained and translated for the Nuclear Proliferation International History Project [NPIHP] by Oleksandr Cheban.
106. Ibid.
107. Ibid.

able, unclear, and unfounded.[108] Vitaly Khlopin, the head of Leningrad's famed Radium Institute, felt the proposal "contain[ed] many fantasies" and appeared to have been written by people who "have never dealt with large amounts of radioactive material."[109] Without endorsement from the top, this initial attempt to innovate in the domain of "radioactive poisoning agents" went nowhere. This sequence of events supports Evangelista's thesis that the stifling of initiative marked the first stage of Soviet weapons innovation.[110]

Only after intelligence determined that other foreign governments were defending against the military use of radioactive material did high-level Soviet interest in the development of RW take hold. This interest was apparent in a January 1943 report, which alleged that "Americans are building sensitive Geiger-Muller contraptions, which they will mount on the roofs of city buildings in order to detect radioactive substances as soon as they are dropped."[111] Soviet decisionmakers gained additional insights in January 1946 when Henry Smyth's report, "Atomic Energy for Military Purposes," was translated into Russian and distributed among the Soviet defense establishment.[112] The document contains Smyth's findings about the potential utility of radioactive poisons and U.S. defensive research in this area. Eleven months later, the Soviet Council of Ministers issued Order No. 13789 authorizing a thematic list of scientific research work to be undertaken related to nuclear physics, including research on the "possibilities of protecting organisms from the poisoning effects of radioactive agents." This task was assigned to the Institute of Organic Chemistry of the Academy of Sciences of the Soviet Union, the

108. See "Conclusion of National Institute of Chemical Studies of Soviet National Committee of Defence on Invention of UIPhT Fellows Which Was Sent to Agency of Military Chemical Defense," February 1941, doc. no. 89, *Atomic Project of USSR: Documents and Materials*, Vol. 1, Part 1, p. 220, https://digitalarchive.wilsoncenter.org/document/121634. Obtained and translated for NPIHP by Oleksandr Cheban.
109. "Conclusion of Radium Institute of Academy of Sciences on Invention of UIPhT Fellows Sent to Agency of Military Chemical Defense," April 17, 1941, doc. no. 96, *Atomic Project of USSR: Documents and Materials*, Vol. 1, Part 1, pp. 228–229, https://digitalarchive.wilsoncenter.org/document/121635. Obtained and translated for NPIHP by Oleksandr Cheban.
110. Evangelista, *Innovation and the Arms Race*, p. 69.
111. "Iz spravki 'Ispol'zovanie reaktsii rasshchepleniya urana dlya voennykh tselej,' podgotovlennoj po agenturnym dannym" [From the reference "The use of the uranium fission reaction for military purposes," prepared using data from agents], January 13, 1943, *Atomnyj proekt SSSR: Tom (1938–1945), Chast' 1* [Atomic project of the USSR: volume 1 (1938–1945), part 1] (Moscow: Science, FizMatLit, 1998), p. 291, http://elib.biblioatom.ru/text/atomny-proekt-sssr_t1_kn1_1998/go,291/.
112. "Spravka V.A. Makhneva o rassylke knigi G.D. Smita 'Atomnaya energiya dlya voennykh tselej'" [V.A Makhneva's reference to the distribution of G.D. Smyth's book, "Atomic Energy for Military Purposes"], January 23, 1946, doc. no. 164, *Atomnyj proekt SSSR: Tom II (1945–1954) Kniga 2* [Atomic project of the USSR: volume 2 (1945–1954), book 2] (Moscow: Science, FizMatLit, 2000), p. 404, http://elib.biblioatom.ru/text/atomny-proekt-sssr_t2_kn2_2000/go,404.

Ministry of Chemical Industry, and the Chemical Institute of the Red Army, reinforcing the perceived overlap between radiological and chemical weapons within the Soviet defense establishment.[113]

Although the documentary record does not indicate precisely when Soviet RW research assumed an offensive dimension, this orientation was evident by 1947. A report from September of that year noted that the program of work at Laboratory B (part of the facility known today as Snezhinsk[114]) included developing methods for the use of fission products as combat poisoning substances, as well as defensive measures.[115] By the end of 1947, V.L. Vannikov—deputy to Soviet secret police chief Lavrenti Beria in the Special Committee of the Atomic Project—was clearly contemplating specific military applications of radioactive products, too. He wrote to Joseph Stalin on December 17, 1947, that "radioactive materials, considering their resilience, can be used at times of war in large scale as equipment for long- and short-effect artillery shells, for an air bomb, for long- and short-effect aviation and, finally, for sea mines and torpedoes, similarly to how they're used as poisonous material for chemical ammunition."[116]

It is unclear whether Vannikov reached this conclusion based on research conducted in Laboratory B or through knowledge of corresponding projects in the West. If the latter, he may have been informed by spies embedded in the U.S. atomic weapons program. The most prominent of these is Klaus Fuchs, whose signature is present on a June 1, 1949, document from the United

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113. "Prilozhenie No. 1 Tematicheskij perechen' nauchno-issledovatel'skikh rabot po yadernoj fizike, podlezhashchikh vypolneniyu sekretnym poryadkom" [Appendix no. 1. thematic list of scientific research work on nuclear physics to be carried out by secret order], *Atomnyj proekt SSSR: Tom II (1945–1954), Kniga 3* [Atomic project of the USSR: volume 2: atomic bomb, 1945–1954, book 3, (Moscow: FizMatLit, 2002), p. 91, http://elib.biblioatom.ru/text/atomny-proekt-sssr_t2_kn3_2002/go,91.

