Pernicious Ideas in World Politics: "Peaceful Nuclear Explosives"

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Abstract

Transnational epistemic communities develop and propagate ideas that can facilitate interstate security cooperation, such as the arms control ideas that helped restrain U.S.-Soviet competition (Adler 1992), but they can also diffuse dangerous ideas that threaten national and international security.

This paper examines the genesis, dissemination, and causal influence of the idea of "peaceful nuclear explosives" (PNEs), according to which atomic blasts would dredge ports, dig canals, and extract natural resources. Edward Teller and colleagues at Lawrence Livermore National Laboratory (LLNL) developed the concept in the late 1950s, in part to preclude an international ban on nuclear weapons testing. These scientific entrepreneurs won generous governmental support for their "Plowshare" program of atomic science and engineering. Nuclear laboratories in the Soviet Union embraced the concept and conducted an even more extensive PNE program. In the 1960s and 1970s, the U.S. Atomic Energy Commission and the International Atomic Energy Agency promoted PNEs through international scientific conferences.

State agencies and factions in Australia, Brazil, India, and South Africa subsequently exploited the PNE concept to advocate developing the functional equivalent of atomic weapons. This paper illuminates how the inherent ambiguity or "multivocality" (Padgett and Ansell 1993) of the PNE concept enabled formation of heterogeneous coalitions in these four states. Within these programmatic coalitions, advocates and opponents of atomic weapons collaborated in technological development because the PNE concept allowed them to hold fundamentally different understandings of the objectives of their developmental activities.

This paper employs historical process tracing, counterfactual reasoning, and comparative analysis to evaluate data gathered through interviews with Brazilian, Indian, and U.S. officials, declassified documents, technical reports, news accounts, and secondary reports and studies.

Introduction[1]

This paper aims to answer an historical question of considerable theoretical interest: ***Why would a state enjoying a near-monopoly on weapons of apocalyptic power deliberately promote their development by other states?***

Although today the notion defies credulity, for over two decades the United States avidly and effectively promoted a dangerous idea, that of "peaceful nuclear explosions" (PNEs). It hardly requires an advanced degree in nuclear physics to recognize that any device small enough to fit in an aircraft yet powerful enough to level a city has serious military implications. But in the early years of the atomic age, the prestige and influence enjoyed by nuclear scientists like Edward Teller were enough to outweigh this obvious concern. PNE advocates in the U.S. nuclear weapon laboratories won many battles with their counterparts in other U.S. agencies. Those overruled included officials advising or serving in the National Security Council, Joint Chiefs of Staff, and U.S. Department of State, who feared the further spread of atomic explosives would undermine U.S. national security, and believed that the PNE rationale offered a convenient pretext for building and testing atomic weapons.[2]

Teller and his associates established some conventional political alliances with other agencies, and with the U.S. Congress. But the fundamental basis for the influence of the PNE advocates was their special claim to knowledge, that they alone could understand the technical basis of the promise PNEs held for humankind. Their scientific expertise lent credibility to their assertions that with continued nuclear testing, they could develop "clean" and "peaceful" atomic explosives, i.e., devices that would be fallout-free and solely dedicated to non-military purposes. The concept of an *epistemic community* best accounts for the causal impact of such a network of technical specialists.[3] In this case as elsewhere, their influence

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[2] Committee on Nuclear Proliferation 1965:20; Wheeler 1966:3; Pollack 1966:2; U.S. Arms Control and Disarmament Agency undated:21, 39; author's interview with Van Doren 1994.

[3] An epistemic community is a network of scientific professionals, whose knowledge-based claims to authority can influence policymaking, often across bureaucratic and national divides. They are most apt to enjoy influence when they enable policymakers to define bureaucratic and national interests in regard to new policy questions, when such issues are characterized by great uncertainty about complex cause-and-effect relationships. Such expert communities share a common knowledge base, causal and normative beliefs, standards for evaluating claims, and a policy project. They therefore differ from interest groups, bureaucratic coalitions, and professional disciplines, which may have some but not all of these shared characteristics (Haas1992:2-3, 18).

helped the United States and other countries define national interests with regard to the new and uncertain implications of atomic energy.

This paper is organized into four parts, which explain this remarkable story. The first recounts the origins of the idea of PNEs, and the second describes how the idea was disseminated internationally. The third considers the impact of the PNE idea on the prospects for nuclear nonproliferation, by tracing its influence in selected countries that produced nuclear weapons or considered doing so. The concluding section offers a brief evaluation of theoretical approaches to accounting for the international experience with PNEs. The paper concludes with a brief postscript on contemporary U.S. national security policy.

PART I: U.S. ORIGINS

In the early years of the atomic era the United States largely defined the salient issues and set the international agenda.[4] Viewed in hindsight, U.S. proselytizing proved unduly optimistic about the cost and safety of nuclear energy. But following the U.S. lead, the expectation that atomic energy would be inexpensive and vital to national development led many states to devote substantial resources to nuclear programs. Although scarcely recalled today, for two decades U.S. scientists and officials also promoted the idea of "peaceful nuclear explosives," envisioning the use of atomic blasts to dredge ports, dig canals, and extract natural resources. Although the United States set in motion the global rush to develop atomic energy, within a few short years it was evident that once diffused, neither nuclear technologies nor the ideas propagated with them could be readily controlled. Thus U.S. policies helped create the global problem of nuclear nonproliferation; how to ensure that the rising number of states with advanced nuclear technologies would not follow the example set by the United States and build the bomb.

Atoms for Peace

In the immediate postwar period, international understandings of nuclear energy were dominated by the awesome display of destructive power wielded by the United States in Hiroshima and Nagasaki. But in 1953, U.S. President Dwight D. Eisenhower launched the Atoms for Peace program, which promised to share the peaceful benefits of atomic power with countries outside the Soviet bloc. In part this effort sought to make a virtue of necessity, as U.S. officials believed that the Soviet Union and countries in Western Europe would circumvent U.S. secrecy regarding atomic energy. Hence they expected that global diffusion of nuclear technology could be slowed and channeled, but not prevented. This effort also constituted an audacious exercise in re-framing understandings of atomic energy, of redefining what this new technology meant for countries and peoples around the world.[5] Explicitly seeking to "hasten the day when fear of the atom will begin to disappear from the

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[4] Nuclear history is not unusual in this respect; "Countries like the United States that are large, powerful, and speak out on most issues with enormous volume, if not with enormous clarity, can influence others' definitions of reality" (Jervis 1989:178).

[5] For a useful historical review of Atoms for Peace, see Pilat, Pendley, and Ebinger 1985; for an early view see Kramish 1963.

minds of people," the Eisenhower Administration engaged in a global campaign to transform the "image of the bomb that heretofore had been associated with U.S. nuclear policy."[6]

Atoms for Peace had an immense impact on U.S. and international nuclear history.[7] The campaign raised expectations about the future role of atomic energy in industrial development, initiating a "worldwide drive toward nuclear power."[8] It reversed the initial U.S. policy of complete denial of nuclear technologies, and spurred a global shift from national secrecy to international openness and cooperation.[9] The United States helped sponsor international conferences in Geneva in 1955 and 1958 that "opened a floodgate of technical and scientific information about virtually every aspect of the civil nuclear fuel cycle with the exception of uranium enrichment, over which the United States still held a monopoly."[10] U.S. influence also shaped a number of important choices regarding technological alternatives in developing the nuclear fuel cycle,[11] and established the pattern of high government subsidies to establish civilian nuclear industries.[12]

Atoms for Peace had important political and legal consequences at home and abroad. U.S. provision of information, training, and subsidies for nuclear development created new domestic interests and government agencies in two-dozen countries, including Argentina, Brazil, Indonesia, and South Africa.[13] In seeking access to uranium and thorium, for example, the United States essentially created Brazil and South Africa's nuclear mining

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[6] Scheinman 1987:18. Eisenhower proposed the creation of an international atomic energy agency to administer a stock of nuclear materials contributed by the United States and other countries, the main aim of which "would be to devise methods whereby this fissionable material would be allocated to serve the peaceful pursuits of mankind. Experts would be mobilized to apply atomic energy to the needs of agriculture, medicine, and other peaceful activities. A special purpose would be to provide abundant electrical energy in the power-starved areas of the world. Thus the contributing powers would be dedicating some of their strength to serve the needs rather than the fears of mankind" (Eisenhower 1953).

[7] As a leading authority notes, "it would be difficult to overestimate the importance of Atoms for Peace" as a watershed in U.S. and international nuclear history (Scheinman 1987:18).

[8] Stadie 1996:23; see also Bunn 1992:83.

[9] Fischer 1997:10.

[10] Scheinman 1987:19.

[11] For example, although the technology was not yet mature and the United States would later reverse course during the Carter Administration, "the United States set the early agenda by promoting the reprocessing of spent fuel while pursuing tight international controls of the extracted plutonium" (Stadie 1996:24).

[12] Gall 1976:191.

[13] In the 1954-58 period alone, the United States reached 22 bilateral agreements for nuclear cooperation. These entailed provision of information, training, and aid in acquiring equipment and materials, including nuclear research reactors, for which the United States provided a financial subsidy of $350,000 each (Scheinman 1987:18; see also Medhurst 1997:588-89). These reactors also created a market for a product over which the United States held a global monopoly: highly enriched uranium fuel. On U.S. aid to nuclear development in Indonesia, see Cornejo 2000.

sectors.[14]

But the most widely diffused and perhaps most consequential impact of Atoms for Peace was in creating a new framework for international understanding of what nuclear energy would mean for states and other actors around the world. By framing atomic energy as *the* safe, inexpensive, and readily available power supply of the future, Atoms for Peace fostered internationally shared expectations that every country that sought economic development needed to acquire atomic power, or else it would be left behind by the rest of the modernizing world. It thus promoted nuclear development before reliance on nuclear energy was commercially viable or appropriate.[15]

As a rhetorical campaign, Atoms for Peace also diverted U.S. and international attention from the cornerstone of U.S. defense policy under Eisenhower: a frenetic buildup of atomic weapons in support of the U.S. doctrine of massive retaliation.[16] The political author of Atoms for Peace was also the executive patron of far more atoms for war.[17] As a secret report on psychological aspects of U.S. foreign policy noted in 1955, this effort in re-framing the international meaning of nuclear energy proved quite successful:

> In its reliance on nuclear strategy the United States inevitably must pay a considerable penalty in the psychological and political fields. The Atoms for Peace Program has reduced the extent of this penalty and has detracted [sic] popular attention away from the image of a United States bent on nuclear holocaust. A position has been reached in which the Atoms for Peace Program has begun to serve as a counterpart to the American strategy of nuclear deterrence. We are beginning to create an image of America as the guardian of peace and the foremost promoter of progress.[18]

At home, making the atom a safe and productive part of every American's life dampened public fears of nuclear warfare. Abroad, the Atoms for Peace campaign fomented general

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[14] Füllgraf 1988:38; Nazaré 1987:1; Nuclear Fuels Corporation of South Africa (Pty) Limited 1996.

[15] Nye 1981:17. An industry analyst notes, "It remains unclear why the introduction of nuclear power in the U.S. and elsewhere was conducted with such haste, a haste which has proven so detrimental to its development. There was no obvious need, especially in the U.S., to rapidly replace coal and oil for the production of electricity" (Stadie 1996:24). International nuclear history was marked by a tremendous gap between expectations about future energy generation and actual nuclear capacity, with the gap widest in the 1970s (Stadie 1996:23).

[16] In the United States, the program was key in persuading the U.S. Congress to amend the 1946 Atomic Energy Act to allow provision of nuclear weapons to NATO allies (Medhurst 1997:576).

