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The relationship of new weapons in the American arsenal to research and development (R&D) has often been assumed to be characterized by a linear model of the dependence of technology upon science. According to this model, basic research leads to new scientific knowledge, which in turn is applied to the end of developing new technologies. The linear model has a long history, but it has been specially emphasized since World War II by scientists justifying support for basic research on grounds of its indispensability to the advance of civilian and military technology.

The martial claims of the linear model were spectacularly verified by the success of the Manhattan Project. Here was a revolutionary new weapon—the atomic bomb—that had originated in the research of physicists into the structure of the nucleus, a subject of esoteric interest with little if any likely practical utility. Or so it had seemed until the discovery of nuclear fission, in 1938. After Hiroshima and Nagasaki, physicists as well as other advocates of science insisted that the highly technical weapons of the war—not only the atomic bomb but radar, rockets, and myriad other devices—had depleted the reservoir of basic knowledge. The reservoir had to be refilled, not least for the sake of national security, with federal programs in support of basic research and training in areas pertinent to national defense.[1]

Thus, in the name of national security, a vast federal R&D structure was established in the postwar years. A key feature of this structure was the support provided to civilian scientists in extragovernmental institutions by new military or militarily relevant agencies, notably the Office of Naval Research, the Air Force Office of Scientific Research, and the Atomic Energy Commission, and by the military's longstanding technical bureaus (for example, the Army Signal Corps or the Navy Bureau of Ordnance). In addition, a far-flung scientific advisory apparatus was created, linking the military with scientists from academia and industry. For almost a quarter century after 1945, defense research expenditures rose virtually exponentially even in constant dollars, accounting through 1960 for 80% or more of the entire federal R&D budget. In 1950, it was estimated that there were 15,000 defense research projects; in the early 1960s, perhaps 80,000.[2] With the rise of the space program and the disillusion with the military attendant upon the war in Vietnam, the fraction

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1. Daniel J. Kevles, *The Physicists: The History of A Scientific Community in Modern America* (New York: Alfred A. Knopf, 1978), p. 341.

2. Karl Compton to Robert Russell, Dec. 26, 1950, Karl T. Compton and James R. Killian Papers, MIT Archives, Collection AC4, Box 246, folder 2; Herbert York, "Autobiography," (unpublished manuscript; forthcoming, Norton, 1987), Chap. X, p. 5.

of federal R&D monies devoted to defense fell below 50% by the mid-1970s, but it has now recovered to almost 70% of a federal R&D budget that totals some $57 billion.

Federal support of R&D has, of course, produced a cornucopia of strategic and tactical weapons, including thermonuclear warheads and intercontinental ballistic missiles, supersonic aircraft and smart bombs, surveillance satellites and nuclear-powered submarines. However, the historical facts of military R&D call the linear model into severe question. On average, no more than—and in recent years much less than—about 5% of the defense research budget has gone for basic research.[3] The other 95% or more has been devoted to applied research, development, and testing. The point here is not that the government has gotten what it has paid for but that it has paid for activities likely to result in things that it wanted—in this case, innovative weapons systems.

In the early 1970s, the Defense Department completed a study of the origins of twenty major weapons systems between 1945 and 1965. Published as *Project Hindsight*, the study concluded that fewer than one percent of the innovations required for the systems had originated in undirected basic scientific research carried out after 1945. Another eight percent were found to have their roots in research directed to defense or civilian needs. The vast majority—91%— had emerged from programs aimed at particular technological developments.[4] Critics faulted the study for shortsightedness: the success of the martially utilitarian research had depended strongly upon work in the basic sciences stretching back a century or more. To a great extent, the critics were right. However, the issue is not the obvious one that there can be no applied science without a science to apply. It is, rather, that the major advances in weapons systems were not fueled by compelling new progress in the self-determined basic sciences. They resulted from deliberate attempts by the defense establishment to call forth such advances by projecting slightly beyond what was known to what might be desired.[5]

The interplay between the known and the desired suggests that the linear model might perhaps be replaced by something more akin to a feedback model, where technical possibilities interact with strategic or tactical needs, and definitions of such needs shape the generation of technical possibilities. Herbert York, the director of the Livermore Laboratory from its inception, in 1952, to 1958, the Director of Defense Research and Engineering from 1958 to 1961, and both a defense adviser and arms-control activist afterwards, has recalled how the development of the

