Technology Creep and the Arms Race: A World of Absolute Accuracy

This is the second of three articles about how technology is affecting the arms race.

U.S. defense and arms control policy-makers are wrestling with the fact that, unless something is done about it, 90 percent of U.S. land-based missiles could be vulnerable to a preemptive Soviet missile attack in the mid-1980's. For the Soviets to have this capability, which the United States already possesses or will soon possess, is widely viewed as destabilizing, since in a crisis each side would have an incentive to launch a first strike to deny the other the chance to do likewise.

For both the Soviet Union and the United States, the technical capability of achieving 90 percent success on a first strike is the result of the growing accuracy of intercontinental ballistic missiles (ICBM's), which in turn has resulted from the gradual creep of a wide range of military and civilian technologies. Incremental advances in a number of fields—electronics, materials, gravity, geodesy, and others—all contribute to the growing accuracy of the ICBM forces on both sides, and make it virtually inevitable that these missiles (which, when they were first built, were lucky to land within 5 miles of their target) will soon be able to land within a few hundred feet. This capability is sometimes called absolute accuracy, since once an ICBM becomes accurate enough, it is virtually certain to destroy its target.

The growing accuracy of both ICBM forces is posing a serious military and political quandary for the two superpowers. On the U.S. side, negotiators at the Strategic Arms Limitation Talks (SALT), Pentagon weapons system designers, and civilian policy-makers are looking for ways to deflect the impact of the trend toward absolute accuracy. To put it more generally, the Carter Administration is asking whether the ill effects of this form of technology creep can be halted.

The answer seems negative at present. The SALT II treaty with the Soviet Union, which is now being finalized and is expected to be sent to the Senate for approval in coming months, seems unlikely to arrest the trend. And the principal Pentagon answer—a new $25 billion Air Force plan for a 5000 square mile field of mobile ICBM's that could survive even a very accurate Soviet first strike—may solve the military problem but drag horrendous arms control problems in its wake. Equally controversial are the policy-makers' solutions: that the United States could save its land-based ICBM's by going to a policy of launching them on warning of attack, or that the 1972 antiballistic missile (ABM) treaty could be changed to permit ABM defense of land-based missile silos. Finally, attempts by some university analysts to argue that ICBM vulnerability is the result of the mathematical models on which nuclear war scenarios are fought and by the Arms Control and Disarmament Agency (ACDA) to convince people that the problem can be analyzed away if better models are used, have so far failed to assuage the fears that have been aroused.

So, there is a consensus that a world of absolute ICBM accuracy looms and that the gradual march of technology is leading us to it. But there is no consensus on what should be done about it; if anything, the stage is being set for a fractious national debate.

The last time U.S. policy-makers confronted a similar upcoming dislocation in the balance of strategic forces was the early 1970's, when the United States was getting ready to give single ICBM's the ability to deliver 2, 3, or even 14 nuclear weapons to as many different targets. This capability known as MIRV, for multiple independently targeted reentry vehicles, was widely perceived as destabilizing because, like absolute accuracy, it increases the chance of success of a nuclear first strike and hence the attacker's incentive. But in the SALT I negotiations, despite much debate, Henry Kissinger decided not to make a MIRV ban a condition of the final accords. Now both sides have MIRV, and it is the Soviet MIRV that poses the future lethal threat to U.S. land-based ICBM's. So today's problem is an outgrowth of the perhaps necessary imperfections of yesterday's arms control treaty.

Kissinger has said since that he wished he had given more thought to the "implications of a MIRVed world" at the time. Now, it may be important to explore the implications of a world of absolute accuracy.

It is not surprising that the modernization of both ICBM forces has basically defied control through the arms control treaty process. The 1972 SALT I treaties and 1974 accord signed at Vladivostok controlled it only in the sense of putting ceilings on the number of missiles both sides can deploy. In fact, SALT has become a process of definition, counting, and verification of the existence of large items of hardware: ABM radars, submarines, missile launch tubes in submarines, bombers, land-based missile sites, and the like.

But the more subtle elements of ICBM modernization elude formal definition, official head counts, and verification by the cameras aboard reconnaissance satellites. In its attempts to limit ICBM modernization through SALT, the Carter Administration has tried to limit "qualitative improvements" in existing missiles and "new types" of missiles. As Zbigniew Brzezinski explained to a group of reporters last March, the realities of what goes on inside the payload of a missile do not fit this Procrustean rack of definitions.