[17] Under President Eisenhower, the U.S. nuclear weapons arsenal grew from 1,200 warheads in 1952 to some 18,700 in 1960 (Fischer 1997:11). When Eisenhower took office, U.S. production capability was limited to 140 nuclear weapons annually. By the end of his second term, that capability had been augmented some fifty-fold, to over 7,000 nuclear weapons annually. With this huge expansion of U.S. production capacity under Eisenhower, the United States was able to produce 14,884 nuclear warheads during the 1959-1961 period alone (Schwartz 1998:77).

[18] Possony 1955:203; also quoted in Medhurst 1997:579. The report noted, "if the psychological pressures [justifying Atoms for Peace] are disregarded, there is really no great urgency about nuclear power as such, since the conventional fuels will be adequate to maintain the momentum of electrification for many years to come" (Possony 1955:209).

demand, and encouraged interested actors who would use American technologies and ideas in ways U.S. officials would later regret. Designed in significant measure to divert attention from massive expansion of the U.S. nuclear arsenal, this atomic initiative of the 1950s would haunt the United States with the specter of nuclear proliferation for the next four decades.[19] The history of the "pacific" bomb offers perhaps the most striking example of how U.S. agencies encouraged the international diffusion of technological capabilities that would check U.S. military power and undercut U.S. national security.

Promoting a Peaceful Bomb

International interest in "peaceful nuclear explosives" originated in their enthusiastic promotion by the United States and the Soviet Union in the heyday of the Cold War. Beginning in the 1950s, the superpowers' marketing campaign "unlatched a nuclear Pandora's Box" with harmful long-term consequences for nuclear nonproliferation.[20] In part, we can attribute the grossly exaggerated claims that PNEs would offer dramatic cost savings in diverse areas of civil engineering – with nominal health or environmental consequences – to the widespread "nuclear euphoria" of the era.[21] But of more direct causal significance, initially the U.S. national nuclear weapons laboratories were the foremost advocates of PNEs, as later were their counterparts in the USSR. The labs invented this rationale and marketed it at home and abroad as part of their efforts to thwart an international agreement on halting nuclear weapons testing.[22]

In the United States, promotion of PNEs was also a response to rising public fear of atomic fallout and resulting opposition to nuclear explosive testing. In an effort to re-frame

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[19] It can be argued that without international norms and institutions created by the United States through the Atoms for Peace program, nuclear technological diffusion might have been even more widespread and nuclear proliferation less controlled (Scheinman 1985:202-03). Evaluating this counterfactual is important to reach an historical judgment on the wisdom of the Atoms for Peace program. But it is indisputable that the program did diffuse sensitive nuclear technologies, and helped create domestic nuclear constituencies in many developing countries.

[20] Scheinman 1987:26.

[21] E.g., "the tremendous release of concentrated energy in a nuclear explosion can have application in the worlds of commerce and science. Indeed, the outstanding feature of the peaceful prospects for nuclear explosives is the wide applicability of this tool for economical use and basic research…. Future productive uses in this field are limited only by the imagination and ingenuity of the experimenters" (Teller *et al.* 1968:21, 313).

[22] Fischer 1997:151. See also Teller 1958:1-4; Seaborg with Loeb 1981:198. The labs' protagonism on PNEs reflected a broader pattern of self-promotion. In a 1994 retrospective workshop involving key participants from the early years, "Many [weapons] designers argued that a large part of the laboratory job was in fact selling, that is, convincing the potential users, the military and the government, that they needed what the laboratories were designing. As one former laboratory director saw it, 'If we had waited for Washington to tell us exactly what was needed, such selling would not have been necessary, but that is not the way we went about our business, especially after we brought competition [i.e., LLNL] onto the nuclear scene.'" The Los Alamos-Livermore rivalry catalyzed development of safer and more capable nuclear weapons, but it also spurred the arms race with the USSR (Greb and Adkins 1994:5, 7).

the meaning of nuclear weapons and of the Atomic Energy Commission (AEC) for U.S. and international audiences, the AEC launched a program called "Project Plowshare." Complementing this attempt to exploit the Biblical injunction "to beat swords into plowshares,"[23] PNE advocates also offered modern scientific reassurance that any nuclear fallout from PNEs would be inconsequential[24] and that costs would be reasonable.[25]

Dr. Edward Teller, co-creator of Lawrence Livermore National Laboratory (LLNL), was the most active and effective proponent of PNEs. While best known today for his role in the U.S. development of the hydrogen bomb, his intellectual progeny also include the 1980s "Star Wars" anti-missile program[26] as well as diverse projects to employ PNEs. In 1968, McGraw-Hill published a textbook written by Teller and three colleagues entitled *The Constructive Uses of Nuclear Explosives*.[27] The book outlined in impressive, scientific detail the manifold advances that nuclear explosives would offer contemporary civilization.

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[23] "And he shall judge among the nations, and shall rebuke many people: and they shall beat their swords into plowshares, and their spears into pruning hooks: nation shall not lift up sword against nation, neither shall they learn war anymore" (Isaiah 2:4).

[24] E.g., in using PNEs, "*Radiation will present no uncontrollable hazard* if its concentration does not exceed tolerable limits outside the area evacuated because of blast and seismic hazards. That is, we must be able to predict what radioactivity will ultimately do and estimate the margins for error. Because *release of radioactivity at any level is a nuisance,* there must be continuing efforts to reduce to a minimum the quantities of radioactivities produced and released to the biosphere." In using PNEs as earth-moving devices, *"with careful engineering, most of the residual radioactivity will be buried harmlessly* far beneath the bottom of the crater." Except for one deep cut in the Colombian route in the new canal studies, "the question of technical feasibility is essentially the question of safety, radioactivity, air blast, and ground shock. *Radioactivity is the least of the problems."* In using PNEs to create quarries for mining crushed rock for dam and roadbed construction, "according to data from two recent experiments, *radioactive contamination of the aggregate does not pose any problem."* On proposals to use PNEs for seawater desalinization, "we must *worry* about radioactive contamination of the fresh water which we are producing," but Teller maintains that this is no basis for ruling out this application. In constructing nuclear craters for use as water reservoirs, "*in one season essentially all the tritiated water can be extracted and beneficially used to irrigate selected crops."* (Teller *et al.* 1968:80; 17; 225; 267; 284-85; 284-85; 236; italics added for emphasis).

[25] Although actual costs of nuclear explosives were never declassified during Project Plowshare, the AEC released figures to enable firms, agencies, and foreign governments to plan for PNE applications. The AEC said that it would charge approximately $350,000 for provision of a 10kt device, and $600,000 for at 2MT nuclear explosive. Thus, "charges for nuclear explosions in the 10kt-to-2MT range are almost independent of yield; while the energy release increases 200 times, the cost does not quite double" (Teller *et al.* 1968:81-84, 214).

[26] Broad's investigation led him to charge, "Over the protests of colleagues, Teller misled the hightest officials of the United States government on a critical issue of national security, paving the way for a multibillion-dollar deception in which a dream of peace concealed the most dangerous military program of all time" (1992:1). See also Fitzgerald 2000, especially pp. 127-46.

[27] Edward Teller, Wilson K. Talley, Gary H. Higgins, and Gerald W. Johnson, *The Constructive Use of Nuclear Explosives,* (New York: McGraw-Hill, 1968). This originated in courses taught to college seniors and graduate students by two of the authors at the Berkeley and Davis campuses of the University of California in 1961 and later years (Teller *et al.* 1968:viii).

Teller first publicly proposed the PNE idea in a symposium at LLNL in February 1957, and its positive reception led to initiation of the Plowshare program in June of that year.[28] As an official LLNL publication recalls,

> the [November 1958-September 1961] test moratorium was perhaps Teller's greatest challenge as Director [April 1958-June 1960], as he was faced with keeping the Lab viable and the people working on nuclear designs, even though they couldn't conduct any tests. During this time, plans were laid for a program exploring the peaceful uses of nuclear explosives–Project Plowshare.[29]

Initially modest in size and scope, under the leadership of Teller, Ernest Lawrence, and Herbert York, LLNL grew by 1958 to encompass 3,000 employees operating with an annual budget of $55 million. In 1957, LLNL won approval to initiate three large development projects: the Polaris nuclear missile, a nuclear ramjet for unmanned aircraft, and the Plowshare Program.[30] In gaining Washington's support for these efforts, LLNL became a serious competitor to the first U.S. nuclear weapons lab at Los Alamos.

Teller and his colleagues at LLNL viewed the moratorium on nuclear weapons testing that began in 1958 as an unacceptable constraint on their activities and ambitions for the lab.[31] As the secret U.S. government history of the period notes:

> The Livermore [LLNL] staff were fighting desperately for future nuclear device testing, either underground under the auspices of Plowshare, in deep space, or any other way that could be found.[32]

In retrospective accounts, nuclear weapons designers recalled the moratorium on testing as an "end of the decade crisis," a "very traumatic period for us," and a "demoralizing time" for those engaged in the design, development, and production of nuclear weapons.[33]

In lobbying U.S. decision-makers during the moratorium, Teller maintained that "peaceful nuclear explosives" could be distinguished from nuclear weapons, and that the former should be permitted under any U.S.-Soviet test ban arrangement. At this time, however, Soviet officials expressed no interest in a PNE program. The Soviets accurately noted, moreover, that without extremely intrusive monitoring it would be virtually impossible to distinguish a PNE explosion from that of a nuclear weapon. They presumed – again accurately – that mutual inspection of nuclear devices would remain political inconceivable during the Cold War.[34] U.S. advocates of PNEs, however, apparently

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[28] Wilt and Hacker 1998. According to Teller and his colleagues, the idea that became Plowshare originated in the fall of 1956, with Egyptian closure of the Suez Canal: "A small group of scientists gathered at Lawrence Radiation Laboratory at Livermore, California, to consider the possibility of cutting another canal through friendly territory with nuclear explosives." Although this particular plan was dropped, the basic idea was retained and the Plowshare Project germinated around the initial group at Livermore (Teller *et al.* 1968:vi).

[29] Lawrence Livermore National Laboratory 1998.

[30] Hacker 1998.

[31] Teller 1958:1-4; Greb and Adkins 1994:8.

[32] Ogle 1985:117.

[33] Greb and Adkins 1994:7.

[34] Although the Soviets opposed the concept of "peaceful nuclear explosives" when the U.S. labs

avoiding facing this obvious fact through social-psychological contortions. As a secret U.S. government study of national nuclear history recalled:

> it would be very simple to conduct weapons tests under the guise of Plowshare. This latter politically difficult point led to a sort of schizophrenia in the [lab] community, in which it was simply not proper to admit the possibility of using Plowshare for evasion purposes.[35]

Although there could be some technical differences between mass-produced PNEs and nuclear weapons, in basic terms the two are fundamentally indistinguishable.[36] In particular, the two types of devices are fundamentally similar in range of relevant yields, as in the need for rugged devices. Thus, in brief, PNE tests would "provide an excellent cover for military activities."[37]

"Clean" Bombs

Teller and colleagues at LLNL also promoted the related idea of "clean" nuclear explosives, ones whose reduced fallout would make them more useful either for battlefield tactical employment as weapons, or as PNEs. These would be advanced thermonuclear devices (commonly called hydrogen or "H" bombs). Thus, Teller declared in the annual lecture of the American Nuclear Society in 1963,

> By using thermonuclear explosives we can avoid producing the large quantities of radioactive materials characteristic of fission explosions. Having produced a crater we might enter it at once after the explosion without exposing ourselves to more radioactivity than the personnel of our Laboratory are permitted to take as a routine matter. Explosives of such cleanliness have not yet been produced, but there is no doubt that they are feasible and require only a few more years for development.[38]

In briefing Eisenhower seven years earlier in 1957, Teller had claimed that partially "clean" weapons were already on hand, and assured the president that with continued nuclear testing, the U.S. laboratories could develop entirely "clean" devices within a "matter of six or seven years" time.[39] Fourteen years after Teller's promise to Eisenhower, Plowshare still had

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initially promoted it during the 1958-61 testing moratorium, they eventually became avid proponents. Unconstrained by public concerns for health or environmental consequences, the Soviet PNE program was much longer-lived and more extensive, both in terms of the number of explosions and the types of applications investigated through them. The USSR conducted a total of 116 PNE tests between 1965 and September 1988 (Schwartz 1998:79). As late as 1991, a Soviet trading firm sought to market nuclear explosions for commercial applications, such as disposal of toxic waste (Goldblat 1994:48). For an historical assessment of the Soviet PNE program, see Nordyke 1996.