3. Paul Forman, "Behind Quantum Electronics: National Security as a Basis for Physical Research in the United States, 1940-1960," unpublished manuscript, pp. 31-32 (forthcoming in *HSPS*, 17 (1987). The recent figure has been about 3%. Franklin A. Long and Judith Reppy, "The Decision Process for U.S. Military R&D," in Kosta Tsipis and Penny Janeway, eds., *Review of U.S. Military Research and Development, 1984* (Washington,D.C.: Pergamon-Brassey's, 1984), p. 7.
4. Melvin Kranzberg, "Science, Technology, and Warfare: Action, Reaction, and Interaction in the Post-World War II Era," in Monte D. Wright and Lawrence J. Paszek, eds., *Science, Technology, and Warfare* (Washington, D.C.: Office of Air Force History, 1971), pp. 147-48. Vannevar Bush, the director of the wartime Office of Scientific Research and Development, once reflected: ". . . science does not operate in a vacuum, but is conditioned by the political system that controls its operations and applications. . . . What science produces, in the way of applications within its own changing limitations, depends upon what is desired by authority, by those who rule or represent a people." Vannevar Bush, *Modern Arms and Free Men* (New York: Simon and Schuster, 1949), pp. 5-6.
5. Project Hindsight, of course, missed militarily important technological innovations that emerged after 1965 from relatively undirected basic research in the twenty years prior to that date. Perhaps the most salient example would be the laser, but it must be remembered that the military became heavily involved in laser work very early in the history of that innovation and that it had a good deal to do with determining the direction taken by laser R&D. See Forman, "Behind Quantum Electronics," *passim*.

advisory committee apparatus fostered such a feedback relationship:

> Participation in these committees led to a remarkable and important synergism. I, and other laboratory leaders—both non-profit and industrial—brought to these committees and the military services to whom they reported fresh information about what we were doing and reliable projections of where it might lead. In return we developed an understanding of the likely characteristics of future military requirements that was far more accurate and timely than would otherwise have been the case. Equally important, we also acquired a first-hand working knowledge of the doctrines and strategies underlying our development and procurement plans, knowledge which we could have obtained no other way, knowledge which each of us used to steer the course of the programs for which we were responsible.[6]

A crucial assumption of the feedback model is that there exists a set of military requirements that is at least to some degree independent of technological possibilities. This assumption permeates the literature on arms control and the arms race, where it is taken for granted that innovations in strategic weapons originate in response to the actions of the Soviet Union and/or to needs dictated by strategic doctrine. Graham T. Allison and Frederic Morton have observed: "A careful review of the literature of arms control and strategy finds no important issue less studied than the question of what determines the number and character of the weapons in American and Soviet force postures. Arms-control analysts have persistently and systematically neglected the processes by which nations develop and procure weapons. Rather than recognizing the weapons-acquisition process as a central piece of the arms-control puzzle, the literature has substituted a simplification of the problem. According to this simplification, a nation's arsenal of weapons is viewed as the product of governmental choices made on the grounds of calculations about national strategic objectives and doctrines."[7]

The assumption that technological effort proceeds to a significant extent from doctrinal dictates would seem questionable. For example, the stockpiling of nuclear weapons—and one might add the development of the hydrogen bomb—in the decade following World War II derived less from rigorous calculations of strategic needs than it did from a commitment to overwhelm the Soviets if necessary with means offered by nuclear and thermonuclear technology.[8] York has written of the strategic arms race that "in the large majority of cases the initiative has been in our hands," citing not only the atomic bomb but intercontinental bombers and submarine-launched ballistic missiles. No rigorous calculation lay behind the decision, in the early 1950s, to require the Atlas intercontinental ballistic missile to deliver a one-megaton thermonuclear warhead. Why one megaton? "The answer is," York has recalled, "because and only because one million is a particularly round number in our culture. We picked a one-megaton yield for the Atlas warhead for the same reason that everyone speaks of rich men as being millionaires and never as being