"What is a new type?" Brzezinski asked rhetorically. "Is the improvement of a marginal type, changing of the screws, a significant improvement or not? How about the introduction of a new guidance system for an existing missile? At what point do minor improvements become major improvements? At what point do improvements become qualitative changes?"

Changes to the inside of a missile elude not only definition but verification—another reason why they have been a SALT problem. Even MIRV, the most prominent modernization of recent years, poses verification problems. Aerial reconnaissance, radar tracking posts, and observation ships can determine that a Soviet missile might be MIRVed by watching its flight tests. But these methods cannot determine whether an entire class of deployed ICBM's has MIRV on board. The new generation of Soviet land-based ICBM's, the SS-17, SS-18, and SS-19 missiles, have both MIRVed and non-MIRVed versions. The United States insisted in 1974 that all missiles of these classes be counted as MIRVed whether they were or not. If a large improvement like MIRV poses such verification problems, verification will be more difficult for such things as a change from a mechanical to a floating sphere for inertial sensing, or the use of a more refined computer model of the flight

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path—both of which can vastly improve the lethality of ICBM's.

In one sense the SALT I accords helped bring about the present problem of ICBM accuracy. As SALT historian John Newhouse has written, they "failed to hobble MIRV" and so allowed an arms race in payload refinements. But SALT I did curb the arms race in the size of the U.S. and Soviet missile arsenals by setting a 5-year interim ceiling on the number of "launchers"—tubes in submarines or in the ground from which ICBM's must be launched. (The ceilings were 2350 for the Soviet Union and 1710 for the United States.) The 1974 Vladivostok accord refined these ceilings to 2400 for both sides, including bombers and air-to-surface ballistic missiles. It also added a ceiling of 1320 on the number of MIRVed missiles each side could have. The parts of the final SALT II accord that have been released publicly appear to continue the process of lowering these ceilings and refining the mix of things each side can have to make the strategic balance more stable.

But creeping technology has been a problem. Just as the budding MIRV technology eluded negotiators at SALT I, cruise missile technology—then in the very early stages—foiled the negotiators of the 1974 Vladivostok accord. The accord included "air-launched missiles," which the United States later, when it saw more clearly the potential of the self-propelled terrain-hugging weapons, declared meant only free-fall ballistic missiles. But the Soviets, also becoming aware after the fact that the United States was developing a "new" strategic weapon, argued that the language covered cruise missiles. And this dispute has intensified since 1974, as the potential of the technology has become clearer. It has been one of the major obstacles to a SALT II accord.

The Carter Administration, immediately after taking office, attempted to deal with the emerging problem of the trend toward absolute accuracy. In a "comprehensive" new plan it put forward in March 1977 in Moscow, the Administration proposed a limit of six flight tests a year by each side's ICBM's, a major cut from the hundreds of tests now made by both sides. Later, Defense Secretary Harold Brown explained the widely shared view that limiting flight tests is the only way to limit the trend to high accuracy. "At six [tests] a year you can be pretty sure that your missiles work, but you will be much less sure about how accurate they are. . . . I think . . . that that would give a fair confidence that the silo-based missiles would at least get vulnerable much more slowly." But Brown also explained that test limits can slow, but not halt, the trend: "Nothing lasts forever and I don't think we would be prepared to assure on that basis that 15 or 20 years from now they would not be vulnerable."

A test of the launch procedure for the MX missile rising from its underground trench. Within 60 seconds, the missile breaks through the ground to the ready position shown in bottom picture. [Photos courtesy of the Boeing Co.]

But the Soviets rejected the March proposals immediately, and SALT II under the Carter Administration has revolved around a more modest effort to continue to lower the Vladivostok ceilings. These limits will be in the treaty itself; an accompanying 3-year protocol will try to restrict "new types" of missiles and "qualitative improvements"—although there apparently remain problems of defining which new missiles, particularly in the submarine-launched category, should be exempted. A third part of the package will be a "statement of principles" for SALT III in which the Administration hopes to include elements of its March 1977 approach. So essentially, SALT II would not halt the trend to absolute accuracy. The problem, it seems, will continue with or without a SALT II treaty.