[35] Ogle 1985:135.

[36] Jasani 1979:287.

[37] Davies 1979:293, 299, 301.

[38] Teller 1963:4.

[39] An even more misleading account of the briefing leaked to the *New York Times*, which ran a front-page headline account entitled "U.S. Eliminates 95 Percent of Fall-Out from the H-Bomb" (Broad 1992:46; who cites Stephen E. Ambrose, *Eisenhower the President* (New York: Simon & Shuster, 1984), p. 399; and also John W. Finney, "U.S. Eliminates 95 Percent of Fall-Out from the H-Bomb," *New York Times* 25 June 1957, p. 1).

not succeeded in developing radioactivity-free nuclear explosives, although Livermore scientists claimed "considerable progress" toward that end by the year 1970.[40]

In any case, there proved to be little interest in such devices among the U.S. armed forces, which sought to maximize rather than limit the destructive effects of nuclear weapons.[41] While fallout-free devices were never perfected during subsequent decades of nuclear testing, the *idea* of "clean" bombs was quite successful. In the late 1950s and early 1960s it served as a potent weapon in Teller's rhetorical arsenal against a complete ban on nuclear weapons testing.[42] By averting a total ban in this key period, Teller and fellow weaponeers were able to continue testing for another thirty years.

Plowshare

After the testing moratorium ended in 1961, Project Plowshare became a major LLNL program in the 1960s,[43] in the context of continuing international efforts to limit testing and domestic concern about radioactive fallout. In total, the AEC conducted 27 Plowshare nuclear explosive tests in Colorado, Nevada, and New Mexico between December 1961 and May 1973. From initiation of studies of possible applications in 1958 to the program's termination in 1977, the United States spent over $770 million on the effort. Some $27 million alone were spent on Teller's favorite effort, Project Chariot, which sought to use nuclear explosives to build a harbor in Alaska.[44]

Plowshare envisioned using PNEs for a wide range of engineering and scientific purposes. Proponents envisioned two general types of engineering applications: nuclear excavation using blasts near the surface, and underground engineering that would involve deeply buried PNEs.[45] Near-surface explosions of PNEs would be used to construct sea-level canals, ocean harbors, to divert groundwater and build reservoirs, and to construct highways. Deep applications would include natural gas and petroleum extraction and underground storage, and deep as well as surface (or strip) mining. Other engineering applications would involve chemical, electricity and isotope production, and geothermal and nuclear power generation. Scientific applications included experiments in neutron and space physics, seismology, and meteorology.[46]

For example, Project Carryall sought to apply PNEs to highway construction, by

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[40] Lessler 1970:1563, 1568.

[41] Greb and Adkins 1994:8; see also Broad 1992:73.

[42] Broad 1992:49.

[43] Hacker 1998.

[44] Schwartz 1998:79. Project Chariot was designed during 1957-61 to offer a model for using PNEs for harbor construction. It would have used one 200kt and four 20kt simultaneous explosions to form an entrance channel and small harbor. The project was terminated after being postponed several times, in part because it would offer little economic benefits to the region (Teller *et al.* 1968:228-29). On the project, see O'Neill 1994; on its environmental and health legacies, see Vendegraf 1993.

[45] Hacker 1998.

[46] Teller *et al.* 1968; Jasani 1979:288; Davies 1979:294-96.

cutting a new roadway through the Bristol Mountains in California. It would have used 22 devices ranging from 20kt to 200kt in yield, for a total explosive yield of 1.73MT.[47] With such applications, "the highway-transportation industry will be in a position to be a better component in the national assembly line."[48] Project Oil Sand would have used a PNE to attempt to recover oil from a deposit near Alberta, Canada. The proposal, initially developed by Richfield Oil Company in 1957, was never implemented: "First because of the nuclear-test moratorium and later for political reasons, the experiment has not yet been executed, but it is still considered to be desirable."[49] Another proposal was for a "Project Moses," which would use PNEs to release water frozen under the lunar surface for use by astronauts.[50]

According to PNE proponents, building a sea-level "canal across the Central American Isthmus appears to be the most thoroughly economic application of atomic energy to large-scale excavation."[51] They first explored this possibility in detail in 1957, when President Eisenhower ordered a study of improving the Panama Canal. This evaluation incorporated the PNE option, and the concept became central to research-and-development efforts in nuclear-catering technology. Analysts examined five different routes in the initial 1960 studies: two through Panama, and one each through Mexico, Costa Rica, and Colombia. According to PNE advocates, all five would be cheaper than deepening and widening the existing canal. These five different options would have used between 185 and 925 nuclear explosive devices to blast through the isthmus.[52]

Viewed from a contemporary perspective, the Plowshare Program is distinguished by its disregard for the environmental and health consequences of nuclear explosive testing, and by U.S. officials' machinations to preclude public influence on the decision-making process. For example, in 1962 the 104kt "Sedan" test in Nevada created the world's largest artificial crater, as well as raining fallout 200 miles downwind from the blast.[53] In February 1967, the *Pittsburgh Press* revealed that the AEC and the Colombia Gas Corporation had been secretly planning for two-and-a-half years to construct an underground cavern in north-central Pennsylvania to store natural gas. The AEC had informed Pennsylvania government officials a year before the press revelation, but state officials were sworn to secrecy to forestall public knowledge of the project.[54]

The U.S. Plowshare program was terminated in 1977, as a result of several factors. These included the 1963 Partial Test Ban Treaty (PTBT) prohibition on atmospheric venting of radiation, public opposition to nuclear testing, U.S. environmental legislation, technical problems including failure to produce economically feasible applications for industry

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[47] Teller *et al.* 1968:239-244.

[48] Teller *et al.* 1968:240.

[49] Teller *et al.* 1968:259.

[50] Teller *et al.* 1968:285.

[51] Teller *et al.* 1968:18.

[52] Teller *et al.* 1968:215-18.

[53] Horgan 1996; Schoengold, DeMarre, and Kirkwood 1996:31-32.

[54] Krygier 1998.

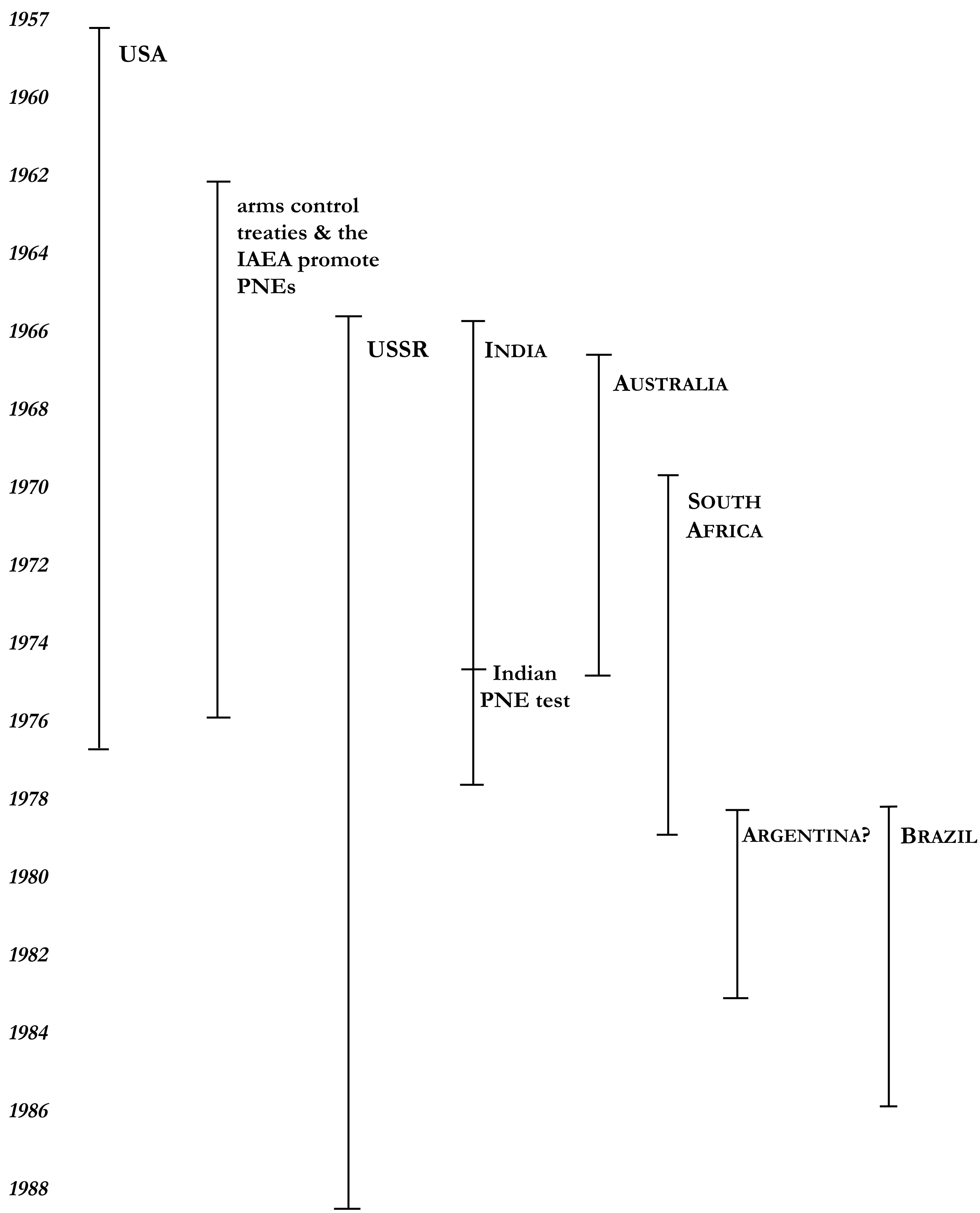
(especially given the relative cost of nuclear compared to conventional explosives), funding cuts resulting from escalation of the Vietnam War, as well as mounting concern for the impact of PNEs on nuclear proliferation.[55] However, the impact of the program and the idea it propagated endures to this day, codified in international law and manifest in national nuclear histories around the world.

PART II: INTERNATIONAL DIFFUSION

Although the U.S. and Soviet PNE programs proved unsuccessful in their efforts to develop nuclear excavation and underground engineering applications, the *idea* of PNEs had enduring, widespread, and negative consequences for nonproliferation. U.S. and Soviet marketing of PNEs made them central questions in the drafting of the Latin American nuclear-weapon-free-zone treaty (Treaty of Tlatelolco) and the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) during the 1960s. Article 18 of the Treaty of Tlatelolco defines permissible use of PNEs, while Article V of the NPT provides a lengthy and detailed legal framework for the use and control of PNEs. In the 1970s, as described below, both India and South Africa used the PNE rationale to initiate what eventually became nuclear weapons programs. Until the early 1990s, the idea of PNEs also had pernicious consequences for the prospects for nonproliferation in Argentina and especially in Brazil. As late as the mid-1990s, interest in the PNE option originating in the U.S. and Soviet weapons labs nearly blocked Chinese participation in the Comprehensive Test Ban Treaty (CTBT). The diagram below illustrates the international diffusion of the PNE idea.

[55] Schwartz 1998:79; Seaborg with Loeb 1981:248; see also Sylves 1986:55-59; Hacker 1998.