6. Kranzberg, "Science, Technology, and Warfare," in Wright and Paszek, eds., *Science, Technology, and Warfare*, pp. 3-4.
7. Graham T. Allison and Frederic A. Morris, "Armaments and Arms Control: Exploring the Determinants of Military Weapons," in Franklin A. Long and George W. Rathjens, eds., *Arms, Defense Policy, and Arms Control* (New York: Norton, 1976), pp. 101-102.
8. Gregg Herken, *The Atomic Bomb in the Cold War, 1945-1950* (New York: Alfred A. Knopf, 1980).

tenmillionaires or one-hundred-thousand millionaires. It really was that mystical, and I was one of the mystics."[9]

The consequences of the choice, however, were considerable. The thermonuclear size of the payload permitted a relaxation of accuracy for the missile well below what would have been required with a nuclear weapon. And the one-megaton figure meant that a missile could be lighter than one powerful enough to deliver a warhead of higher yield. The allowance of a larger targeting error and lighter weight permitted the development of the first ICBM a year or two faster than would have been possible otherwise, thus avoiding a worse furor over the alleged missile gap of 1958-1960 than the one that actually erupted. In retrospect, the U.S. ICBM program seemed wisely designed to counter the Soviet initiative in the area. In this context, one can well understand the observation of Harvey Brooks, a veteran of scientific advising to the government, that "military requirements tend to become after-the-fact rationalizations of technical ideas cooked up at a relatively low level in the military-technical-contractor bureaucracy."[10]

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One can hardly expect strategic weapons innovations to be responses to real Soviet actions or the doctrines that they stimulate. As Allison and Morris note, "*weapons are deployed only after a long process* of research, design, and development." Lags of ten to fifteen years are not uncommon between the inauguration of weapons research programs and the formulation of the strategic doctrine in which the weapons will figure, not to mention the acquisition of knowledge concerning the actual Soviet capabilities against which they will operate. Decisions concerning R&D in strategic weapons necessarily, therefore, involve judgments concerning expectations of Soviet actions, or possible actions.[11] For this reason, a good deal of defense R&D is conducted to avoid technological surprise. It is also pursued to maintain a qualitative superiority in weapons, in conformity with the longstanding U.S. policy of relying on technological sophistication and power to offset the Soviet advantages in conventional forces, particularly large standing armies.

However, what the Soviets might do strategically, what surprises they might generate, what constitutes qualitative superiority—all these criteria hinge on deliberations that inevitably involve the patrons and practitioners of defense R&D. Little is known of a systematic nature about the role that the defense research community plays, in interaction with other groups, to determine the nation's strategic defense posture. To the end of devising a systematic approach to the issue, I would like to suggest here that several key areas qualify as categories for analysis: industrial defense contractors; the government's own weapons laboratories; the defense bureaucracy, particularly the individual armed services; and the general politics of national security.[12]

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9. Herbert York, *Race to Oblivion: A Participant's View of the Arms Race* (New York: Simon and Schuster, 1970), pp. 230-31, 89-90. See also York, "Autobiography," chap. XI, pp. 5-6.
10. York, "Autobiography," chap. VII, pp. 10-12; Harvey Brooks, "The Military Innovation System and the Qualitative Arms Race," in Long and Rathjens, eds., *Arms, Defense Policy, and Arms Control* (New York: Norton, 1976), p. 92.
11. Allison and Morris, "Armaments and Arms Control," in Long and Rathjens, eds., *Arms, Defense Policy, and Arms Control*, p. 122.
12. Herbert York suggests that in the 1970s for-profit think tanks became a major influence in the determination of defense

The vested interest of defense contractors in the arms race can easily be measured in terms of profits and jobs. Defense-oriented industries now employ more than five million people, some five percent of the labor force (another five percent comprises members of the armed services, civilian employees of the services, and employees of defense agencies).[13] Nevertheless, defense contractors are clearly less crucial to the overall economy than they are to themselves, including their employees and stockholders, their Congressional representatives, and the Department of Defense, with which they are symbiotically linked in a relationship of mutual dependence. In the weapons area, what comends them to DOD is their ability to satisfy its understanding of its missions. As both the contractors and the Defense Department well know, that ability hinges heavily on R&D, a point expressed by the fact that since 1945 the ratio of defense R&D to weapons acquisition costs have generally risen from five percent to a peak of over fifty percent and have amounted to between twenty-five and thirty percent in recent years.[14]