The "solutions" to the problem that have been proposed outside the arms control framework are beginning to be aired in Congress and in the press, and promise only to become more controversial.

The growing accuracy of Soviet and U.S. ICBM's is a military problem, so it is not surprising that the Air Force, which operates the U.S. ICBM's, has been working up military solutions. In recent months, no fewer than five scientific advisory groups in the Pentagon and the White House have been studying these plans. Basically, they are looking for a mobile basing system that would keep those who target Soviet missiles wondering where the U.S. ICBM's actually are. In this way, a significant fraction of the mobile-based missiles would escape a first-strike attack by even the most accurate Soviet missiles. The fact that the United States would retain this force after being attacked would deter a Soviet first strike.

According to the Air Force, the system now gaining consensus would be a new missile field, probably in Nevada, California, or Arizona, spotted with 5000 vertical concrete tubes linked together by roads. Over these roads, 25 vehicles would move at all times, carrying long

horizontal cases that might or might not contain ICBM's in launch canisters.

The vehicles would go through the motions of removing and depositing missiles in all the holes in a procedure designed so that Soviet aerial reconnaissance could not determine whether a missile was actually being removed or inserted. In fact, there would be only one ICBM for every 20 holes; but Soviet reconnaissance would not know, at any particular time, which holes contained ICBM's.

Moreover, since the missile housed in the system would be the MX, the destructiveness of the surviving U.S. ICBM force would be sufficient, the Air Force argues, to deter the Soviets from trying a first-strike attack. In short, to the tune of $22 billion to $32 billion, the Air Force would play a giant shell game with Soviet missile targeters.

Another proposed solution is the so-called trench system (see photographs). In this variant, the mobile missiles in the 50- by 100-mile missile field would all be underground, in trenches 12 to 20 miles long. One missile, it is presumed, would be in each trench. The trenches would be constructed to allow the missile to be launched from any of a number of "aim points." The trench system's arithmetic is similar to that of the vertical silo system described above; the missile field area would contain 250 trenches with 250 missiles, and would present Soviet targeters with 5000 aim points. Presumably, the Soviets would not know at any particular time where the 250 missiles were located.

Still another scheme is the "garage." In this plan each ICBM would live in its own garage, where most of the time Soviet reconnaissance could verify its location. But when the United States learned that a Soviet ICBM attack had been launched, each U.S. ICBM would begin moving along one of the spokelike tunnels radiating from its central garage, toward one of ten points in the tunnel from which it could be launched. This system purports to outwit Soviet targeters, who must program their missiles before launching them. So far, at least two opposed schools of thought have been emerging on all these schemes, which are called multiple aim point (MAP) systems because they all embody that common objective. The view that appears to have the upper hand within the Carter Administration is that since SALT does not really solve the problem of the vulnerability of U.S. land-based missiles, and since MAP might do so, MAP is an essential complement to SALT and should be proposed concomitantly.

The contrary view, held by some members of the arms control community, is that MAP poses serious problems of verification. How can the Soviets be sure that there is not an ICBM in *every* MAP hole? And, when the Soviets have their own MAP, how can the United

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Senate Bill Gives Bright Idea Back to Inventor

A chronic complaint of universities is that government rules on the transfer of patents derived from federally funded research are so thick with red tape that it saps the incentive to be inventive. Years can slip by before a funding agency decides whether or not to return patent rights to the inventor's organization, and, as often as not, the agency decides to hold on tight.

A new Senate bill, however, will try to cut the bureaucratic knots by automatically assigning limited rights to the inventing organization. Introduced by Senators Robert Dole (R–Kans.) and Birch Bayh (D–Ind.), the bill would give universities, nonprofit organizations, and small businesses the lion's share of the commercial benefits from their federally funded research.

Under the bill, the inventing organization could license a discovery to private industry, with exclusive control being granted for 5 years. It also would provide a kickback to the federal agency, provided the patent proved to be a moneymaker. If not licensed after a prearranged period, the patent would automatically revert to the government. Excluded from the bill would be government-owned institutions, such as Argonne National Laboratories, in which the government would retain control of all discoveries.