"Peaceful Nuclear Explosives" (PNEs):
National Programs and International Diffusion



Building an International Scientific/Technical Community

Under the auspices of Plowshare, U.S. advocates of PNEs organized an extensive network of specialists engaged in advancing the science and engineering of "peaceful nuclear explosives." This network included not only technical specialists at the national laboratories, but also at the federal and state geological, mining, and weather bureaus. The AEC, national labs, and leading professional scientific and engineering societies sponsored major scientific symposia on PNEs that brought together hundreds of specialists at Livermore in 1957, San Francisco in 1959, Davis, California in 1964, and Las Vegas, Nevada, in 1970. The latter three meetings were open to foreign participants, as they were designed in part to cultivate international interest in PNEs. Representatives from Australia, Canada, France, Israel, Mexico, South Africa, Switzerland, and the United Kingdom attended the 1964 gathering.[56] Participants from sixteen countries attended the 1970 session, which included representatives from five foreign governments and eighteen foreign industrial firms.[57] U.S. efforts to publicize Plowshare included bringing foreign guests to attend PNE nuclear explosive tests. Among the 350 observers for the 1961 "Gnome" test – the first in the Plowshare series – were visitors from nine foreign nations.[58] Plowshare advocates at Livermore publicly suggested conducting nuclear excavation projects in regions literally around the world, and proposed specific locations in at least twenty countries.[59]

Although the United States took the lead, the IAEA and other states also promoted the emergence of an international Plowshare community. This culminated in five international conferences held in Vienna in the 1970s to advance PNE science and technology. Over two-dozen states that would develop or seriously consider developing nuclear weapons attended these sessions, where specialists from the United States, the Soviet Union, and France shared the latest advances in PNE science and engineering. Perhaps most noteworthy from today's vantage, the participants included representatives from Algeria, Egypt, India, Iraq, Israel, Libya, and Pakistan.

Bibliographical compilations by the U.S. AEC and the IAEA convey a sense of the sheer scale of this cutting-edge, multinational, technical enterprise. In 1969, the AEC published a collection that included 265 books, scientific articles, conference and technical reports, university course materials, and films.[60] The following year, the IAEA published a 466-page bibliography with 1759 references to sources in English, French, Italian, German, Japanese, Polish, Russian, and Ukrainian. The IAEA catalogued and promoted PNE research published in general scientific and technical journals, as well as specialist publications in a wide range of fields.[61] The U.S. AEC and its field agencies and

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[56] Sylves 1986:39; U.S. Department of Energy 1998:20-24.

[57] American Nuclear Society and U.S. Atomic Energy Commission 1970 Vol. I:iii.

[58] U.S. Department of Energy 1961; U.S. Department of Energy 1998:21.

[59] Algeria, Argentina, Australia, Bolivia, Brazil, Canada, Chile, Colombia, Costa Rica, India, Malaysia, Pakistan, Panama, Paraguay, Peru, Philippine Islands, South Korea, Sudan, Tunisia, and United Arab Republic (Toman 1970:269).

[60] U.S. Atomic Energy Commission 1969.

[61] These included analytic chemistry, applied physics, chemical engineering, civil engineering, ecology, econometrics, geography, geology, geophysics, high explosives, instrument control systems, marine

laboratories, especially LLNL (then Lawrence Radiation Laboratory) were the most prolific corporate authors and publishers of PNE research.[62]

An ad hoc working group convened at the IAEA in December 1969, and organized the first IAEA session on PNEs in March 1970. It included 60 participants from 28 countries and three international organizations. The second session in January 1971 included 65 representatives from 25 member countries. Thirty-one countries sent participants to the third PNE conference at the IAEA in late 1972. Following the Indian PNE test in 1974, some 36 countries sent participants to Vienna for the fourth PNE meeting. The last session, in November 1976, indicated declining interest, with fewer technical papers delivered and only 25 countries represented.[63] In 1979, the IAEA Board of Governors finally issued technical assistance guidelines specifying that peaceful uses of nuclear energy did *not* include "research on, or development, testing or manufacturing of a nuclear explosive device."[64]

The following tables summarize participation in the five IAEA conferences on PNEs held between 1970 and 1976, highlighting the involvement of Australia, Brazil, India, and South Africa.

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geology, mechanical engineering, meteorology, microclimatology, natural resource extraction, nuclear energy, nuclear medicine, oceanography, particle physics, petroleum engineering, seismology, sociology, and transportation (see IAEA 1970).

[62] IAEA 1970:390-93.

[63] IAEA 1970; IAEA 1971; IAEA 1972; IAEA 1975; IAEA 1978.

[64] Scheinman 1987:244.

International Participation in IAEA Conferences on PNEs

	*Statement**	*Reps.†*	*Additional Countries‡*	*Intl. Orgs.*
I ***1970***	Australia France India Japan South Africa Sweden UK USA USSR	2 8 1 1 1 1 3 7 2	**Argentina**, Austria, Belgium, Bulgaria, **China**, Cuba, Denmark, Finland, **Israel**, Italy, Philippines, Poland, Portugal, **Switzerland**, Thailand, Turkey, Uruguay, Venezuela, West Germany, **Yugoslavia**	IAEA UN WHO
II ***1971***	Australia France India UK USA USSR	2 10 1 5 10 3	**Algeria**, Austria, Belgium, **Brazil**, Chile, West Germany, **Iraq**, **Israel**, Italy, **Pakistan**, Philippines, Poland, **South Africa**, **Sweden**, Thailand, Egypt, **Yugoslavia**	EC Comm. UN WHO
III ***1972***	Egypt France USA Venezuela	1 16 19 3	**Argentina**, **Australia**, Austria, Belgium, **Brazil**, Canada, Chile, Denmark, Holy See, **India**, **Indonesia**, **Israel**, Italy, Mexico, Panama, Poland, **Romania**, **South Africa**, Spain, **Sweden**, **Switzerland**, **UK**, **USSR**, Turkey, Venezuela, West Germany	EC Comm. UN WHO
IV ***1975***	Australia France India Sweden Thailand UK USA USSR W. Germany	1 6 2 1 1 1 15 3 3	Austria, Belgium, Canada, Chile, Denmark, East Germany, Guatemala, Holy See, Hungary, **Israel**, Italy, **South Korea**, Kuwait, Lebanon, **Libya**, **Pakistan**, Panama, Philippines, Poland, **Romania**, **South Africa**, Venezuela	UN WHO
V ***1976***	Egypt France Sweden UK USA USSR W. Germany	5 6 2 1 12 2 4	**Australia**, Austria, Belgium, Bulgaria, Denmark, East Germany, Greece, Guatemala, **Indonesia**, **Iraq**, **Israel**, Italy, Japan, **Libya**, Mexico, **Pakistan**, **South Africa**, **Sweden**, Thailand, **Yugoslavia**	*none listed*

* Countries presenting a formal statement on their national PNE program.

† Number of country representatives attending conference.

‡ Countries attending conference that did not present a national statement; **bold** type in this column indicates current or former nuclear weapon states, or states that have either pursued nuclear weapon option or weapon production programs.

IAEA Conferences on PNEs:
Participation by Argentina, Australia, Brazil, India, and South Africa

			Agency	Participant
I ***1970***	**Argentina**		Comisión Nacional de Energía Atómica	A.J. Carrera
	Australia	* #	AAEC Research Establishment	A.R.W. Wilson
			Australian Embassy, Vienna	C.M. Gray
	Brazil		*did not participate*	
	India	*	Bhabha Atomic Research Centre	R. Chidambaram
	South Africa	*	Embassy of South Africa, Vienna	K.R.S. v. Schirnding
			Embassy of South Africa, FRG	D.B. Sole
II ***1971***	**Argentina**		Comisión Nacional de Energía Atómica	A.J. Carrera
	Australia	*	AAEC Head Office	R.K. Warner
			AAEC Research Establishment	A.R.W. Wilson
	Brazil		Comissão Nacional de Energia Nuclear	J.J. Laborne
	India	*	Bhabha Atomic Research Centre	R. Chidambaram
	South Africa		Embassy of South Africa	K.R.S. v. Schirnding
III ***1972***	**Argentina**		Comisión Nacional de Energía Atómica	A.J. Carrera
	Australia		Australian Atomic Energy Commission	A.R.W. Wilson
	Brazil		Instituto Engenharia Nuclear – D.F.N.	O. Ferreira Lemos Jr.
	India		Bhabha Atomic Research Centre	R. Chidambaram
	South Africa		Embassy of South Africa, Vienna	K.R.S. v. Schirnding
IV ***1975***	**Argentina**		Comisión Nacional de Energía Atómica	A.J. Carrera
	Australia	* #	AAEC Research Establishment	A.R.W. Wilson
	Brazil		*did not participate*	
	India	*	Bhabha Atomic Research Centre	R. Chidambaram
			Bhabha Atomic Research Centre	R. Ramanna
	South Africa		Permanent Mission of S. Africa to the IAEA	K.R.S. v. Schirnding
V ***1976***	**Argentina**		Comisión Nacional de Energía Atómica	A.J. Carrera
	Australia		Australian Atomic Energy Commission	A.R.W. Wilson
			Australian embassy, Vienna	N.R. McDonald
	Brazil		*did not participate*	
	India		*did not participate*	
	South Africa		Permanent Mission of S. Africa to the IAEA	K.R.S. v. Schirnding
			Permanent Mission of S. Africa to the IAEA	A.W. Kuhn

* Presented formal statement on national PNE program.

Chaired the conference.

International Treaties and Organizations

Teller and other U.S. proponents of PNEs viewed international efforts to control the spread of nuclear weapons as obstacles to their ambitions.[65] While in theory not mutually exclusive, in political practice, national and international promotion of PNEs directly undercut efforts to stem the global spread of nuclear weapons capabilities. The idea of PNEs did so first by impeding negotiations to halt or restrict nuclear weapons testing, and second by providing a useful rationale for nuclear option or weapon advocates in several countries.

For two decades, U.S. ambitions to employ "peaceful nuclear explosives" posed a major obstacle to banning nuclear weapons tests.[66] Ironically, between the late 1950s and late 1960s the United States and Soviet Union reversed positions on PNEs. In initial negotiations in 1958, the Soviets sought to ban all nuclear testing, but by 1960s they were interested in employing PNEs themselves. Their negotiators demanded that any treaty include rights to inspect both blueprints and the interior of devices, which prompted strong objections from Plowshare advocates in the U.S. policy deliberations. If Soviet inspections were permitted, AEC officials would only be able to use "obsolete" devices, those earlier designs that produced greater radioactive contamination. In negotiations toward a complete test ban after 1963, however, the U.S. and Soviet positions were reversed, with the United States urging that PNEs be banned.[67]

Arms control treaties also contributed to international diffusion of the PNE idea, through their discussion in U.N. and other international meetings, via bilateral and multilateral negotiations, their official publicity and news reports, as well as by defining national and international laws through treaty texts. The following chart summarizes the treatment of PNEs in relevant accords during the 1960s-1990s. A brief discussion of highlights follows below.

PNEs in Nuclear Arms Control Treaties, 1963-1996

		General Treaty Provisions	Role of PNEs	Treaty Text on PNEs
PTBT	***1963***	▪ Prohibits nuclear explosions in the atmosphere, outer space, or under water. ▪ Prohibits underground nuclear explosion if they distribute radioactive debris outside the territorial limits of the state conducting the explosion.	All nuclear explosions are considered equally in the treaty, due to difficulty in differentiating weapon test explosions from civilian explosions.	"Each of the Parties to this Treaty undertakes to prohibit, to prevent, and not to carry out any nuclear weapon test explosion, or any other nuclear explosion, at any place under its jurisdiction or control."

[65] In their words, "…international agreements or treaties which are designed to limit the development of nuclear weapons may, unfortunately, apply to the peaceful uses of nuclear explosives as well" (Teller *et al.* 1968:v).

[66] Seaborg with Loeb 1981:198.