Industrial research accounted for almost half of the weapons innovations examined in Project Hindsight, universities (including contract research centers) for only about an eighth. Industry is the largest performer of overall federally sponsored research and development. In 1970, 52 cents of the federal R&D dollar went to industrial firms, compared with 16 cents to universities and colleges; in 1980, the industrial share was 48 cents, compared with 21 cents to colleges and universities.[15] The industrial share of the defense R&D dollar is still higher—amounting to 70 cents in the 1980s (within the industrial sector, twenty-five major firms receive about 75% of defense R&D contract funds). In recent years, these monies have been supplemented by the Defense Department's Independent Research & Development program. Under this program, DOD supplies overhead payments on procurement contracts that industrial firms can use for militarily-relevant research projects of their own initiation. On average, the amount available to industry comes to about three percent of their total sales to DOD. In 1982, typically, the major defense contractors spent about $4.5 billion on R&D projects that they initiated and they received reimbursements under the IR&D program of about $2 billion—a sum exceeding the total budget that year of the National Science Foundation.[16]

Not surprisingly, a hefty fraction of the nation's scientists and engineers in fields pertinent to the military are employed in defense-related industries. In 1982, defense employment involved about eleven percent of mathematicians and statisticians outside of academia; twenty percent of

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posture. In recent years, these firms have advanced new strategies, tactics, and ideas about innovative weapons systems. They have also provided an important home for defense intellectuals associated with the out-of-government party and a source of members for such high- level committees as the Defense Science Board. York to the author, Feb. 23, 1987.

13. *Statistical Abstract of the United States, 1984*, p.345; Solly Zuckerman, *Scientists and War: the Impact of Science on Military and Civil Affairs* (New York: Harper and Row, 1966), p.27.

14. Franklin Long and Judith Reppy, "Introduction," and Jacques S. Gansler, "The Defense Industry's Role in Military R&D Decision Making," both in Franklin A. Long and Judith Reppy, eds., *The Genesis of New Weapons: Decision Making for R&D* (New York: Pergamon, 1980), pp.3, 41; Long and Reppy, "The Decision Process for U.S. Military R&D," in Tsipis and Janeway, eds., *Review of U.S. Military Research and Development, 1984*, p.10.

15. Kranzberg, "Science, Technology, and Warfare," in Wright and Paszek, eds., *Science, Technology, and Warfare*, pp. 147-48; the distribution figures may be calculated from the data in *Statistical Abstract of the United States, 1985*, p. 575.

16. Long and Reppy, "The Decision Process for U.S. Military R&D," in Tsipis and Janeway, eds., *Review of U.S. Military Research and Development, 1984*, pp. 7-9. Gansler, "The Defense Industry's Role in Military R&D Decision Making," in Long and Reppy, eds., *The Genesis of New Weapons: Decision Making for R&D*, p. 41.

electrical engineers; twenty-five percent of physicists; and almost forty percent of aeronuatical and astronautical engineers.[17] Thus, a stake in weapons innovation is to be found among a sizable segment of the country's technical community, clearly a far larger fraction of the relevant technical work force than the fraction of the total labor force found in the defense industry. The implications for weapons policy-making are considerable, since scientists and engineers constitute a strategic elite with the ability, by virtue of their technical expertise, to influence policy far out of proportion to their absolute numbers.

A major portion of defense R&D contracts go to large rather than small manufacturing firms. For example, in fiscal 1977 almost half of the funds spent on defense research and development went to eight companies. For a variety of reasons—including desire for a successful track record, confidence in the firm's stability, and the like—the Defense Department prefers to deal with large firms. On their part, only the large firms can afford to play in the defense research game. The procedural regulations that govern R&D as well as procurement relationships between the Pentagon and its suppliers occupy 3,000 pages. Contractor proposals are even more voluminous, with some coming to 26,000 pages and involving 1,600 people in their preparation.[18] The large firms maintain sizable R&D capabilities, because with "R"—and especially "D"—comes a technical knowhow that provides the firm with an advantage in seeking production contracts. Thus, firms with research contracts are naturally impelled to push for what production contracts require—weapons acquisition and deployment—and they command significant lobbying power for accomplishing their purposes in the executive and legislative branches of the government.