The bill, called the Small Business Nonprofit Organization Procedures Act, comes in the wake of a new policy adopted on 18 July by the General Services Administration (GSA) that also tries to untangle the system of patent transfers. Known as Institutional Patent Agreements (IPA), these guidelines encourage government agencies to give universities and nonprofit organizations control of their federally financed discoveries (*Science*, 17 March). Such agreements were in common use by federal agencies before 18 July, but each was in a slightly different form. The new GSA rule calls for a single standard.

To get control of patent rights, a research organization with an IPA has to petition the funding agency on a case-by-case basis. The result is often chaotic. Says Doyle: "Rarely have I witnessed a more unfortunate example of over-management by the bureaucracy."

Even getting an IPA can be a problem, according to one federal patent official. "Right now you have three candidates for IPA's stuck in the clearance procedure at HEW. And they may never get it. The agency decides which institutions have technology-transfer capabilities and which ones don't." The bill makes no such distinctions. It says that any university, small business, or nonprofit organization is capable of managing its own invention rights better than the government has been able to do in the past.

Opponents of the bill feel that it goes too far in allowing profit-making firms to benefit from federally financed research. Supporters of the bill, however, say that under the present system, benefits are few and far between. Some researchers supported with federal funds are even reported to shy away from innovative research because of the red tape that comes with a discovery.

Let Rats Move Over: Marsupials Are on the Move

In the continuing search for new and better lab animals, a prime candidate may have been overlooked that literally resides in the backyard of the biomedical community. To wit, the lowly opossum. With its pointed white face, beady black eyes, and long naked tail, it might pass for a very large rat. But alas, you say, it is a marsupial, and unsuited to be a human surrogate.

Not so, says William Jurgelski, a cell biologist at the National Institute of Environmental Health Sciences in Research Triangle Park, N.C. An enthusiast who thinks in practical terms, Jurgelski has formed a Committee for the Establishment of a National Marsupial Center.

Why marsupials? Take the baby opossum. Half-formed, with stubs for hind

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States be sure that they do not have a missile in every hole? Why wouldn't MAP induce the Soviets to build more warheads to target every hole? Moreover, they say that the Soviets may be becoming upset by the idea that in the final stage of the SALT II negotiations, President Carter would suddenly embrace a new strategic program that is big (covering an area the size of Connecticut), expensive ($22 billion to $32 billion), and threatening (further enhancing the U.S. first-strike capability). Obviously, the arguments on both sides will be developed only when a final SALT agreement becomes known and the Administration selects a specific MAP scheme.

One extremely important but little-heeded recommendation is that the premise that U.S. ICBM's will be vulnerable, be reexamined. This view was stated most strongly in a 1976 article in the Harvard journal, *International Security*. It argued that rather than destroying 90 percent of the victim's land-based missiles on a first strike, the Soviet ICBM force with small slips in performance might destroy only 50 percent. The many uncertainties that would bedevil any first use of the ICBM force in such a massive attack may be great enough, the paper argued, to deter one. Obviously, as missile technology becomes more refined, these uncertainties and unknowns will loom larger. But this view has not gained much ground.

Two other policy options, launch on warning and ballistic missile defense, have become part of the absolute accuracy debate. Although neither suggestion has been made formally or received much publicity as yet, both have serious implications.

The United States already has geosynchronous satellites that can sense the heat trails from Soviet missiles as soon as they lift into the upper atmosphere, and so would know within minutes of a Soviet ICBM launch. These satellites are complemented by other systems, notably the distant early warning radars strung across Canada and Alaska. Moreover, research under the mellifluous label of "attack assessment" is refining these capabilities, so that the exact trajectories of the missiles, which silos they come from, and what targets they seem to be headed for could all be instantly made known to military leaders. Perhaps because the technology has come so far, the Carter Administration has regularly hinted that it could, if it wished, solve the U.S. ICBM vulnerability problem by simply announcing that it will launch its land-based missiles if its sensors decide a Soviet ICBM attack is under way.

But while such a policy may rescue the 1054 U.S. ICBM's from destruction, it could sink other stable aspects of the strategic balance. Not only are the early warning satellites vulnerable to attack, but they can be fooled: in one inci-

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legs, and a brain only partially complete, the infant emerges from its mother's birth canal barely one-half inch long. It then wiggles up the mother's belly, searching for a meal. Upon finding a nipple, it begins to nurse. Within a few days its jaws fuse so the infant cannot release the nipple. This "abortion which has learned to survive outside the womb" is a perfect model, says Jurgelski, for problems difficult to study in the pregnant animal. The effect of toxins can be tested. Brain, lung, and immune system development can be closely watched. Limb regeneration can also be studied. The opossum, moreover, has 22 large chromosomes (two or three times the size of a human's) and sex chromosomes that are clearly different under the light microscope.