[67] Seaborg with Loeb 1981:40, 248.

		General Treaty Provisions	Role of PNEs	Treaty Text on PNEs
PTBT	***1963***	▪ Prohibits nuclear explosions in the atmosphere, outer space, or under water. ▪ Prohibits underground nuclear explosion if they distribute radioactive debris outside the territorial limits of the state conducting the explosion.	All nuclear explosions are considered equally in the treaty, due to difficulty in differentiating weapon test explosions from civilian explosions.	"Each of the Parties to this Treaty undertakes to prohibit, to prevent, and not to carry out any nuclear weapon test explosion, or any other nuclear explosion, at any place under its jurisdiction or control."
Tlatelolco	***1967***	▪ Obligates Latin American parties not to acquire or possess nuclear weapons. ▪ Prohibits Latin American parties from storing or deploying nuclear weapons on their territories by other countries. ▪ Nations outside the treaty zone must apply the denuclearization provisions to territories in the zone for which they are internationally responsible.	Parties may carry out peaceful nuclear explosions, provided they do so in accordance with the provisions of articles 1, 5, and 18 of the treaty.	"Contracting Parties may carry out explosions of nuclear devices for peaceful purposes–including explosions which involve devices similar to those used in nuclear weapons–or collaborate with third parties for the same purpose, provided that they do so in accordance with the provisions of this Article and the other articles of the Treaty, particularly articles 1 and 5."
NPT	***1968***	▪ Parties agree not to transfer nuclear weapons, other nuclear explosives, or control over such devices, to any recipient. ▪ Non-nuclear-weapon states agree not to receive any nuclear weapon or nuclear explosive, and not to acquire or manufacture nuclear explosives. ▪ Parties must accept IAEA safeguards to verify fulfillment of treaty obligations.	Each NWS party agrees not to provide fissionable material or related equipment to any NNWS for peaceful purposes, unless that material is subject to the safeguards required by article 3.	"Each non-nuclear-weapon State Party to the Treaty undertakes to accept safeguards, as set forth in an agreement to be negotiated and concluded with the International Atomic Energy Agency…with a view to preventing diversion of nuclear energy from peaceful uses to nuclear weapons or other nuclear explosive devices."
TTBT	***1974***	▪ Prohibits underground tests with a yield exceeding 150kt. ▪ Calls for exchanges of geographical and other data to assist parties in verifying that tests do not exceed the 150kt limit.	Explicitly does not prohibit underground use of PNEs.	"The provisions of this Treaty do not extend to underground nuclear explosions carried out by the Parties for peaceful purposes."
PNET	***1976***	▪ Bans individual nuclear explosions with a yield over 150kt; group explosions with an aggregate yield over 150kt unless individual explosions can be identified and measured; and group explosions with an aggregate yield over 1,500kt. ▪ Permits PNE use in third-party territories, if in compliance with yield limits and other PNET and NPT provisions.	Parties may carry out nuclear explosions for peaceful purposes if they are in compliance with the yield limitations and other provisions of the TTBT and PNET treaties, and in accordance with the NPT.	"The Parties will develop cooperation on the basis of mutual benefit, equality, and reciprocity in various areas related to carrying out underground nuclear explosions for peaceful purposes."

		General Treaty Provisions	Role of PNEs	Treaty Text on PNEs
PTBT	***1963***	▪ Prohibits nuclear explosions in the atmosphere, outer space, or under water. ▪ Prohibits underground nuclear explosion if they distribute radioactive debris outside the territorial limits of the state conducting the explosion.	All nuclear explosions are considered equally in the treaty, due to difficulty in differentiating weapon test explosions from civilian explosions.	"Each of the Parties to this Treaty undertakes to prohibit, to prevent, and not to carry out any nuclear weapon test explosion, or any other nuclear explosion, at any place under its jurisdiction or control."
CTBT	***1996***	▪ Prohibits any nuclear explosion, whether for military or civilian purposes.	Provides for a review conference ten years after the treaty enters into force, at which time any state party to the treaty can request formal reconsideration of the ban on PNEs.	"[T]en years after the entry into force of this Treaty a Conference of the States Parties shall be held to review the operation and effectiveness of this Treaty…On the basis of a request by any State Party, the Review Conference shall consider the possibility of permitting the conduct of underground nuclear explosions for peaceful purposes."

Averting an End to Nuclear Weapons Testing

In June 1957, AEC Chairman Lewis Strauss brought Edward Teller, Ernest Lawrence, and Mark Mills to lobby against the Soviet proposal for a two- or three-year moratorium. They persuaded Eisenhower to reject the proposal, on the grounds that within seven years of further testing, they could develop "clean" nuclear explosives (i.e., without radioactive fallout) for tactical military use in Europe and for the U.S. Plowshare program.[68]

By 1962, AEC scientists were even more convinced that "clean" devices were necessary to realize the diverse potential of PNEs, and that only the most sophisticated explosives – those that could not be revealed to the Soviets without compromising national security – would be appropriate for Plowshare. The AEC enjoyed considerable support on the Joint Committee on Atomic Energy in the U.S. Congress, and internal U.S. deliberations reflected recognition that any accord reached with the USSR curtailing Plowshare would likely meet opposition by influential legislators.[69] However, in negotiations toward a partial ban on nuclear testing in Moscow in July 1962, the U.S. essentially accepted the Soviet demand to treat PNEs in the same terms as nuclear weapons tests, in exchange for Soviet concession on language of the withdrawal clause.[70] Hence signatories of the Limited Test Ban Treaty (LTBT), by which signatories pledge in Article I:

> not to carry out any nuclear weapon test explosion, or any other nuclear explosion…if such explosion causes radioactive debris to be present outside the territorial limits of the State under whose jurisdiction or control such explosion is conducted.[71]

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[68] Seaborg with Loeb 1981:9.

[69] Seaborg with Loeb 1981:195-98.

[70] Seaborg with Loeb 1981:244-49, 255.

[71] Although Khrushchev reportedly had high hopes for Soviet use of PNEs, he believed that peaceful applications could be negotiated after Cold War tensions were reduced through an end to

Scientists from the U.S. labs disagreed on the merits of ratifying the LTBT, as they did on many other issues. Edward Teller, then associate director of the Livermore laboratory, testified in opposition to the LTBT, as did lab director John Foster. Among other reasons, Teller asserted that because some measurable radiation would be produced by most PNEs, the LTBT would effectively curtail the Plowshare program. However, Los Alamos director Norris Bradbury, as well as a number of other prominent U.S. nuclear specialists, urged the Senate to ratify the accord.[72] Then-chair of the AEC Glenn Seaborg also favored ratification.[73] As part of an energetic personal campaign to win Senate consent, President John F. Kennedy wrote an open letter to senate leaders. Among other measures, he pledged that the United States

> will vigorously pursue its…[Plowshare] programs within the terms of the treaty and, when such developments make possible constructive uses of [peaceful] explosions…will seek international agreement under the treaty to permit such explosions.[74]

The Senate ultimately ratified the treaty by a vote of 80 to 19, which significantly exceeded the two-thirds majority required. That same day, the Senate unanimously approved what was at the time the largest peacetime defense appropriation in U.S. history.[75] In this as in many arms control endeavors during the Cold War, a positive step toward constraining the superpower arms competition helped motivate defense spending that partially negated the contribution of the effort.[76]

From the NPT to the CTBT

The terms of the 1968 NPT explicitly promoted PNEs among other pacific applications of atomic energy, as a result of U.S., Soviet, and international interest in using such powerful explosives for civil engineering, mining, or other non-bellicose purposes.

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weapons testing and other arms control measures (Seaborg with Loeb 1981:244-45). While U.S. decision makers recognized that this exchange ran contrary to the pro-PNE constituency in the U.S. Congress and executive agencies, winning Soviet concessions on withdrawal was imperative for Senate ratification of any accord. Moreover, it was reasonable to imagine negotiating amendments to the LTBT, if and when PNE technologies were proven in the future (Seaborg with Loeb 1981:245, 248).

[72] Seaborg with Loeb 1981:272-3.

[73] Later, however, Seaborg lamented giving sincere but ultimately inaccurate testimony that persuaded key senators, including the former chair of the Joint Committee on Atomic Energy, Senator Clinton Anderson, to support the LTBT. Seaborg explained that AEC specialists hoped to develop nuclear explosives that resulted in very little radioactive contamination, and excavation techniques that would contain any radiation produced in PNE uses. The AEC also based its optimism on a liberal interpretation of contamination, and was ultimately overruled by the Arms Control and Disarmament Agency (ACDA), which concluded that any release of any radioactive particles would violate the accord (Seaborg with Loeb 1981:267-68).

[74] Seaborg with Loeb 1981:279.

[75] Seaborg with Loeb 1981:281, 287.

[76] U.S.-Soviet arms control initiatives helped drive the superpowers' weapons programs in at least five distinct ways (Rathjens, Chayes, and Ruina 1974:13-21).

According to the treaty, the benefits of PNEs would be provided by nuclear weapon states to non-nuclear-weapon states party to the accord.[77] Indeed, Article V states that PNE technology *must* be provided on request to non-nuclear weapon member states, albeit under international supervision to ensure that there is no transfer of weapons-applicable technology. The NPT's explicit encouragement for non-member states to utilize the benefits of PNEs functioned as "a clear green light," which led to the IAEA conferences on PNEs.[78] Despite the Indian explosion of a PNE in 1974, the first NPT Review Conference in 1975 reaffirmed:

> the obligation of Parties to the Treaty to take appropriate measures to ensure that potential benefits from any peaceful applications of nuclear explosions area made available to non-nuclear-weapon States Party to the Treaty in full accordance with the provisions of Article V [of the NPT] and other applicable international obligations.[79]

It further mandated that these "nuclear explosion services" should be provided on a non-discriminatory basis and at as low a cost as possible.

The United States and Soviet Union also crafted a bilateral accord granting formal status to PNEs under international law. U.S. and Soviet negotiations labored for over a year to negotiate exceptions for PNEs within the terms of the Threshold Test Ban Treaty (TTBT) signed in July 1974, which banned explosions greater than 150kt in yield. However, the two parties failed to identify a technical basis to distinguish "peaceful" from military nuclear explosions to allow PNE blasts of more than 150kt.[80] In May 1976, the superpowers signed the Treaty on Underground Nuclear Explosions for Peaceful Purposes (also called the Peaceful Nuclear Explosions Treaty-PNET).[81] The PNET made at best a marginal contribution to Cold War arms control, and it:

> may even have had a [net] negative impact on the policy of preventing nuclear-weapon proliferation, by providing respectability to the argument of those states that seek to develop a nuclear-weapon capability under the guise of an interest in peaceful explosions.[82]

Later, in the 1990s, Chinese interest in PNEs delayed and nearly blocked conclusion of the Comprehensive Test Ban Treaty (CTBT). In December 1995, engineers at a

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[77] Scheinman 1987:27.

[78] Davies 1979:298. On IAEA activities on PNE development, see Fischer 1997; see also IAEA 1970; 1971; 1972; 1975; 1976. In recounting international interest in PNEs, Fischer (1997:151-52) notes, "it is remarkable that serious consideration should have been given to creating another agency [in addition to the IAEA] for the purpose of promoting what turned out to be a failed technology. Perhaps one reason was that the two superpowers themselves had done so much to boost this idea."

[79] "Final Declaration..." 1975.

[80] Seaborg with Loeb 1981:295-97.

[81] The PNET was crafted to be subordinate to the PTBT, in adopting its 150kt yield limit, in prohibiting explosions that release radioactivity outside the territorial limits of the state conducting the explosion, and in prohibiting termination of the PNET while the PTBT remains in legal force (Goldblat 1994:46-47). For a brief official U.S. history of negotiations, and the text of the PNET protocols and treaty, see: (http://www.state.gov/www/global/arms/treaties/pne1.html).