One can point to several outstanding examples of the process, starting with the nuclear-powered airplane, research on which originated in 1946 under high priority. A succession of review committees found the project increasingly dubious on technical grounds. Nevertheless, key industrial contractors—notably General Electric, Pratt and Whitney, and the Convair Corporation—lobbied hard, though unsuccessfully, after Sputnik to transform the effort into a full flight-development program. A similar but more sustained effort surrounded the ill-fated B-70 bomber, which the Air Force badly wanted in the late 1950s and which it touted as imperative to offset the Soviet missile capability. In 1957, contracts were awarded to North American Aviation, in southern California, to develop the B-70 by building several prototypes. In 1959, by which time $300 million had been spent, the Eisenhower administration decided to scale back the B-70, since the U.S. ICBM program was coming along well enough to make the bomber unnecessary. During the Kennedy administration, Secretary of Defense Robert S. McNamara reduced the program still further, though not without a fierce battle. The Los Angeles County Board of Supervisors resolved that the administration should reinvigorate the program, noting that "much of the work of constructing these bombers would be done by Los Angeles area concerns."[19]

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17. David L. McNicol, "Defense Spending and the United States Economy," in Thomas Lucid, Judith Reppy, and George Staller, eds., *The Economic Consequences of Military Spending in the United States and the Soviet Union* (Ithaca, N.Y.: Report on the Conference Sponsored by Peace Studies Program, Committee on Soviet Studies, Cornell University, May 9 and 10, 1986), p. 39.
18. Gansler, "The Defense Industry's Role in Military R&D Decision Making," and Edwin A. Deagle, Jr., "Organization and Process in Military R&D," both in Long and Reppy, eds., *The Genesis of New Weapons: Decision Making for R&D*, pp. 41-46, 163.
19. York, *Race to Oblivion*, pp. 61-62, 66-74, 52-59.

The industrial proponents of the B-70 and of nuclear-powered aircraft found powerful allies in the Congress among air-power advocates as well as representatives of their own states and districts. Such issues can draw together otherwise anomalous coalitions. For example, Carl Vinson, a Georgia Democrat and the chairman of the House Armed Services Committee, railed against the B- 70 cutbacks, and so did Senator Barry Goldwater of Arizona, a brigadier general in the Air Force Reserve as well as a conservative Republican, and Senator Clair Engle of California, another Air Force Reserve officer, who was also a liberal Democrat.[20] Indeed, the power of defense contractors in the weapons development process is grounded in complicated linkages that cut across regional, partisan, and ideological lines and that abound among major industrial firms, the individual armed services, and the Congress.

However, policy initiatives in the strategic weapons area tend to originate within the executive branch, particularly in the interaction between the defense bureaucracy and the research community. York has observed that the scientific advisory system makes it possible for "the most exuberant and persuasive of our technologists to promote ideas and sell hardware that often take us far beyond the point that mere prudence requires."[21] (In the 1950s, the exuberant technologists could be spokesmen for corporate interests; conflict of interest standards then were less strict than they became later.) However, many of the exuberant technologists are to be found not only in industry but in the government's own armed-service service and civilian weapons laboratories. Defense laboratories were responsible for almost forty percent of the weapons innovations surveyed by Project Hindsight. In recent years, they have been receiving approximately a quarter of defense R&D monies and, like industrial R&D contractors, they have a bureaucratic stake in sustaining the system of weapons innovation.[22] Yet their enthusiasm for new weapons technologies no doubt also expresses some combination of professional ambition or opportunism, ideological conviction or concern for national security—and a taste for technical sweetness, a powerful technological drive, a consuming desire to bend the resources of the state to satisfy a Promethean will.

Salient examples come to mind from the rolls of the postwar defense research and advisory establishment. Wernher von Braun, consumed by the aim of building giant rockets and accomplishing space flight, transmuted his orbital ambitions into imperatives of postwar American national security. He cared a good deal more about bigger rockets than about military needs, but, unable to sell adventures into space, he hawked his technological wares to the American military just as he had done to Hitler. "All I really want is a rich uncle," he told T. Keith Glennan, the NASA administrator.[23] Edward Teller was a tireless zealot of thermonuclear weapons long before the first atomic bomb was developed. He insisted on concentrating on a thermonuclear device at Los Alamos during the war and feverishly advanced the project with still greater commitment in the late 1940s. Teller's technological drive, inflamed more than von Braun's by a fierce anti-Communism, was perhaps more persistent and longstanding.