The problem is rearing marsupials. Shy and eccentric, they need special care to ensure reproduction. In the course of some cancer research, Jurgelski was able to build up a large colony of opossums—but other scientists have not been so successful. Many have abandoned research because of lack of suitable rearing techniques.

The proposed center would be devoted to the breeding, maintenance, and study of more than 100 species of American and Australian marsupials. The kangaroo, koala, wombat, and other large marsupials would be excluded.

Though access to marsupials is now limited, Jurgelski has letters from more than 30 scientists who are willing to work on the center. Even the National Aeronautics and Space Administration is interested. Since the infant opossum stays firmly attached to its mother, NASA scientists believe the opossum may be a good experimental animal for the weightless conditions of space. NASA may put opossums aboard the Space Shuttle.

Second-Guessing the Swedes *OMNI* Style

Is winning the Nobel Prize a matter of politics, personalities, and being in the right place at the right time, or is it a matter of hard work and keeping your nose clean? According to a new stab at the laureate formula appearing in the premier issue of *OMNI*, a slick coffee-table blend of science fact and fiction, it takes a precise proportion of each.

The one-two-three's of walking away with a Nobel are spelled out by William K. Stuckey in an article replete with predictions of the 1978 Nobel Prize winners in physiology/medicine, chemistry, and physics. Stuckey's method draws on interviews conducted over 8 years with a dozen Swedish judges and some 60 Nobel laureates. From the resulting insights into the power politics of Swedish prize selecting, Stuckey rolls bits of sage advice. On visibility, for example, Stuckey says: "To know you is to love you, of course, but the Swedes can't know you if they can't see you. One must be in the right place for that, since Scandinavian vision is extremely narrow. They can't see you, unfortunately, if you've developed your antigravity device at North Dakota or your hyperspatial rejuvenator at Aleutian Polytech."

Stuckey then names high visibility campuses here and abroad, and even predicts where new power centers will spring up. His formula also mixes in tidbits gleaned from the pages of the *Science Citation Index*. But it's not just a numbers game. The most cited scientist of all time, says Stuckey, would be a lousy bet for a Nobel Prize because most of the citations are to a fluke paper that described a cheap and sensitive method for measuring small amounts of protein.

With a little number-juggling, and a bit of hocus-pocus, Stuckey then takes his picks for the 1978 Nobel Prizes. For physiology/medicine, Sweden's Sune Bergstrom and his life-preserving prostaglandins, his understudy Bengt Samuelsson, and "the grand wizzard of the neurotransmitter," Ulf von Euler, will take the award in a Swedish three-way sweep. In chemistry, Harvard's Robert Woodward and Cornell's Roald Hoffman will walk away with the prize. In physics, Arno Penzias and Robert W. Wilson of Bell Labs "should win for their near mystical detection of what is called three-degree radiation, the magical leftover whisper of the Big Bang that started it all."

—William J. Broad

dent a U.S. early warning satellite was "blinded" for hours by a flare from a ruptured Siberian gas pipeline. The distant early warning radars are said to have been fooled by objects ranging from migrating Arctic geese to the rising moon. So it could be undesirable for a President to order the destruction of one country, and risk the destruction of his own, on the advice of such machines. Politically, a launch-on-warning policy would raise a storm of domestic controversy, not only from arms controllers, who would worry about the dangers of such hair-trigger launches, but from conservatives, who would complain that a President confronted with blinking machines and a horrendous choice might hesitate, do nothing for 25 minutes, and lose his land-based ICBM's without striking back in return.

Finally, a solution that is, on the face of it, cheap and stable would be for both sides to defend some fraction of their land-based ICBM's from ballistic missile attack. Richard Garwin, of the IBM Corporation, has proposed an array of ingenious devices—from gravel spewed in the air around a silo to a pole fence that would disable an attacking warhead so that it would fall to the ground a dud. Pentagon research into ballistic missile defense, which is allowed under international agreements, suggests other more conventional schemes.