[82] Goldblat 1994:47.

professional meeting in Beijing proposed to excavate a canal from the Brahmaptra River in order to irrigate the country's arid northwest region.[83] According to Chinese diplomats involved in the CTBT negotiations, U.S. nuclear specialists who had been involved in Plowshare and later in U.S.-China lab-to-lab exchanges, as well as their Russian counterparts from the Soviet PNE program, had persuaded Chinese scientists that PNEs could prove to be invaluable for national economic development.[84]

This brief review indicates the negative impact of the PNE idea on the prospects for ending nuclear weapons testing for over three decades. The damage to prospects for nonproliferation, however, was not limited to delaying a halt to testing. Not only did arms control treaties fail to halt the superpowers' arms race, but the negotiation and ratification of treaties helped disseminate the PNE idea to a number of countries that would consider developing the bomb.

PART III: PROLIFERATION IMPACT

National Nuclear Programs

Part III of this paper summarizes the influence of the PNE concept in four countries that developed or considered producing atomic explosives: India, Australia, South Africa, and Brazil. India's 1974 test of a "peaceful nuclear explosion" remains the most often-recalled event in the history of PNEs. As the role of the PNE rationale in India's nuclear program is quite well known, it is sketched only in broad terms in this paper. South Africa is commonly recognized for its unique nuclear history; as it is the only state ever to build and then voluntarily disarm itself of a nuclear arsenal. In-depth studies have also found that the PNE rationale played a surprisingly important role in bringing the country over the nuclear proliferation threshold. Today, Australia is widely known as a global leader in nonproliferation affairs. Recent archival studies have revealed, however, that in the 1960s and into the 1970s Australian officials seriously considered acquiring nuclear weapons. This paper reveals further that Australia played a noteworthy role in the international promotion of PNE, especially in Brazil. There, expectations that PNEs held tremendous prospects for geographic re-engineering were higher than in any other developing country, and for a longer period of time. This paper also explains the role of the PNE rationale in motivating construction of a mysterious shaft bored deep underground on a military base in the Amazon, which was revealed by the Brazilian press in 1986 and "buried" by the Brazilian president in a theatrical ceremony in 1990.

The review of these four nuclear histories presented below indicates that the PNE idea played at least three distinct roles that increased the risk of nuclear proliferation: 1) as an additional reason for developing indigenous fissile material production capability, and refusing to accept international safeguards on indigenous nuclear facilities; 2) as a smokescreen for "rogue" bureaucratic factions to pursue nuclear explosive development,

[83] Horgan 1996.

[84] Horgan 1996; Arnett 1996.

despite lack of governmental approval; and 3) as a political and ethical "bridge" between divergent factions within heterogeneous coalitions engaged in technological development. In this last role, the enabling "power" of PNE idea resulted from its *multivocal* character.[85] The "peaceful" characterization of nuclear explosive devices allowed different actors to simultaneously view the same technological development efforts as oriented toward diametrically opposite purposes. Thus proponents and critics of nuclear weapons could be reconciled in support of "peaceful" nuclear explosives. The following table briefly summarizes PNE and nuclear weapons programs, described in further detail in the case studies below. The dating presented here is suggestive rather than definitive.

	PNE Research or Development Program	**Nuclear Weapon-Production Program**
India	1964-74	1980s-present
Australia	1962-70	none
South Africa	1969-78	1979-91
Brazil	1978-86	none

INDIA

India's PNE program was originally inspired by a very large U.S. exhibit in Geneva, which depicted how to quickly increase oil output and build large lakes using PNEs. Indian observers were also invited to attend the U.S. Project Rulison, which involved stacked use of PNEs as a boring technique, as well as a "very impressive" Soviet use of PNEs for lake formation.[86] Indian representatives participated in the first four IAEA conferences on PNES, and presented formal statements on India's national program in 1970, 1971, and 1975, as well as a technical paper on their 1974 PNE test at the 1975 session.[87]

Indian officials exploited the PNE idea in their 18 May 1974 explosion of a "peaceful" nuclear device at Pokhran. Indeed, the Lal Bahadur Shastri-led Congress Party government initiated the program in 1964 as a peaceful nuclear explosive effort, and consistently justified it as such for over a decade as a PNE program. Persuasive accounts

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[85] Multivocality characterizes social behavior when different actors understand the same actions in fundamentally different ways. It is of causal significance when "single actions can be interpreted coherently from multiple perspectives simultaneously...single actions can be moves in many games at once, and...public and private motivations cannot be parsed" (Padgett and Ansell 1993:1263).

[86] Author's interview with Rammana 2001. He directed the Indian PNE development team in the late 1960s, and presented a paper on the 1974 Indian PNE test at the fourth IAEA conference on PNEs, held in Vienna in 1975. On Plowshare's influence in motivating Indian PNE aspirations, see Perkovich 1999:35, 90-99.

[87] IAEA 1970:9-10, 448; IAEA 1971:7-8; 349; IAEA 1974:484; IAEA 1975:9, 418-20, 474; Chidambaram and Ramanna 1975.

indicate that the U.S. and Soviet PNE programs inspired many Indian scientists and decision makers, leading them to believe that PNE technology would offer great benefits for India. However, some actors may have exploited the PNE rationale to cloak ulterior strategic goals and programmatic intentions.[88] Although the 1974 explosion "dealt a severe blow to the hopes for nuclear stability that had been building around the NPT and the nonproliferation regime," a contemporaneous assessment of the available technical data by a Livermore analyst concluded that all available evidence indicated that the Indian test was a peaceful use of nuclear explosive energy.[89]

Our confidence in counterfactuals is always limited, and assessing alternative Indian nuclear histories are no exception. But without the idea of a PNE as a means to rationalize the Indian program, the pattern of evidence indicates that the nuclear explosive program might not have been carried forward. And even if it had been brought to the point of readiness, without the "peaceful" rationale, President Indira Gandhi might well never have authorized that a test be conducted. The PNE idea functioned in Indian decision making and public justification as a normative bridge from a foreign policy oriented by the ideas of Gandhi and Nehru, toward a contemporary realpolitik conception of nuclear capabilities and foreign relations. Only in the 1990s was the 1974 testing team willing to acknowledge that the 1974 PNE had military significance.

AUSTRALIA

In 1962, U.S. and Australian officials first discussed a concrete application of "peaceful nuclear explosives" for Australia, that of building an artificial harbor at Cape Keraudren on the northwest coast. During September and October of 1963, a technical mission of Australian scientists traveled to the United States to learn about the Plowshare program and review research on science, engineering, and safety aspects of PNEs. The team concluded that with further development, PNE technology "could assume a significant, if limited, role in the construction of major works and the exploitation of mineral resources in Australia."[90]

As elsewhere, Australians made no secret about their interest in PNEs during the 1960s and 1970s. Specialists from Australia attended the 3rd Plowshare Symposium, held at UC-Davis in April 1964.[91] The 1966 annual report of the Australian Atomic Energy

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[88] Perkovich 1999 offers an authoritative study of Indian nuclear development. On the role of the PNE rationale in the early years, see pp. 82-85, 126-27; 135-36; 159; 161-189.

[89] Scheinman 1987:174; Nordyke 1974:2. In his technical assessment, Nordyke observed that structural characteristics of the Indian explosion were "strikingly similar to those depicted in the enclosed LLNL drawing (Fig. 5) for the purpose of demonstrating the technique of chemical mining."

[90] U.S. Department of Energy 1998: 16; IAEA 1970:315; which cites A.R.W. Wilson, E.B. Pender, and E.K. Carter, *Peaceful Uses of Nuclear Explosives – An Evaluation, for Australian Purposes, of Proposed Civil Engineering and Mining Applications*, Technical Mission to the USA, September-October 1963, AAEC(SP)R1, (Coogee: Australian Atomic Energy Commission, March 1964).

[91] U.S. Department of Energy 1998:22.

Commission (AAEC) openly described research on PNE applications.[92] Australian scientists participated in all five IAEA-sponsored international conferences on PNEs during 1970-76, and an Australian representative offered a report on the national program in the 1970, 1971, and 1975 meetings.

Indeed, Australia took a clear leadership role in the international diffusion of PNEs. AAEC representative A.R.W. Wilson chaired the IAEA gatherings in both 1974 and in 1975.[93] Moreover, the AEC mission to assess Plowshare received widespread attention in Australia and abroad. It was noted with particularly keen attention in Brazil, where the favorable Australian evaluation was seen to corroborate high Brazilian expectations for PNEs.[94]

In January 1969, the United States and Australia formally announced a joint program to evaluate the use of PNEs to construct a harbor at Cape Keraudren. The immediate impetus for the announcement is unclear, but it fulfilled longstanding aspirations of the U.S. Plowshare community.[95] In a classified letter in February 1967, Livermore Associate Director Glenn Worth urged the AEC to "initiate negotiations leading to selection of a site for an experimental harbor on foreign soil." Noting that no cost-effective application of nuclear excavation had been identified in the United States, he stressed that:

> A useful excavation project is needed. A harbor in a developing country or an area where six to ten [nuclear] explosives could be fired simultaneously in flat terrain would be ideal.[96]

For planning purposes, Werth recommended that a harbor demonstration project be conducted in fiscal year 1970.[97] Specialists at Livermore reportedly examined the Keraudren project in some detail in 1968, in response to a request from a major ocean transport firm. Considering a plan to detonate five 200kt devices, their analysis indicated that a low-cost harbor could be constructed in Australia, which would offer a "tremendous amount of information" relevant to cutting a trans-isthmian canal in the Americas.[98]

Beyond economic benefits anticipated from the immediate project, some Australian officials may have seen this as an opportunity to justify acquiring a nuclear weapons capability. As the United States pressed for support of the NPT in the UN

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92 IAEA 1970:2; which cites Australian Atomic Energy Commission, *Fourteenth Annual Report for the Year ended 30th June, 1966*, NP-16359.

93 IAEA 1970:3-4, 448-49; IAEA 1971:3-4; 349-50; IAEA 1972:482; IAEA 1975:3-4, 474; IAEA 1976:194.

94 Comissão Australiana de Energia Atómica [reprinted] 1967:133

95 See Teller 1963:8-9; Knox 1967:15-17; Werth 1967.

96 Werth 1967:6.

97 Werth 1967:8.

98 Toman 1970:259-60. Toman states that Livermore's research on Keraudren was conducted in 1968, which would indicate that it took place before the U.S.-Australian announcement in January 1989. Toman was not personally engaged in this effort, however, and his dating may be erroneous. Alternatively, if accurate, the 1968 dating could indicate that LLNL was seriously engaged in evaluating the Keraudren project before receiving authorization from the Australian or U.S. governments.

General Assembly, in late 1968 a mission comprised of U.S. AEC and ACDA officials engaged Australian decision makers in Canberra to try to understand their reticence to support the NPT. They reportedly:

> found the Australians very interested in just how far they could go under the treaty toward developing a nuclear-weapons capability so that they would not be behind India and Japan if either of those countries suddenly withdrew from the treaty.[99]

These and other indications led U.S. State Department officials to predict Australian efforts to develop nuclear capabilities that would put it "in a position to achieve a bomb within months of withdrawal from the NPT."[100] This expectation gained further credence when in 1969 the head of the AAEC noted that:

> Nuclear explosives…will provide a basis from which an Australian government, at any future date feeling that nuclear weapons were essential to provide this nation's security could move with the minimum delay to provide such means of defence.[101]

As U.S. officials told their Australian counterparts in 1968, the NPT would prohibit non-nuclear-weapon signatories from developing their own PNE devices.[102] Unwillingness to make this pledge apparently accounted in part of Australian reticence to sign the NPT.