114. Thomas B. Cochran and Robert Standish Norris, "Russian/Soviet Nuclear Warhead Production," (Washington, D.C.: National Resource Defense Council, 1993), p. 33, https://fas.org/nuke/cochran/nuc_09089301a_114.pdf.

115. "Otchet o rabote 9-go Upravleniya MVD SSSR po sostoyaniyu na 1 sentyabrya 1947 g." [Report on the work of the 9th directorate of the ministry of internal affairs of the USSR as of September 1, 1947], doc. no. 345, *Atomnyj proekt SSSR: Tom II (1945–1954), Kniga 3* [Atomic project of the USSR: Vol. 2 Bk. 3], p. 698, http://elib.biblioatom.ru/text/atomny-proekt-sssr_t2_kn3_2002/go,698/. This preliminary research effort aligns with a second stage of Soviet weapons innovation that Evangelista terms "preparatory measures," which are "often instituted in response to events abroad." See Evangelista, *Innovation and the Arms Race*, p. 71.

116. "Prilozhenie 7. Pis'mo B.L. Vannikova I.V. Stalinu po voprosam zashchity ot atomnogo oruzhiya ot 17 dekabrya 1947 g." [Appendix 7. Letter to V.B. Stalin from B.L. Vannikov on the issue of protection against atomic weapons dated December 17, 1947], in A.K. Chernyshyov, *Tvorets istorii XX veka Nikolaj Nikolaivich Semyonov v atomnom proekte SSSR* [History maker of the 20th century Nikolai Nikolaevich Semyonov in the atomic project of the USSR] (Moscow: Torus, 2016), p. 133, http://elib.biblioatom.ru/text/chernyshev_tvorets-istorii-semenov_2016/go,135/.

Kingdom's National Archives on the tactical and strategic utility of RW.[117] Although it is possible that Fuchs informed his Soviet handlers about British interest in these weapons, his final rendezvous with them took place in the spring of 1949, and it is unlikely that he knowingly passed along information related to British or American RW pursuits.[118] A more likely source of Soviet knowledge about offensive RW, however, was the German and Austrian scientists who were "recruited" to work on the Soviet atomic program during this time.[119] Their link to the Soviet RW program is clear from a letter written by the Chief of the 9th Directorate, Col. Gen. A.P. Zavenyagin, to Beria in January 1946.[120] Zavenyagin oversaw the program that recruited and supervised German scientists working on the Soviet atomic project during the postwar period.[121] His letter refers to a cache of German documents from 1944 that mention "the development of an atomic bomb and uranium warfare agents/poisons."[122] By 1946, large numbers of German scientists were working in the Soviet Union as part of its nuclear enterprise, including at Laboratory B, which, in September 1947, was tasked with developing defenses against, and weapons based on, radiological poisons.[123]

development of the soviet rw program

Whatever the source of their knowledge, Soviet officials were acutely aware of the direction U.S. research on RW was taking by April 1950. One document

117. Klaus Fuchs, "Letter to William Marley, HP/R352," *Military Liaison with Porton—Fission Product Warfare—General (1949–1951)*, June 1, 1949, box AB 6/544, National Archives, London, United Kingdom. Note: Archive was accessed before its withdrawal from public view by UK Nuclear Decommissioning Authority in December 2018.
118. M.W. Perrin, "Record of Interview with Dr. K. Fuchs on 30th January, 1950," *Michael W. Perrin interviews with Dr. Klaus Fuchs following his arrest for espionage, January to March 1950*, January 30, 1950, box AB 1/695, National Archives, London, United Kingdom. Note: Archive was accessed before its withdrawal from public view by UK Nuclear Decommissioning Authority in December 2018.
119. For the most comprehensive study of these scientists, see Oleynikov, "German Scientists in the Soviet Atomic Project," p. 4.
120. "Pis'mo A.P. Zavenyagina L.P. Beriya s predstavleniem spravki o sostoyanii rabot po ispol'zovaniyu atomnoj energii v Germanii i spiska nemetskikh spetsialistov, rabotayushchikh v Sovetskom Soyuze" [Letter from A.P. Zavenyagin to L.P. Beria with the submission of an inquiry on the status of work on the use of atomic energy in Germany and a list of German specialists working in the Soviet Union], doc. no. 158, *Atomic Project of the USSR*: Vol. 2, Bk. 2, p. 374, http://elib.biblioatom.ru/text/atomny-proekt-sssr_t2_kn2_2000/go,374/.
121. Oleynikov, "German Scientists in the Soviet Atomic Project," p. 4.
122. "Letter from A.P. Zavenyagin to L.P. Beria," doc. no. 158.
123. "Prilozhenie No. 2. Spisok nemetskikh spetsialistov, rabotayushchikh v Sovetskom Soyuze" [Appendix 2. list of German specialists working in the Soviet Union], *Atomic Project of the USSR*: Vol. 2, Bk. 2, p. 378, http://elib.biblioatom.ru/text/atomny-proekt-sssr_t2_kn2_2000/go,378/; and Oleynikov, "German Scientists in the Soviet Atomic Project," p. 16.

from this period identifies "radioactive O[travlyayiushchie] V[eshchestva]," or radioactive poisoning agents, as among the "new types of atomic weapon" under production in the United States.[124] A decision was made shortly thereafter to invest significant Soviet institutional resources in the development of RW. These efforts persisted under strict secrecy until the late 1950s and involved numerous design bureaus, testing facilities, and scientific institutes within the sprawling Soviet defense complex.