20. *Ibid.*, pp. 55-6.
21. *Ibid.*, pp. 11-12; York, "Autobiography," chap. VII, pp. 3-4.
22. Kranzberg, "Science, Technology, and Warfare," in Wright and Paszek, eds., *Science, Technology, and Warfare*, pp. 147-48; Long and Reppy, "The Decision Process for U.S. Military R&D," in Tsipis and Janeway, eds., *Review of U.S. Military Research and Development, 1984*, p.7
23. Quoted in York, "Autobiography," chap. X, p. 18.

Yet behind the master weapons builders has stood—and continues to stand—a sizable cadre of scientists and engineers, the inhabitants of the weapons and weapons-related laboratories. They may be architects of Armageddon, but they are not so much consumed by overarching technological visions as absorbed in particular—and often particularly challenging—technical tasks. They live and work in a classified world which, while highly compartmentalized and hierarchical, no doubt has some type of structure of prestige and rewards for technical accomplishment. They derive direct pleasure from the technical elegance of the systems on which they work. A consultant to one of the major weapons laboratories recently remarked, "When I see one of those nuclear weapons, compact and sophisticated in its gleaming coat, I think to myself that it is truly beautiful. It's only when I remind myself what it can do that I realize how utterly ugly it really is."[24]

Such ugliness does not ordinarily deter the Promethean will that is rationalized by high national purpose. Herbert York has recalled that during his directorship of Livermore, he initiated research outside the design and development of particular thermonuclear weapons. The auxiliary projects included basic research in magnetic fusion and neutron cross-sections and applied work towards fashioning fission and fusion warheads at extremes of size, weight, and yield without regard to specific military requirements. York added:

> I had two complementary benefits in mind in pushing this philosophy. First, it seemed to be the best way to assure continuing American superiority in nuclear weaponry. Second, it provided the kind of intellectual stimulus and prospect for adventure that young scientists usually find only in basic research. . . .
>
> This approach meant that the laboratory leadership had to engage in a continual effort to sell its ideas, to anticipate military requirements, and to suggest to the US military ways in which its new designs could be used to enhance military preparedness and better support our general nuclear strategy. If we had waited for Washington to tell us exactly what was needed in terms of dimensions, yield, special output, or other technical parameters, such selling would not have been necessary, but that is not the way we went about our business at Livermore, nor did they do things that way at Los Alamos either, especially after we brought competition onto the nuclear scene.
>
> Some observers have criticized the laboratories for engaging in this selling activity. They charge that it pushes the nuclear arms race further and faster than would otherwise be the case. That is certainly true, but it is also true that it resulted in the US military having better weapons, and better in this sense does not usually mean 'bigger and more destructive' as is frequently charged. Better more often means better adapted to a given delivery system, more appropriate to some specific purpose and therefore frequently smaller and producing less collateral damage, safer against accidents, and so on.[25]

In later years, those auxiliary programs came to include high-energy beams for defensive weapons and free-electron lasers, both of which figure importantly in President Reagan's Strategic

24. Author's interview with the consultant, who would prefer to remain anonymous. See York, *Race to Oblivion*, pp. 234-35.
25. York, "Autobiography," chap. VI, pp. 28-29.

Defense Initiative.[26] Not surprisingly, the Livermore Laboratory seems to have played an important role in the origins of SDI. (The presence of technocratic ambition in the arms race, York has noted, is not confined to the United States. On a visit to the SALT delegation in Geneva, he asked one of the Soviet delegates why Russia had initiated their anti-satellite program. The Soviets, York remarked, must have known that this action would stimulate a U.S. response. The Soviet delegate replied in essence: "You know how it is. You have the same thing in your country. Some young ambitious technicians get hold of an idea they believe is both practical and important and they promote it and push it until finally the authorities let them go ahead with it.")[27]