The complication, however, is that under the landmark 1972 SALT I treaty on ABM, each side is permitted to build ballistic missile defenses at only one site. Deployment of any kind of ABM at the missile sites would require modification of the treaty.

But it is likely that any moves by the Administration to reopen the ABM treaty would rattle the foundations of arms control itself. The landmark document prohibited a twist in the arms race that was at least as destabilizing as the threat of absolute ICBM accuracy. As the State Department's SALT brochure says, the treaty prevented both sides from building themselves "bullet proof vests" that could tempt either to launch a first strike in the belief that it was invulnerable. Politically, U.S.-Soviet relations have been so strained recently that it is questionable whether a treaty signed in the mellower days of détente, if reopened for negotiation, would itself survive. So the proposal to move to ballistic missile defense, while appearing in some sense cheap, may have a heavy price.

Clearly, the military and political quandary posed by the inevitable improvements in U.S. and Soviet ICBM accuracy is generating a fertile field of solutions. But many of the solutions, whether they entail turning over an area the size of Connecticut for a new ICBM system or reopening a landmark treaty, will have important and independent consequences. So, as the policy-makers seek to avoid a world of absolute accuracy, they should give equal thought to what the alternative worlds would be like.—DEBORAH SHAPLEY

NRC Panel Renders Mixed Verdict on Rasmussen Reactor Safety Study

The old Atomic Energy Commission's Reactor Safety Study (RSS), intensely controversial ever since the first draft of it was issued in 1974, has now come under a severely critical but not entirely unfavorable judgment by a review panel appointed by the Nuclear Regulatory Commission (NRC), a successor agency to the AEC.

The panel, in its recent report to the NRC, concluded that the RSS—known as the Rasmussen study after MIT professor of nuclear engineering Norman C. Rasmussen who chaired it—failed to arrive at a convincing assessment of the probability of major nuclear accidents occurring. It also concluded, however, that the RSS was a useful pioneering effort to apply fault-tree/event-tree analysis* to the extraordinarily complex nuclear reactor systems.

The Rasmussen study was issued in final form about 3 years ago as the culmination of an effort commissioned by the AEC in 1972 to put to rest the then growing controversy over reactor safety. The Union of Concerned Scientists and other groups and individuals critical of nuclear power have denounced it as grossly misleading in its conclusion that the chances of a catastrophic nuclear accident are almost vanishingly small.

Last spring a year ago, the NRC, with encouragement from the House Subcommittee on Energy and the Environment chaired by Representative Morris Udall (D–Ariz.), established the RSS review panel and named Harold W. Lewis of the University of California at Santa Barbara to head it. Included among the seven panel members were some individuals who had been critical of the RSS and some who had defended it.

Lewis himself had chaired the American Physical Society (APS) study group which in 1975 issued a report that expressed no confidence in the "absolute values" as to risks set forth in the RSS draft report. Frank von Hippel of the Center for Environmental Studies at Princeton University, also a member of the APS study group, had been an outspoken critic of the RSS. On the other hand, the panel included persons such as Walter B. Lowenstein, director of nuclear safety analysis for the Electric Power Research Institute (an entity created and supported by the utility industry) and Herbert J. C. Kouts of the Brookhaven National Laboratory, who was director of the AEC's reactor safety research division at the time the Rasmussen study was under way (with one of Kouts's deputies serving as staff director).

In view of this diversity of attitudes and backgrounds represented on the Lewis panel when it began work in August 1977, the degree of consensus finally achieved is remarkable. The panel members were, in fact, unanimous in their principal conclusions, which were:

- The "absolute values" of risk set forth in the RSS are far less accurate than claimed and "should not be used uncritically either in the regulatory process or for public policy purposes." According to the panel, the estimates of risk might be either high or low (it could not determine which), for the error bounds are in general "greatly understated." This is true, the panel said, because of inadequacies in the data base, an inability to quantify "common cause failures" (a breakdown of several discrete systems as the result of an event such as a fire or earthquake), and "some questionable methodological and statistical procedures."
- The RSS has succeeded in providing a "logical framework for the discussion of reactor safety, information about the

*Event-tree analysis begins with a particular event and then traces forward in causal sequence along the paths that derive from it. Fault-tree analysis is similar, except that the analysis proceeds backward in time from an event to trace the connections and discover the circumstances which may have led to it.

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