It seems doubtful that Soviet policymakers appreciated the relatively small investment the United States was making in RW, given that perceived foreign threats were a major driver behind the formal establishment of the Soviet RW program. After two years of preliminary research, the Soviet pursuit of RW moved from low-level efforts into what Evangelista characterizes as a phase of high-level, targeted response to weapons development abroad.[125] It involved the reallocation and redirection of existing resources toward research and development on RW, including, significantly, within the Soviet Navy. On July 10, 1951, its 6th Directorate established two special scientific/research subdivisions devoted to conducting research on radiological weapons. These subdivisions, referred to as the 15th and 1st Directorates, were housed under research institutions NII-10 (Nauchno issledovatel'skiy khimicheskiy institut) and NII-17 (Nauchno issledovatel'skiy meditsinskiy institut).[126] Their base, a nineteenth-century explosives laboratory on Vasilyevsky Island in Leningrad, provided an inconspicuous location for this clandestine work.[127]

On paper, both the 1st and 15th Directorates were responsible for researching the effects of nuclear weapons on naval equipment.[128] In practice, though, they weaponized radioactive waste so that it could be utilized in different warhead and bomb munitions. They also tested the effects of radioactive substances on humans and animals. Their plan of work was mapped out by specialists at the 1st Main Directorate of the Soviet Council of Ministers under

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124. "'Vypiska iz soobshcheniya' o novykh obratsakh atomnogo oruzhiya SShA" ["Extract from Message" on new models of atomic weapons in the USA], doc. no. 17, *Atomnyj proekt SSSR: Tom II: Atomnaya bomba, 1945–1954, Kniga 7* [Atomic project of the USSR: volume 2: atomic bomb, 1945–1954, book 7] (Moscow: FizMatLit, 2007), p. 38, http://elib.biblioatom.ru/text/atomny-proekt-sssr_t2_kn7_2007/go,38/.
125. Evangelista, *Innovation and the Arms Race*, p. 73.
126. In either 1956 or 1957, NII 10 and NII-17 were absorbed into NII 16. See Keith Dexter and Ivan Rodionov, "The Factories, Research and Design Establishments of the Soviet Defence Industry: A Guide," database version 20, Department of Economics, University of Warwick, May 2018, https://warwick.ac.uk/vpk/.
127. Tereshkin, "'Dirty Bomb' of Leningrad."
128. A.A. Greshilov, N.D. Egupov, A.M. Matyushchenko, *Yadernyj shchit* [Nuclear shield] (Moscow: Logos, 2008), p. 242, http://elib.biblioatom.ru/text/greshilov_yaderny-schit_2008/go,2/.

V.L. Vannikov, whose leading role in promoting both defensive and offensive RW research indicates the importance of high-level advocates in the weapons adoption process.[129]

Program participants claim that the plutonium production plant Mayak provided the radioactive solution with which the two naval directorates worked.[130] The actual source of this material, however, was likely Laboratory B, which had been charged with weaponizing radiological poisons in 1947. The substance in question—called Solution 904—was reportedly derived from spent fuel from which the plutonium had been extracted. Its radioactivity came primarily from high levels of zirconium-95 and niobium-95—the same isotopes recommended for use in the U.S. RW program. This solution was transported to Leningrad by train in 500 kilogram containers filled with thirty liters of atomic waste each.[131] Once specialists there had formulated it into the correct concentration for experimentation, the substance was referred to as "SK (or "Spetskomitet") concentrate." When it had been mixed with a viscous substrate (resin, for example) to make it difficult for an adversary to remove, it was called "SK preparation."[132]

The Soviet Union tested the lethality of this substance in prototype weapons at four known locations during the mid-1950s. The Navy primarily carried out its RW experiments in the northwest archipelago of islands in Lake Ladoga—an area known as Object 230.[133] Although the experiences of different program participants do not always align perfectly, it is clear that the scale of testing at Object 230 was significant. These experiments included effects tests on animals aboard a captured German vessel moored near Makarinsaari island, and often resulted in the inadvertent exposure of test site personnel to "SK" in the process.[134]