In the United States, the authorities not only respond to but often encourage the technological drummers. Interservice rivalry fosters marriages of mutual advantage between the individual armed services and the enthusiasts of the weapons laboratories. By sponsoring R&D programs in diverse weapons, each service maintains rights in the mission areas that the weapons define. In the early 1950s, the armed services initiated development of six different missiles. Two were intermediate range ballistic missiles—the Air Force's Thor and the Army's Jupiter, which was forged by Wernher von Braun's team at the Redstone Arsenal in Huntsville, Alabama. In terms of range, accuracy, warhead size, and engines, the Jupiter was virtually identical to the Thor. Nevertheless, von Braun joined forces with high Army officials and saw to it that the Jupiter was brought to completion and even deployed.[28]

York has commented on the general missile duplication issue:

> We spent about twice as much money and we employed about twice as many people on these development programs as we should have. . . . From the point of view of arms control and the arms race, these excesses in dollars and people also had serious consequences. The extra organizations and the extra people resulted in a larger constituency favoring weapons development. This larger constituency in turn strengthened those forces in the Congress 'which hear the farthest drum before the cry of a hungry child,' and consequently the whole arms race spiraled faster than before. Many of the leaders within this overexpanded missile industry correctly foresaw that they would be in trouble when all of these concurrent crash development programs finally resulted in some deployed hardware. They rightly anticipated that any follow-on developments would have a very hard time competing with the even larger funds needed for such deployments, and they provided some of the most strident voices among those proclaiming the 'missile gap' of the 1958-60 period.[29]

In the larger arena of national security, military R&D becomes an instrument of political purpose. What factions may give up in arms control agreements, they have often sought to regain through renewed emphasis on R&D. Arms control advocates had hoped that the partial nuclear test ban treaty of 1963 would slow down the nuclear arms race, but the price of ratification in the Senate

26. *Ibid.*, chap. VI, pp. 30-31.
27. *Ibid.*, chap. XV, pp. 26-27.
28. York, *Race to Oblivion*, pp. 83-84; See Michael Armacost, *The Politics of Weapons Innovation: The Thor-Jupiter Controversy* (New York: Columbia U. Press, 1969).
29. York, *Race to Oblivion*, pp. 102-104.

was a commitment to maintain a test program sufficient to "satisfy all our military requirements." Since underground tests were more complicated than atmospheric ones, the Atomic Energy Commission felt compelled to conduct tests at a faster pace and on a more regular basis than it had in the 1950s. In the eighteen years before the test ban, the United States and the Soviet Union had conducted 469 nuclear tests; in the ten years after the treaty, 424.[30]

In the 1950s, the United States began research and development on an anti-ballistic missile system (ABM)—a project that was given to the Army in 1958 and that the Army was determined to sustain after authority over all long-range offensive missiles was awarded to the Air Force. The aim in those days was missiles that would rise to attack and destroy incoming Soviet warheads. The effort produced, first, the Nike Zeus and the Nike X, both of which were declared inadequate for deployment by technical review boards. The boards, however, recommended continued ABM R&D, stressing among other things the necessity of insuring against technological surprise. The R&D led to new ABM systems—Sentinel, then Safeguard—with the latter given limited deployment. When this piggyback program was abandoned with the ratification of SALT I in 1972, hawks insisted on stepping up the development of the B-1 bomber and the deployment of the Trident submarine as well as of multiple, independently targetable re-entry vehicles (MIRV). Ratification was also accompanied by exhortations to increase military R&D of both an offensive and defensive nature.[31] Such R&D seems to have led to an acceleration of what is known as the "qualitative arms race"—that is, the qualitative improvement of offensive systems within the limits of the treaty. It was also, no doubt, responsible for advancing ABM research to the point where its advocates could prevail upon President Ronald Reagan to embrace the Strategic Defense Initiative.

There is perhaps no more telling example of the interaction of laboratory ambitions, interservice rivalry, and the politics of national security than MIRV. MIRV originated in response not to the reality of but to the apprehension of a possible Soviet ABM system that might first be deployed on a limited basis but later extended throughout Russia. As John Foster, the Director of Defense Research and Engineering, testified to Congress in the 1960s: "Our current effort to get a MIRV capability on our missiles is not reacting to a Soviet capability so much as it is moving ahead again to make sure that whatever they do of the possible things that we can imagine they might do, we will be prepared." Technically, MIRV began with the idea of overwhelming an ABM by incorporating several warheads on a single missile so that they would fall in a cluster on the target. That scheme quickly evolved into the targeting of each warhead independently. The laboratories pushed for the development and deployment of MIRV. The idea was technically sweet, it worked, and it promised to increase strategic offensive power at relatively little cost.[32]