In a meticulously researched study based on previously classified Australian sources, Walsh documents a pattern of Australian efforts to attain indigenous control over advanced nuclear technologies during the 1964-72 period. These culminated in 1969, and included a secret nuclear cooperation accord with France, a bid to construct a power reactor and perhaps a uranium enrichment facility, as well as the U.S.-Australian PNE project at Keraudren.[103] The harbor project was soon halted, however, in March 1969 when officials determined that they lacked adequate financial grounds for proceeding ahead.[104]

Prospects for an Australia nuclear weapon program, even under a PNE guise, were essentially terminated with the NPT's entry into force for Australia in January 1973. In fulfilling its NPT commitment by signing a safeguard agreement with the IAEA in 1974, Australia pledged to provide the agency sufficient access to:

> ensure that safeguards will be applied…on all …special fissionable material in all peaceful nuclear activities within the territory of Australia, under its jurisdiction or carried out under its control anywhere, for the exclusive purpose of verifying that such material is not diverted to nuclear weapons *or other nuclear explosive devices*.[105]

Thus Australian engagement with the international diffusion of PNEs came to an end, fortunately without taking the country over the nuclear proliferation threshold.

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[99] U.S. Arms Control and Disarmament Agency undated:90.

[100] Policy Planning Council, U.S. Department of State 1968:3.

[101] Walsh 1997:19 note 117; who cites *Australian,* 14 July 1969, p. 3.

[102] U.S. Arms Control and Disarmament Agency undated:90.

[103] Walsh 1997:9-12; see also Hymens 2000:8-13.

[104] Toman 1970:259; U.S. Department of Energy 1998:16; Hymens 2000:21 note 77. See also Green 1997 for a review of Australian sources on the rise and fall of the Keraudren project.

[105] Italics added for emphasis. "Agreement between Australia and the International Atomic Energy Agency…" 1974, Article II.

SOUTH AFRICA

Inspired by the U.S. Plowshare program, in the 1960s South African researchers became interested in exploring the use of PNEs for mining and construction.[106] South African representatives attended the 3rd Plowshare Symposium at the UC-Davis in 1964, as well as all five of the IAEA international PNE conferences in Vienna, during the 1970-1976 period.[107] In 1969, the Atomic Energy Board (AEB, later Atomic Energy Corporation, or AEC) formed an internal committee to research technical and economic aspects of PNEs for the mining industry.[108] In addition, the AEC proposed to employ PNEs to excavate harbors and underground tanks for oil storage.[109] While initial investigations were limited to literature surveys, serious interest grew with the emerging expectation that South Africa would master uranium enrichment technology, which would provide fissile material for a nuclear explosive.[110] Early on, this effort was conducted in the open, and South Africa publicly discussed its PNE program at the first IAEA international conference on PNEs in 1970.[111]

In March 1971, Minister of Mines Carl de Wet approved a research program for employing PNEs in the mining industry, and authorized the AEB to conduct research on building an explosive device. The agency acquired information on nuclear explosive fabrication from open sources, including volumes of declassified data from the U.S. Manhattan Project, as well as PNE data provided by LLNL in the international IAEA conferences.[112] In a 1974 report to Prime Minister John Vorster, the AEB concluded that it could indeed build a nuclear explosive device. Vorster responded by approving PNE development and construction of an underground nuclear test site.[113]

Although there is limited reliable data on exact dates of subsequent key decisions in this program, the available evidence indicates that nuclear explosive development in South Africa was justified for at least a half-decade in terms of developing a "peaceful nuclear explosive." During much of this period, the project was maintained as a tightly held state secret initially due to the sensitivity of its effort to develop enrichment technology, and later "because the world was fast turning against the use of nuclear explosives for civil applications." According to Waldo Stumpf, subsequent head of the AEC, only in 1977 did the government alter the objective of its nuclear explosive program from peaceful purposes to developing a nuclear deterrent capability.[114] Armaments Corporation (Armscor) officials

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106 Stumpf 1995/96:4.

107 U.S. Department of Energy 1998; IAEA 1970:13-14, 448-51; IAEA 1971: 350-53; IAEA 1972:482-86; IAEA 1975:474-48; IAEA 1976:197.

108 Albright 1994:6; who cites IAEA 1993.

109 Liberman 2000:15.

110 Stumpf 1995.

111 IAEA 1970:13-14.

112 Liberman 2000:28; Hibbs 1993a:10; 1993b:3.

113 Stumpf 1995/96:6; Albright 1994:6.

114 Stumpf 1995; Stumpf 1995/96:5.

date the transition as somewhat later. They maintain that in October 1978, Prime Minister P.W. Botha decided "to shift the emphasis" of the nuclear program from PNEs to developing nuclear weapons, just one month after taking office.[115]

It should be noted that some South African and other international sources provide different estimates on the initiation of the country's nuclear weapons program. According to F.W. de Klerk, president of South Africa from 1989-1994, the decision to "develop a limited nuclear deterrent capability" was made "as early as 1974."[116] IAEA safeguards officials charged with verifying South Africa's past nuclear activities likewise report that the prime minister approved a "limited program for development of nuclear weapons as a deterrent" in 1974.[117] According to a 1983 U.S. intelligence report, "[deleted passage] indicates that South Africa formally launched a weapons program in 1973," and that scientists were instructed to develop gun-assembly, implosion, and thermonuclear weapons designs.[118] However, none of these sources provide reason to doubt that at least the initial steps were entirely justified within the South African government and research community in terms of the PNE rationale.

Reiss attempts to resolve discrepancies in official accounts by concluding that South African decision-makers and nuclear scientists would have known that a PNE was equivalent to a first-generation nuclear weapon.[119] While Reiss' observation is true in principle, in operational terms the first South African devices were very large, heavy, and could not be transported by aircraft. In this sense, they were better suited for controlled underground explosion, be it for the purpose of a political demonstration, or for use in civilian engineering.

Furthermore, in perhaps the most thoroughly researched study to date, Liberman finds that the PNE rationale served to overcome moral objections among some scientists in the early stages of the nuclear explosive program.[120] He also confirmed a finding reported by other researchers, that the armed forces were entirely excluded from decision making and denied information regarding the PNE project.[121] Hence Liberman concludes on the basis of interviews with key participants that South Africa carried out a PNE program, not a bomb project, until 1977-1978.

Thus although India was the first state to emulate the superpowers by testing a "peaceful nuclear explosive," South Africa initiated and carried out a clandestine PNE program concurrently with the Indian effort. As in India, the conceptual impetus and substantial technical information for the South African program originated in the United States, and was facilitated by the IAEA's efforts to organize an international epistemic community around the peaceful uses of atomic explosives. In the early years in both of

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[115] Hibbs 1993a:4; Albright 1993.

[116] *Nuclear Fuel* 1993:7.

[117] Von Baeckmann, Dillon, and Perricos 1995:45.

[118] U.S. Directorate of Intelligence 1982:1.

[119] Reiss 1995:27.

[120] Liberman 2000:29; 15-16.

[121] Liberman 2000:29.

these countries, the PNE rationale bridged communities of specialists who diverged on the morality of the atomic bomb. It thus enabled collaboration among heterogeneous coalitions of individuals who disagreed fundamentally on the nature and purpose of their nuclear developmental activities.

Both the Indian and South African programs, of course, were subsequently transformed into dedicated nuclear weapons production programs. While we can speculate that both eventually would have produced atomic weapons, it is clear that the PNE rationale enabled developmental activities that brought them substantially closer to doing so. Thus the PNE rationale encouraged the acquisition of nuclear weapons by both countries.[122]

BRAZIL

As elsewhere, PNE advocates in the United States led Brazilian policy makers and technical specialists to believe that the devices would offer tremendous new possibilities for civilian engineering. A special edition of *Revista Brasileira de Política Internacional* in 1968 devoted to nuclear policy provides striking examples of U.S. influence. Its text includes numerous public statements by Brazilian officials explaining how the efforts of their U.S. counterparts inspired them to seek to develop PNEs, and why they expected that PNEs "would become the business of the century."[123] One noted that a U.S. book on Plowshare, written with the cooperation of the AEC and published in 1962, identified many specific recommendations for employing PNEs in Brazil.[124] Another noted the striking contrast between U.S. State Department declarations in Geneva that PNEs were not yet technically or economically viable, and the substantial financial investment by the U.S. AEC and private firms in developing the technology in the United States.[125] The journal also translated and reprinted the very favorable report of the Australian AEC on the U.S. Plowshare program.[126]

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[122] Liberman offers a telling assessment of the U.S. role in South Africa: "For nonproliferation goals, the U.S. Plowshare Program was an irretrievable blunder. Had Lawrence Livermore Laboratory not promoted PNEs so assiduously in the 1960s, the AEB might never have launched a PNE program and so would have been less eager to go ahead with a weapons program in the late 1970s (Liberman 2000:58).

[123] Araripe [reprinted] 1968:118.

[124] Modesto da Costa 1967:123-4, who cites Sanders 1962:37, 85-86, 116, 118, 148. Major Modesto da Costa served as chief of staff to the president of the National Nuclear Energy Commission. Eleven of twelve technical references in his report are to U.S. publications; one is to a French source. Sanders' book concludes with an eloquent declaration that undoubtedly resonated with Brazilian cultural aspirations to modern development and progress: "One point is clear: just as old Canute could not hold back the sea, so modern man cannot stem the surging tide of technical progress. Neither the scientist, the diplomat, the politician nor anyone else can turn back the hands of the technological clock. There is no mistaking impediments still in the path of nuclear dynamite and geographic engineering; but we can permit neither technical difficulties nor political "convenience" to blind us to the potential of this technological boon. The world's needs are too pressing and the rewards of nuclear explosives too promising for man to fritter away this opportunity" (Sanders 1962:194-95).

[125] Araripe [reprinted] 1968:114, 117.

[126] Comissão Australiana de Energia Atómica [reprinted] 1967:125-33.

Persuaded by such compelling scientific evidence from leading countries abroad, Foreign Minister José de Magalhães Pinto insisted:

> We neither intend to receive nor to fabricate nuclear arms. We will not deny ourselves, however, the right to research without limitation and eventually to fabricate or receive nuclear explosives that will enable us to execute great works of engineering, to link fluvial basins, open canals and harbors, in short to repair the geography, where it needs it, in promoting the economic development and well-being of the Brazilian people.[127]

By the late 1960s, support for PNEs became "almost an article of faith in Brazilian domestic politics."[128] Brazilian convictions in this regard deeply marked the country's participation in negotiations on the Treaty of Tlatelolco and the NPT.[129] Brazilian representatives participated in the 1971 and 1972 international conferences on PNEs.[130]

Throughout the 1980s, U.S. diplomatic efforts to encourage Brazil to accept verified nuclear nonproliferation commitments were stymied in part by Brazilian conviction that PNEs might be a technology of tremendous future potential.[131] Even as international interest in PNEs waned, Brazilians continued to believe that it made no sense for the country to abjure forever a technology that might one day have technical merit.[132]

In the early 1980s, President João Figueiredo and his chief military advisor General Danilo Venturini supported, at least in principle, Air Force efforts to develop PNEs. The former wrote and the latter signed Exposição de Motivos 011/85, which explicitly authorized Air Force "development of nuclear explosives for pacific objectives."[133] The service used this approval to gain funding for laboratory research on laser enrichment technology, and to drill a shaft at the Cachimbo Air Force base in the Amazon, which it apparently hoped would be used for nuclear explosive testing.[134]

However, when Air Force officials proposed to actually test such a device in late 1984, Figueiredo ordered an evaluation on political and legal grounds. The review concluded that any nuclear explosion would contradict the spirit (although not the letter) of the Treaty of Tlatelolco, and that Brazil's national interest was to master the nuclear fuel cycle and to avoid any activity that would be perceived as an atomic bomb. Hence Figueiredo rejected the proposal, and Venturini reportedly took pains to make clear to testing advocates in the Air Force that this decision was unequivocal.[135] Thus even without

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[127] Magalhães Pinto 1967:9.