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129. E.A. Shitikov, "Istoriya yadernogo oruzhiya flota" [History of the navy's nuclear weapons], in *Yadernye ispytaniya: Kniga 1, Tom 1: Yadernye ispytaniya v Arktike* [Nuclear tests: book 1, volume 1: nuclear tests in the arctic] (Moscow: OAO Moscow Textbooks, 2006), pp. 16–17, http://elib.biblioatom.ru/text/yadernye-ispytaniya_kn1_t1_2006/go,16/. Evangelista highlights high-level advocates and decisions taken at the top levels of the military establishment as critical to weapons innovation in the Soviet Union. Evangelista, *Innovation and the Arms Race*, p. 73.
130. Tereshkin, "'Dirty Bomb' of Leningrad."
131. V.V. Bordukov, "Morskoj sektor na Semipalatinskom poligone" [Maritime quadrant of the Semipalatinsk test site"], *ProAtom*, May 22, 2009, http://www.proatom.ru/modules.php?name=News&file=article&sid=1822.
132. Tereshkin, "'Dirty Bomb' of Leningrad."
133. Anatoly M. Kutskov, "K 61-j godovshchine vojskovoj chasti 99795 'Ob"ekt 230 VMF'" [On the 61st anniversary of military unit 99795 "Object 230 of the Navy"], *Krasnaya zvezda* [Red Star], April 1, 2014, https://zvezda.press/?p=10832&hilite=%2799795%27.
134. Tereshkin, "'Dirty Bomb' of Leningrad"; and Kutskov, "On the 61st Anniversary of Military Unit 99795."

In an (albeit insufficient) effort to protect workers, the radioactive substances developed in Leningrad were stored in cone-shaped lead containers approximately one meter wide, one meter high, and twenty centimeters thick. Although each container was sealed with a lead plug, there were at least two major incidents in which the plug became dislodged, exposing workers to the highly radioactive material within.[135] These incidents and others like them may have eventually contributed to Commander in Chief of the Soviet Navy S.G. Gorshkov's decision to stop work on radiological weapons issues in December 1956.[136] Nevertheless, the radioactive solutions developed and refined by the Navy at its facilities near Lake Ladoga continued to be tested at least three other sites from approximately 1952 to 1957.

Some of the more well-documented RW tests took place at Semipalatinsk Test Site, where the Soviet Union also tested nuclear weapons until 1989. A 2002 monograph published by the Russian Ministry of Atomic Energy indicates that RW tests were carried out at Sectors 4 and 4A of Semipalatinsk from 1954 to 1956.[137] Vitol'd Vasilets, a retired colonel in the Soviet Navy, reports that these tests involved prototype "liquid air bombs" containing radioactive material.[137] Personnel from the Leningrad-based radiological weapons research institutes recall that these cluster munitions were conceived of primarily as a means to attack enemy aircraft carriers at sea.[139]

These liquid air bombs were dropped from two Il-28 planes that had been modified to accommodate this unusual cargo. According to Vasilets, the planes also incorporated safety features designed to protect the crew in case of an

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135. Kutskov, "On the 61st Anniversary of Military Unit 99795"; and Tereshkin, "'Gryaznaya bomba' Leningrada: Operatsiya 'Kit' na Ladoge" ["Dirty bomb" of Leningrad: Operation "Whale" on Ladoga], *Bellona*, April 9, 2015, http://bellona.ru/2015/04/09/kit_na_ladoge/.

136. See E.A. Shitikov, "U istokov yadernogo oruzhiya flota" [At the root of the fleet's nuclear weapons] (Moscow: Kurchatov Institute, 1998), p. 126, http://elib.biblioatom.ru/text/kiae-istoriya-atomnogo-proekta_v14_1998/go,126/.

137. V.A. Logachev et al., "2.2.2. Zagryaznenie mestnosti pri provedenii eksperimentov s boevymi radioaktivnymi veshchestvami" [2.2.2. Contamination of the area in which experiments were carried out with military radioactive substances], *Yadernye ispytaniya SSSR: Sovremenoe radioekologicheskoe sostoyanie poligonov: Fakty, svidetel'stva, vospolinaniya* [Nuclear tests of the USSR: contemporary radioecological state of test sites: facts, witnesses, recollections] (Moscow: Izd.AT, 2002), p. 76, http://elib.biblioatom.ru/text/yadernye-ispytaniya-sssr-sostoyanie-poligonov_2002/go,76/. Vitol'd Vasilets claims that prototype bombs were tested at Semipalatinsk between May 1953 and August 1957. Vitol'd Vasilets, "Pod rukovodstvom Sergeya Koroleva: kak v SSSR ispytyvalos' radiologicheskoe oruzhie v raketnom v bombovom ispolnenii" [Under the leadership of Sergei Korolev: how the USSR tested radiological weapons in rocket and bomb form], *Voenno-Promyshlennij Kur'er* [Military-Industrial Courier], February 14, 2007, https://vpk-news.ru/articles/4178.

138. Vasilets, "Under the leadership of Sergei Korolev."

139. Tereshkin, "'Dirty bomb' of Leningrad."

emergency. Nevertheless, the tests at Semipalatinsk presented serious—often deadly—hazards to the personnel involved. One accident reportedly occurred when a plane transporting a prototype weapon from Zagorsk to Semipalatinsk unexpectedly lost pressure, causing radioactive material to spill out onto the pilots.[140] This weapon, developed for the Soviet Army in either 1951 or 1952, apparently derived its radioactivity from strontium-90 and was therefore exceptionally dangerous. Eventually, the liquid radioactive substances in the test munitions were replaced with a less reactive simulator, but not before this and other accidents caused countless injuries and even deaths.[141]

At the same time that the Soviet Union was testing radioactive liquid air bomb and cluster munition programs, it was also developing missile warheads containing radioactive material. This phase of the Soviet RW program appears to have been initiated in either 1952 or 1953 and may have continued until as late as 1957.[142] As Vasilets recalls, prototype warheads were initially flight tested at the 71st Air Force Test Base near the Crimean village of Bagerove.[143] At least three warhead models were subsequently tested on short- and medium-range missiles at Kapustin Yar, where, despite this preparatory work, their performance was generally disappointing.