30. York, *Race to Oblivion*, p.45; Brooks, "The Military Innovation System and the Qualitative Arms Race"; Allison and Morris, "Armaments and Arms Control"; Long, "Arms Control from the Perspective of the 1970s," in Long and Rathjens, eds., *Arms, Defense Policy, and Arms Control*, pp. 82, 99, 12.
31. Allison and Morris, "Armaments and Arms Control"; Long, "Arms Control from the Perspective of the 1970s"; Brooks, "The Military Innovation System and the Qualitative Arms Race," in Long and Rathjens, eds., *Arms, Defense Policy, and Arms Control*, pp. 12, 82, 99, 114-17
32. Allison and Morris, "Armaments and Arms Control"; Long, "Arms Control from the Perspective of the 1970s"; in Long and Rathjens, eds., *Arms, Defense Policy, and Arms Control*, pp. 12-13, 117-20; York, *Race to Oblivion*, p. 176.

The Air Force and the Navy, both now rivals in the structure of nuclear deterrence, embraced it because the strategic firepower of each would be increased. Secretary of Defense Robert S. McNamara perceived several advantages in MIRV. The technology countered Air Force demands for a new strategic bomber and an expanded missile force. It neutralized the charges of critics at home that the United States was risking vulnerability to Soviet forces and it was actually a high-confidence means of buffering any future Soviet strategic threat, including an ABM. Finally, its clear-cut capacity for overwhelming any Soviet ABM equipped McNamara with a powerful argument against the development and deployment, then being urged, of a major American ABM system. It should not be surprising that, given the multiple reasons for multiple warheads, the deployment of MIRVs continued even after SALT I imposed severe limitations on a Soviet ABM. Indeed, half as many more missiles were MIRVed in the three years after SALT I than in the period before the treaty.[33]

The post-SALT acceleration of the arms race has shaken many arms-control advocates. A number of them have begun to wonder whether arms-control agreements, while carving out islands of non-competition, may only divert the strategic weapons race elsewhere in the vast remaining sea of technical possibilities. As York has noted, "The United States cannot maintain its qualitative edge without an aggressive R&D establishment that pushes against the technological frontiers without waiting to be asked." Yet R&D conducted to sustain U.S. qualitative superiority in weapons can all too easily intensify the qualitative arms race or even destabilize Soviet-American relations, since weapons systems not only express but can cause differences between nation-states.[34]

And behind the establishment's aggressiveness lie the professional ambitions in the laboratories, the economic interests of the defense firms, and the appeal of R&D to factions in Congress and the Executive Branch as an instrument in the competiton for doctrinal advantage. With such charged connections, defense R&D has often seemed to be less a response to assessments of Soviet behavior and more a reaction in one part of the American defense establishment to apprehensions generated in another. York has noted that the "early developments of MIRV and ABM were not primarily the results of any careful operations analysis or anything that might be called provocation by the other side," adding, "Rather, they were largely the result of a continuously reciprocating process consisting of a technological challenge put out by the designers of our defense and accepted by the designers of our offense, then followed by a similar challenge/response sequence in the reverse direction." The process thus yields a grimly paradoxical dynamic—one that Jerome Wiesner, the former science advisor to President John F. Kennedy, once capsuled: "We're in an arms race with ourselves—and we're winning."[35]

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33. Allison and Morris, "Armaments and Arms Control," in Long and Rathjens, eds., *Arms, Defense Policy, and Arms Control*, pp. 105, 120; York, "Autobiography," chap. XIII, pp. 14-15.
34. York, "Autobiography," chap. VI, pp. 29-30; Allison and Morris, "Armaments and Arms Control"; Brooks, "The Military Innovation System and the Qualitative Arms Race"; G.W. Rathjens, "Changing Perspectives on Arms Control," in Long and Rathjens, eds., *Arms, Defense Policy, and Arms Control*, pp. 100-101, 75, 205.
35. Allison and Morris, "Armaments and Arms Control," in Long and Rathjens, eds., *Arms, Defense Policy, and Arms Control*, p. 119; Wiesner's remark was quoted by Carl Kaysen, the former Kennedy national security advisor, in a conversation with the author.