[128] Redick 1995:17.

[129] See especially Wrobel 1991, Chapter IV.

[130] IAEA 1971:350; IAEA 1972:482.

[131] Author's interview with Kennedy 1995.

[132] Author's interviews with Abdenur 1995, Castro Neves 1995, Jaguaribe 1995.

[133] This secret memo was provided to the author in a context that left no doubt as to its content or authenticity. It was subsequently described in part by *Folha de São Paulo*, 16 May 1995, p. 1.

[134] On the role of the Air Force role and other questions regarding the possible test shafts drilled at Cachimbo, see the extensive reporting published by *Folha de São Paulo* during the period 8-27 August 1986, and also on 19 September and 25 November 1990; see also Pinguelli Rosa *et al.* 1990.

[135] Author's interview with Venturini 1995.

signing the NPT or waiving Tlatelolco into force, and in marked contrast to public statements defending Brazil's right to develop PNEs, Brazilian policymakers found themselves constrained in the mid-1980s by the emerging normative and political consensus against nuclear proliferation, and against the notion that any atomic explosion could be "peaceful."

Nevertheless, PNE advocates in the armed forces and civilian nuclear establishment successfully lobbied in the national Constituent Assembly to craft a possible legal exception for their ambitions. Although the new 1988 constitution mandated that "all nuclear activities within the national territory will be permitted only for peaceful purposes and if approved by the National Congress," this provision was seen by supporters and opponents as permitting development of a nuclear explosive, if dedicated to "peaceful" purposes.[136]

As late as 1990, PNEs were openly advocated in public testimony before a congressional investigation of the military's nuclear program. Rex Nazaré, former head of the National Nuclear Energy Commission, stated that Russia employed PNEs in petroleum extraction as the late 1980s. He urged that Brazil retain the right to PNEs, declaring:

> The great question is the following: the very Treaty of Tlatelolco envisions the existence of peaceful explosions. But what is the fundamental point for us? Brazil, in my opinion, should have the capacity to permit, at any moment, you gentlemen and the members of the Executive power to decide the road to follow. It falls to you, and only to you, to say: Is Brazil going one day to do a peaceful explosion, or not? What we could not allow to occur is that the capacity was never developed.[137]

Nazaré failed to persuade congressional skeptics of the distinction between an atomic bomb and a "peaceful nuclear explosive," or that Brazil needed to reserve the right to PNEs. But fear that military officials sought to conduct a PNE test motivated a technical report released in May 1990 by the Brazilian Physicists Society. This technical study concluded that a limited-yield atomic explosive device could be tested in the shaft at the Cachimbo Air Force base.[138] According to then-President Fernando Collor de Mello, senior Air Force officials also privately advocated PNE development in a cabinet meeting at about this same time.[139] In September 1990, Collor made an unprecedented statement for a Brazilian president: he definitively abjured PNEs in a public address before the United Nations.[140]

In 1990-1991, Brazil formally renounced PNEs, agreed to establish a bilateral

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[136] Constituição da República Federativa do Brasil 1988: Title III, Chapter II, Article 21, XXIII, a; Britto de Castro *et al.* 1989:26. This provision was weaker than that advocated by antinuclear activists, not only due to the PNE loophole but also because the final text did not renounce the right to enrich uranium outside of international safeguards, and established no mechanisms to implement civilian oversight.

[137] *Diário do Congresso Nacional* 1990:5707; 5709.

[138] Pinguelli Rosa *et al.* 1990:44. The report was based in part on technical advice provided by the Federation of Atomic Scientists and, ironically, on information from Teller's 1968 textbook on PNEs. The report was released only after internal debate within the organization, as some scientists contended the available evidence was insufficient to conclude that the Cachimbo shaft was designed for testing an atomic explosive.

[139] Author's interview with Collor de Mello 1997.

[140] See *O Estado de São Paulo*, 25 September 1990, for the text of Collor's speech.

safeguards agency with Argentina and to accept IAEA inspection of formerly secret nuclear facilities, and committed to ratifying the Treaty of Tlatelolco.[141] This marked the reversal of a long trajectory toward the proliferation threshold.[142]

PART IV: ASSESSING THEORY AND ILLUMINATING POLICY

Theories can be evaluated in terms of several criteria. These include such intrinsic characteristics as clarity and parsimony, but more fruitfully also involve tests of descriptive or predictive accuracy and explanatory scope against evidence and in comparison with other theories. The following tables offer a tentative assessment of alternative theoretical approaches to explaining the origins, diffusion, and impact of the PNE idea.[143] The first table offers generic expectations based on three approaches to explaining state behavior in international affairs: neorealism, bureaucratic politics, and epistemic communities. These predictions refer only to those states that have sufficient financial and technical resources to realistically expect to be able to eventually produce nuclear weapons, following an affirmative decision to do so.

Theoretical Predictions:
Nuclear Proliferation and PNE Development

	Produce/Acquire Nuclear Explosives for Weapon Purposes	**Produce/Acquire Nuclear Explosives for Civilian Purposes**
Neorealism	yes	no prediction
Bureaucratic Politics	depends on dominant faction	depends on dominant faction
Epistemic Community	no prediction	yes

Neorealist expectations about nuclear proliferation, like security-based predictions in general, have been contradicted by state behavior in a surprising number of cases. Contrary to widely held assumptions in security studies and international relations theory, painstaking historical research has demonstrated that security threats did not drive nuclear proliferation-

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141 On developments during this period, see Redick 1995:24-34; Barletta 2000:173-98.

142 It is a mistaken, however, to view military nuclear development efforts in Brazil as a dedicated nuclear bomb program; there was governmental and military consensus only on developing the technological capacity to create the *option* to build atomic weapons. Moreover, programmatic efforts were driven as much or more strongly, even within the armed forces, by non-weapons objectives (Barletta 2000:231-39; 269-71; Barletta 1997:13-17).

143 This discussion is based an approach presented in Barletta 2000:302-09.

related behavior in rational or obvious ways in India, Australia, South Africa, or Brazil. Indian nuclear explosive development lagged many years behind its potential, despite the country's bitter defeat in war in 1962 by China, and Chinese development of nuclear weapons.[144] Australia sought nuclear weapons from Britain during the time period when it enjoyed greatest security, and categorically abjured the bomb even as China was perceived as posing a rising security threat, and despite India's test of a nuclear explosive.[145] South Africa first developed nuclear explosives, and then officials crafted a wild-eyed rationale to justify a military-strategic purpose for them.[146] Brazil refrained from a dedicated nuclear bomb program in the late 1970s and early 1980s, even as the United States effectively abrogated its security assurances in the Americas during the Falklands/Malvinas War, as British use of nuclear-propelled submarines raised the salience of atomic energy in war, and as Argentina developed the Cóndor II ballistic missile.[147]

Although the standard – of prediction compared against outcome – is useful in evaluating theoretical approaches, it ordinarily does not capture their full value. Most theories offer only probabilistic predictions, and one study cannot disconfirm a theory unless it poses a critical test.[148] Moreover, theories may offer insight in explaining one aspect or stage of an historical evolution, even if they fail to account entirely for its complete trajectory.

The next table portrays in categorical terms a comparative evaluation of alternative theoretical approaches against each other and against the evidence presented in this paper. Approaches are rated on a six-category scale, ranging from most to least valuable for empirical explanation and theory building:

best – provides most accurate and complete explanation in three-cornered test[149]

helpful – predictions accurate, offers insight, and complements other approaches

compatible – available evidence does not justify either rejection or confirmation

contradicted – available evidence contradicts predictions

misleading – initially appears useful, but correlation proves spurious rather than causal

irrelevant – explanatory scope does not apply to empirical question(s) under scrutiny

This scale presumes that few phenomena can be explicated exhaustively by one theoretical approach; combining several approaches typically produces the best explanation (i.e., most accurate and encompassing). Moreover, for the purpose of theory building, an approach that leads to spurious correlation is less productive than one that is readily falsified. Of course, none of these theoretical approaches should be considered disconfirmed or useless

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[144] Sagan 1996/97:65-69.

[145] Walsh 1997:14; Hymens 2000:8-9.

[146] Reiss 1995:7-9, 15-16; 28-29; Liberman 2000:3, 13-27.

[147] Barletta 1999:20-21; Barletta 2000:138-40; Barletta 2001:1-2, 16.

[148] See Stichcombe (1968:24-28) on "crucial experiments" designed to evaluate most-likely theoretical alternatives.

[149] Lakatos (1970:115) emphasizes the importance of "three-cornered fights between rival theories and experiment." A plausible theory should be assessed against both the available evidence and the best theoretical alternative(s) for explaining the phenomenon under scrutiny.

merely on the basis of one study.

Explaining the Origins, Diffusion, and Impact of PNEs:
An Evaluation of Theoretical Contributions

	U.S. Origins	International Diffusion	Proliferation Impact
Neorealism	contradicted	irrelevant	misleading
Bureaucratic Politics	helpful	irrelevant (?)	helpful
Epistemic Community	helpful	best	helpful

It must be stressed that these assessments are rough and remain preliminary until access to more extensive data allows for a better research design and analytic evaluation. In particular, further research would enable more confident evaluation of the respective causal weight of knowledge-based and material interest-driven factors in shaping national PNE programs.

As should be expected, the relevance of particular theoretical approaches varies with respect to the question at hand. Neorealism does not speak directly to the diffusion of science and technology, while an epistemic community approach ought not be expected to account entirely for the sources of national bureaucratic initiatives. In sum, however, the theoretical tools offered by bureaucratic politics and epistemic communities prove most useful in explaining behavior observed in this study. Neorealism proves at best irrelevant and at worst misleading in accounting for state behavior in this study of the spread of nuclear explosives.[150] A combination of bureaucratic and epistemic analysis is most insightful in accounting for the genesis and proliferation consequences of the PNE experience, while an epistemic community clearly drove international diffusion of the PNE idea.

As an analytic approach, research on epistemic communities focuses on the processes by which "consensus is reached within a given domain of expertise and through which the consensual knowledge is diffused to and carried forward by other actors."[151] Like previous studies in the research tradition, this paper on the international history of the PNE idea illuminates how international policy projects are implemented through transnational and trans-governmental coalitions grounded in a core base of technical knowledge.[152] However, the story told in this study should caution against a tacit assumption of earlier research: the apparent presumption that epistemic communities advancing cutting-edge scientific

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[150] On the failure of neorealism to account for state behavior in what presumably ought to be the most realist of all policy realms – state acquisition of weapons of annihilation – see Barletta 2000:313-18.

[151] Haas 1992:19.

[152] Haas 1992:32-33.

knowledge necessarily increase prospects for interstate cooperation and progress in international affairs.

A Postscript on Policy

This study offers a textbook case of how *not* to make U.S. national security policy. It illustrates how in pursuit of parochial interests, bureaucratic agencies can develop and exploit persuasive rationales for nuclear weapons and other advanced military technologies, with deleterious unintended effects. Reflection on this historical experience might enable us to better anticipate the eventual consequences of some contemporary U.S. security policies.

Is there a contemporary analogue, an idea that enjoys allegiance among interested and ideological factions but that may be fraught with unforeseen consequences? An exact duplicate, of course, is unlikely. However, in light of the PNE experience, the following set of questions merit reflection. Will U.S. global promotion of "missile defense" offer a convenient rationale (and perhaps technology transfer) for development of sophisticated anti-missile interceptors by other countries? If so, will any states convert long-range, ground-based, defensive missiles from anti-missile use to offensive purpose as ballistic missile delivery vehicles? As others follow the U.S. lead in developing missile defenses, will states unable to master hit-to-kill technologies turn to nuclear-tipped interceptors, as the United States and Soviet Union did in their early anti-missile programs? Thirty years from now, what are the prospects that for these or other reasons we might look back on the United States' global promotion of "missile defenses" as a pernicious idea in world politics?

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