The two series of missile tests of radiological warheads conducted at Kapustin Yar were codenamed Geran' and Generator. Geran' entailed mounting warheads containing radiological material on R2 short-range ballistic missiles, but testing quickly showed that this particular warhead design was not effective in distributing radioactive material over a wide area.[144] A second series of tests—Generator—debuted two new designs: the first, a warhead filled with radiological material featuring a remote system or radio-controlled altimeter that would detonate a blast charge as it approached its target; and the second, a warhead filled with 100 or more shells containing radiological material that would explode on impact with a target.[145] Some reports also suggest that

140. Ibid.
141. Ibid.
142. Vasilets, "Under the leadership of Sergei Korolev."
143. Ibid.
144. Gennady Rostovskiy, *Kapustin Yar: selo, gorod, polygon* [Kapustin Yar: village, town, test site] electronic book (Moscow: LitRes, 2006); and Evgeny Buyanov and Boris Slobtsov, *Tajna gibeli gruppy Dyatlova* [The mystery of the death of the Dyatlov group] electronic book (Moscow: LitRes, September 5, 2017).
145. V.D. Kukushin, "Rozhdenie raketno-yadernogo oruzhiya" [The birth of nuclear-missile weapons], in *50-ya raketnaya armiya. Kniga 5: Chtoby pomnili. Sbornik vospominanij veteranov-raketchikov* [50th Missile Army, Book 5: So that they remember. Notebook of recollections of veteran-rocketeers] (Smolensk, 2004), as published in G.I. Smirnov, ed., *Raketnye sistemy RVSN ot R-1 k 'Topolyu-M' 1946–2006 gg* [RSMF missile systems from R-1 to Topol'-M, 1946–2006] (Smolensk:

work began on the development of the Generator-5 warhead in 1955. While virtually no information is available regarding this warhead, one source claims that at least three tests on an R-5 intermediate-range missile were carried out before the end of 1957.[146]

Perhaps more interesting than the warhead designs themselves was the environment in which the tests took place. Academician Boris Chetok provides a rare firsthand account of these tests in his memoirs, *Rakety i Luydi* (*Rockets and People*).[147] He recalls how he and other testers were shown the 1953 Soviet science fiction film *Serebristaya pil'* (*Silver Dust*) as a way of briefing them on the Geran' warhead's intended effects. The film depicts a U.S. effort to develop radiological air bombs containing a silver-gray radioactive dust, which malevolent scientists tested on human guinea pigs.

In contrast with participants in the U.S. RW program, who appear to have been unaware of early fiction accounts of these weapons, Soviet specialists who studied the effects of nuclear explosions were actually consulted in the production of *Serebristaya pil'*. According to Chertok, the result was a "film come true," one that showed how radiological weapons could kill without fighting while preserving critical infrastructure. In reality, however, the tests in which Chertok took part demonstrated that these weapons were not ready to be put into use. During preparations for the first Geran' launch, for example, the warhead began to leak what appeared to be radioactive material. While the launch team ran for cover, the senior scientist in charge of testing climbed to the top of the rocket, ran his finger through the trickle of brown liquid, and then tasted it. Concluding (correctly) that the liquid was a simulant, he entreated the team to return to work. "It tastes like crap," he said, "but it's harmless."[148]

THE END OF THE SOVIET RADIOLOGICAL WEAPONS PROGRAM

The Soviet RW program did not end abruptly, but instead withered away over several years. Although the lack of publicly available documents makes it difficult to chart its demise, it is clear that the program never progressed to what Evangelista calls "mobilization" (an all-out effort to pursue innova-

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Smolensk Regional Division of the Academy of Military Sciences of the Russian Federation Russian Strategic Missile Forces, Council of Veterans, 2006), p. 73.

146. Buyanov and Slobstsov, *Mystery of the Death of the Dyatlov Group*.

147. Boris Chertok, *Rockets and People*, Vol. 2: *Creating a Rocket Industry* (Washington, D.C.: NASA History Division, 2006), p. 245, https://www.nasa.gov/pdf/635963main_RocketsPeopleVolume2-ebook.pdf. It is unclear how many of the tests for the Geran' missile employed actual radiological materials and how many involved simulants.

148. Chertok, *Rockets and People*, p. 245.

tion) or "mass production," the final two stages in his model of the typical Soviet weapons innovation process.[149] Several factors help to explain why these weapons never lived up to their promise.

COMPARATIVE LACK OF MILITARY EFFECTIVENESS. The demise of the Soviet pursuit of RW was likely catalyzed by a revised assessment of their military effectiveness relative to other weapons. The Soviet Union conducted its first hydrogen bomb test in August 1953, and its growing arsenal of more lethal nuclear weapons undoubtedly reduced the appeal of primitive radiological dispersal devices. This finding aligns with the substitution effect hypothesis proposed by Michael Horowitz and Neil Narang in their study of the relationship among weapons of mass destruction and the perceptions of CW and BW as "poor man's nuclear weapons." Although Horowitz and Narang do not address radiological weapons, they do find that nuclear, chemical, and biological weapons are typically pursued simultaneously only until a state has acquired a nuclear capability, at which point states are unlikely to continue their CW or BW programs.[150]

The shortcomings of RW would have been especially apparent in comparison to chemical weapons, which were already part of the Soviet arsenal and served a similar battlefield purpose to that envisioned for RW. Joachim Krause and Charles Mallory surmise that a major buildup of Soviet chemical weapons—including tube and rocket artillery, tactical missile warheads, air bombs, spray tanks, and hand grenades—was initiated in the late 1950s, at almost the same time that support for the RW program was waning.[151] The perceived threat of a U.S. chemical weapons attack may have driven resources away from RW research, especially after the United States abandoned its policy on the non-first use of CW in 1956.[152] This decision likely increased the salience of the CW threat for Soviet decisionmakers, given that the Soviet Chemical Troops doubled in size between 1954 and 1965.[153]

LACK OF ORGANIZATIONAL SLACK. The lack of "organizational slack" within the Soviet Union's military establishment may also explain the demise of the Soviet RW program. Evangelista defines this concept as the ex-

149. Evangelista identifies mobilization as the moment when the "leadership endorses an all-out effort to pursue innovation," noting that it directly precedes mass production and adoption into military arsenals. Evangelista, *Innovation and the Arms Race*, p. 52. As the documentary record shows, the Soviet RW program was abandoned far before either of these stages.
150. Horowitz and Narang, "Poor Man's Atomic Bomb?" p. 530.
151. Krause and Mallory, *Chemical Weapons in Soviet Military Doctrine*, pp. 131, 156.
152. The Soviet Union appears to have taken a similar decision by 1962. See ibid., p. 127.
153. Ibid., p. 133.

tent to which an organization has access to uncommitted resources—a key facilitator of weapons innovation.[154] He finds that the Soviet military's emphasis on plan fulfillment left little organizational slack and increased reliance on tried-and-true weapons systems over new technology.[155] It is likely that Soviet military planners eventually decided to devote their finite resources to CW instead of radiological air bombs and cluster munitions, which bore a striking resemblance to Soviet chemical weapons but lacked their proven track record.

CHANGES IN PERCEIVED THREATS. Just as the Soviet pursuit of radiological weapons was a response to the U.S. RW program, changes in perceived threats from foreign adversaries may have shifted Soviet defense priorities away from RW, too. This appears to have been the case with respect to RW research and development within the Navy. By the time Adm. S.G. Gorshkov took over as its commander in chief in January 1956, the United States enjoyed a huge advantage over the Soviet Union in terms of its nuclear-powered fleet, and Gorshkov initiated a major effort to catch up. He would have had few reasons to squander limited resources on the unpromising RW program and, unsurprisingly, ended the Navy's pursuit of RW in December 1956.[156]

HEALTH AND SAFETY CONCERNS. Health and safety concerns may also have diminished Soviet enthusiasm for RW, although the number of unsafe practices in the nuclear sector at that time (and subsequently) is cause for skepticism. Still, the aforementioned accidents likely reduced RW's attractiveness for some branches of the military, especially given the overall lack of organizational slack. Disposal of contaminated machinery and equipment also remained a challenge for decades after the RW program ended. For instance, it took thirty-five years for the ship used to test radioactive contaminants to be recovered, encased in plastic and towed 3,200 kilometers to Novaya Zemlya after it sank in 1956.[157] Whatever the role of safety in the Soviet

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154. Evangelista, *Innovation and the Arms Race*, p. 45. Michael Horowitz uses a similar concept—organizational capacity—to explaine the propensity of military organizations to innovate. See Horowitz, *The Diffusion of Military Power*, pp. 10, 35. Much of the literature on the relationship between slack resources and innovation can be traced back to the seminal work of James G. March and Herbert A. Simon, *Organizations* (New York: John Wiley & Sons, 1958).
155. Evangelista, *Innovation and the Arms Race*, p. 48.
156. Shitikov, "History of the Navy's Nuclear Weapons," p. 17. Vasilets indicates that Soviet research on RW in other military branches stopped only in the 3rd quarter of 1958. Vasilets, "Under the leadership of Sergei Korolev."
157. Anatoly Mikhailovich Kutskov, "Kak eto nachinalos'. Poslednij iz mogikan" [How it all started: the last of the Mohicans], *Tsentral'nyj Voenno-Morskoj Portal* [Central military-maritime portal], March 7, 2014, http://flot.com/history/events/99795/. See, for example, D.J. Bradley, "Radioactive Contamination of the Arctic Region, Baltic Sea, and the Sea of Japan from Activities

decision to cease work on radiological weapons, there is little doubt today that the RW program had serious and long-lasting human and environmental consequences.

CHANGES IN LEADERSHIP. Given that buy-in from high-level decisionmakers was critical to initiating the Soviet radiological weapons program, it is reasonable to assume that their departure likewise contributed to its demise. By 1958, most of the original high-level RW advocates had passed from the scene. In addition to Stalin and Beria, who at a minimum must have blessed the pursuit of a novel weapon system, Zavenyagin died in 1957, and Vannikov stepped down in 1958. Although other senior advocates for RW may have emerged, their voices are not apparent in the material available to us. Indeed, the extreme secrecy and siloed configuration of the Soviet weapons establishment may have constrained the emergence of other forceful proponents for RW. This explanation is consistent with Evangelista's observation that the compartmentalized nature of Soviet military R&D erected major barriers to weapons innovation.

Conclusion

No country has used radiological weapons in war, and there is no evidence that RW were ever incorporated into a nation's military arsenal. Nonetheless, the United States and the Soviet Union were not the only states to pursue—and abandon—radiological weapons. A fragmentary picture of the postwar British RW program emerges from declassified documents in the United Kingdom's National Archives, although no descriptions or analyses of the program have been published to date. Similarly, there is solid evidence of an Iraqi RW program that progressed through the testing stage, although these activities were unknown to the U.S. intelligence community prior to the Gulf War. In addition, a smorgasbord of Israeli government-fueled media reports, U.S. Department of State memos, and Swiss court records point to Egyptian efforts to develop RW and missile delivery systems in the early 1960s, at least in part through collaboration with German scientists and technicians. What all of these actual and purported programs have in common is the failure to yield operational mass-produced weapons.[158] In that sense, the weapons innovation process was never completed.

in the Former Soviet Union," prepared for the U.S. Department of Energy (Richland, Wash.: Pacific Northwest National Laboratory, 1993), p. 12, https://www.osti.gov/servlets/purl/10102627.
158. The British, Iraqi, and Egyptian RW programs are analyzed in considerable detail in a sepa-

This is encouraging news from the standpoint of RW proliferation, and one may hope that information about the experiences of the United States and the Soviet Union will help to dissuade future would-be RW possessors from pursuing such weapons. Besides program abandonment, what are the major commonalities across the U.S. and Soviet initiatives that emerge from our comparative analysis?

One significant common feature is the presence of individual and institutional advocates for RW at the same time these countries were actively developing nuclear weapons. Indeed, RW activities continued and accelerated after the development of the atomic bomb, but once the countries conducted successful hydrogen bomb tests, serious interest in RW diminished. This development appears to stem from increased competition for resources within the U.S. and Soviet defense establishments as the nuclear arms race accelerated, although the bureaucratic politics played out differently in the two countries.

A second commonality of the RW programs of both countries was the recognition of the limited military utility of RW. In part, this was because of the aforementioned WMD substitution effect in which not only atomic and hydrogen bombs, but also chemical weapons, diminished the perceived need for RW. Additionally, the military missions for RW contracted over time and ultimately were reduced to area denial, a role in which they were not clearly cost effective or superior to established weapons systems. Even if RW had been a more attractive battlefield weapon, the strict secrecy under which the program operated inhibited its promotion within the military services.

An additional common feature of the U.S. and Soviet RW programs was the difficulty of weapons innovation despite significant differences in the technical approaches that were pursued. For instance, the Soviet Union utilized radioisotopes extracted from its plutonium reactor as the radioactive source in its prototype RW. The United States also considered this approach but ultimately rejected it in favor of irradiated tantalum.[159] Although both countries were able to produce prototype radiological weapons and test them with some degree of success, the programs failed to generate a new weapon that was adopted for use by their respective militaries, suggesting that future RW aspirants will need strong institutional support in addition to technical knowhow and material. While this finding should give prospective RW proliferators

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rate unpublished report by the authors. See Sam Meyer et al., "Addressing the Threat of State-Level Radiological Weapons Programs," presented at Spring 2019 PASCC Research Results Workshop, Center for Strategic and International Studies, Washington, D.C., March 13, 2019.

159. The United States actually focused on the same radioisotopes ultimately adopted by the Soviet Union—zirconium and niobium.

pause, the dearth of publicly available information about past state-level radiological weapons programs means that major impediments to RW innovation may be overlooked or ignored.

This situation appears to be playing out in Russia today where, despite its own unsuccessful history with RW, Moscow shows renewed interest in advanced nuclear weapons that seek to maximize radioactive contamination. One example is a new weapon, known variously as "Kanyon," "Status-6," or "Poseidon," which, depending on the source, is being designed, developed, and possibly even tested.[160] Although defense analysts differ over the weapon's status and precise characteristics, they typically agree that it is designed to travel long distances at high speed under water for the purpose of striking coastal cities and military targets with a nuclear warhead encased in a cobalt shell. The picture that emerges is of a doomsday weapon that will disperse radioactive "rain" over the target area to cause widespread death and area denial.[161] Contemporary Russian commenters have offered little insight into the military rationale for this new weapon, which appears to have more in common with the oversized "Tsar Bomba" than past radiological weapons.[162] If deployed, however, it would likely provoke the United States to seriously contemplate a response in kind. Under such circumstances, rational calculations informed by past lessons about the limited military utility of RW could well be ignored.

It is also possible that other countries may conclude that RW serve their perceived national interests, too. There is circumstantial evidence, for example, that North Korea considered RW before obtaining a more robust nuclear weapons capability.[163] Given its historical focus on commando operations and

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160. See, for example, Brian Wang, "Russia's Developing 100 Megaton Dirty Tsunami Creating Submarine Drone Bomb," *Next Big Future*, March 5, 2017, https://www.nextbigfuture.com/2017/03/russias-developing-100-megaton-dirty.html; Kyle Mizokami, "Pentagon Document Confirms Existence of Russian Doomsday Torpedo," *Popular Mechanics*, January 16, 2018, https://www.popularmechanics.com/military/weapons/a15227656/pentagon-document-confirms-existence-of-russian-doomsday-torpedo/; and Alex Calvo, "Russia's Nuclear Torpedo Promises 'Extensive Zones of Radioactive Contamination,'" *National Interest*, December 1, 2015, https://nationalinterest.org/blog/the-buzz/russias-nuclear-torpedo-promises-%E2%80%9Cextensive-zones-14474.

161. See, for example, Norman Polmar, "'Status-6' Russian Drone Nearly Operational," *U.S. Naval Institute Proceedings* (Annapolis: U.S. Naval Institute, 2019), https://www.usni.org/magazines/proceedings/2019/april/status-6-russian-drone-nearly-operational.

162. Polmar reports that the development of the unmanned underwater vehicle "has been rationalized as part of several, ongoing Russian efforts to get around US ballistic missile defense systems," but the characteristics of the warhead do not clearly reflect that objective.

163. For a discussion of the North Korean case, see William C. Potter and Jeffrey Lewis, "Cheap and Dirty Bombs," *Foreign Policy*, February 17, 2014, https://foreignpolicy.com/2014/02/17/cheap-and-dirty-bombs/.

proximity to Seoul, North Korea might view RW as useful for contaminating critical infrastructure and troops to impede U.S. and South Korean military operations or for instigating social and economic chaos in the South Korean capital.[164] If so, this perception may be furthered by the absence of contemporary U.S. (and Russian) policies designed to deter the use of RW or develop norms against their use.

In this regard, it is useful to recall a prior but largely forgotten joint effort by the United States and the Soviet Union in the 1970s to prohibit radiological warfare. In an unusual display of superpower cooperation, the two sides negotiated a joint initiative on radiological weapons, which they submitted to the Committee on Disarmament (CD) in Geneva in July 1979. Under the terms of the draft treaty, states parties would undertake "not to develop, produce, stockpile, otherwise acquire or possess, or use radiological weapons."[165] Notwithstanding agreement between Moscow and Washington, however, the initiative foundered over scope and definitional issues, and because of the low priority most delegations attached to the subject. Particularly contentious was the question of whether to extend the RW prohibition to attacks on nuclear facilities, a subject that was no longer academic after Israel destroyed the Iraqi Osirak reactor in June 1981. Although the CD maintained an ad hoc committee on RW for more than a decade, the draft prohibition treaty was removed from the body's agenda of work in 1992.

The CD has been deadlocked since 1996, and there are no signs that it will soon resume business as a negotiating forum. Prospects for U.S.-Russian strategic nuclear arms control negotiations also are bleak. Nevertheless, now may be an opportune moment to revive efforts to prohibit RW, albeit in a different venue. The most logical forum may be the "P-5 process," an ongoing series of nuclear disarmament consultations among the five NPT nuclear-weapon states: China, France, Russia, the United Kingdom, and the United States. Several of these countries expressed interest in expanding the agenda for their consultations in advance of the next NPT Review Conference, and at least one P-5 member previously indicated particular interest in an RW ban as a means to signal the nuclear weapons states' commitment to their disarmament obli-

164. This scenario is depicted in ibid.
165. United Nations, Conference on Disarmament, "Agreed Joint USSR–United States Proposal on Major Elements of a Treaty Prohibiting the Development, Production, Stockpiling and Use of Radiological Weapons," CD/31, July 9, 1979, https://www.unog.ch/80256EE600585943/(httpPages)/9E71219C129E81F7C125814D005817AA?OpenDocument. For a detailed analysis of the negotiations leading to the 1979 draft accord, see Kucharski, Bidgood, and Warnke, "Negotiating the Draft Radiological Weapons Convention."

gations. Although P-5 renunciation of RW would not resemble a multilateral treaty, even an informal five-party declaration would help to strengthen the norm against radiological weapons and raise the political costs of proliferation in this nuclear realm.

An examination of U.S. and Soviet pursuit of RW offers insights into a previously neglected but important chapter of nonconventional weapons development, testing, and eventual abandonment. Along with similar forays conducted by the United Kingdom, Iraq, and possibly Egypt, the U.S. and Soviet RW programs highlight the remarkable parallelism between prescient science fiction treatments of atomic warfare and preternatural, "real world" military developments. In this regard, it is interesting to note the editorial comment by John Campbell at the end of the story, "Solution Unsatisfactory," published in May 1941. It observes that MacDonald's (aka Heinlein's) story "presents a logical possibility of the near future" in which "atomic power plants, in burning atomic fuel[,] will automatically and inevitably produce artificial radioactive ashes." "The story," Campbell argues, "presents the problem mankind must solve some day" and is generalizable "to cover any irresistible weapon," namely, "*how can it be controlled*."[166] A compelling answer to that question continues to elude science fiction authors, policymakers, and academic experts.

166. MacDonald, "Solution Unsatisfactory," p. 86 (italics in the original).