Sid Drell’s Contributions to Arms Control and Strategic Stability

Richard L. Garwin
IBM Fellow Emeritus
IBM Thomas J. Watson Research Center
P.O. Box 218, Yorktown Heights, NY 10598

www.fas.org/RLG/
Email: RLG2@us.ibm.com

Presented in the APS session
“The Future of U.S. Nuclear Forces: What Do We Need?”

Boston CEC, Rm. 258A, 3:42 PM – 4:18 PM
March 7, 2019

Sidney D. Drell was born September 13, 1926 in Atlantic City and died at the age of 90 on December 21, 2016 in Palo Alto. Universally known at "Sid," his life was full of friendship, music, and accomplishment[1]. I had the pleasure over many years of sharing with him some of his activities in the pursuit of strategic stability and control of nuclear weapons. I focus on three examples, any one of which should have earned him the world's deep respect and gratitude.

Sid Drell on satellite imagery

I was to know Sid well through many days and weeks spent together on the President's Science Advisory Committee—PSAC—of which he was a member 1966-71and, particularly, from some of its military-oriented and intelligence panels. His first contact with the field was probably his service in the solution of a technical problem exhibited by the world's first film-return satellite reconnaissance system, code-named CORONA that first flew in August 1960 and last in 1972, returning to Earth a reentry vehicle—RV—containing kilometers of ultra-thin-base, high-resolution, imagery taken by two panoramic drum cameras in the satellite. Each image occupied 7.0 cm by 76 cm length on the film, corresponding typically to 10 by 120 miles on the ground—resulting in stereo coverage of a 120-mile-wide ground swath. In 1963, Sid was asked by Albert D. ("Bud") Wheelon, responsible for the CORONA

[1] An excellent biographical memoir is available: http://www.nasonline.org/publications/biographical-memoirs/memoir-pdfs/drell-sidney.pdf (by Robert Jaffe and Raymond Jeanloz, 2017). I urge you to read it.

Program at the time, to head a small group of physicists to solve an urgent, even catastrophic, problem—the fogging of the film by flame-like exposure to the electrical phenomenon known as "CORONA"—in this case arising from static electricity discharge of the highly insulating film as it was unspooled and transported over a complex path within the satellite, in the vacuum of space. This was brought under control and was Sid's introduction to the highly classified and compartmented field of satellite reconnaissance. Sid took leave from Stanford to work on this problem.

Sid then became a member of the "Land Panel" advisory to the President's Science Advisor at critical periods in the development of advanced satellite reconnaissance—especially imagery, as distinguished from the return of electronic intelligence—ELINT—from space. The work of the Land Panel is described to some extent in my 1995 paper on the CORONA Program[2] and in my remarks on the contributions of Edwin H. Land himself.[3]

Sid's work on satellite reconnaissance contributed greatly to U.S. knowledge of what was going on in the world in "denied areas" and earned him the formal designation as one of only ten "Founder of National Reconnaissance", awarded in the year 2000 by the National Reconnaissance Organization—NRO—on the 40th anniversary of its

---

[2] "CORONA: America's First Reconnaissance Satellite System. A view from the 'Land Panel'" (Draft 4 of 06/07/95), by R.L. Garwin, Notes for presentation in Panel I "The First Satellite Reconnaissance System. Developing CORONA-- its technical problems, improvements and victories," at George Washington University, Washington, DC, May 23, 1995.

[3] "Edwin H. Land: Science, and Public Policy," by R.L. Garwin as presented 11/09/91 at *Light and Life*, A Symposium in Honor of Edwin Land, American Academy of Arts and Sciences, Cambridge, MA. Published in *Journal of the Irish Colleges of Physicians and Surgeons*, Vol. 22, No. 1, January 1993.

formation. Sid’s warm personality, persistence, and friendship enabled him to achieve many successes. On PSAC, he served for many years as a member of the Strategic Military Panel—SMP. Like most PSAC panels, the SMP’s met for two days, about once a month in the Old Executive Office Building west of the White House. The SMP was concerned routinely with Soviet nuclear capabilities against the United States—ICBMs and submarine-launched ballistic missiles (Soviet bombers were handled by my PSAC Military Aircraft Panel), and with defenses against these threats. Each year the SMP would provide for the President a highly classified technical assessment of the strategic confrontation, part of which was usually an analysis of the most recent proposal by the U.S. Army for deployment of missile defenses against Soviet ICBMs and SLBMs. One such, signed by Sid as Chair of the SMP, found its way to the desk of Henry A. Kissinger, President Nixon’s National Security Advisor, and the now declassified document bears the note of Kissinger to his staff, “We must get PSAC out of strategy!” In fact, PSAC was not doing strategy, but looking at options and consequences.

Sid as informal advisor to Henry A. Kissinger—national security advisor and then secretary of state, 1969 to 1975

Paul Doty, Harvard biochemist and close friend of Kissinger on the Harvard faculty, had long been interested and active in the control of nuclear weapons, especially in the

Pugwash movement, where he took the initiative to have side meetings of some of the U.S. delegation to the international Pugwash meetings, with Soviet scientists. Smart and public spirited, Doty and his Harvard colleagues built these meetings into an important channel of communication with Soviet scientists and ultimately nuclear weapon developers, facilitated on the Soviet side by "minders" who duly reported to the highest level of the Soviet government. On the U.S. side, the Doty group would have preliminary meetings with the National Security Advisor, the Secretary of State, and sometimes the Secretary of Defense, and would provide written and oral reports on the discussions. Sid was not a member of that group but he was of another. Doty group.

The Nixon White House staff was suspicious of PSAC and did not have close relations with the PSAC Chair, the President's Science Advisor. Doty, a founder of PSAC, realized that Kissinger was denying himself and the President valuable information and advice, and arranged to have a side meeting the evening of the first day of each of the monthly two-day PSAC meeting, and again breakfast in the White House Situation Room with Kissinger the second day of the meeting. A small group of colleagues met with Kissinger (the Doty Group) and presented often highly classified papers that had been assigned the previous month and accepted new tasks for the following month. Some of these had to do with the problem of MIRV (multiple, independently targeted reentry vehicles), others with limitations on missile defense, and the like. In parallel, Sid and I were members of the Land Panel and were involved with an analysis of the options for the successors to CORONA in space imagery—initially two film-return systems, HEXAGON and GAMBIT and then an option for a system that would return imagery by electronic transmission (radio).

Although we couldn't share this information with the rest of the Doty group, Sid and I regarded it as our obligation to share it with the National Security Advisor, and after being empowered to do so, we hand-wrote a brief note and asked Kissinger's aide to take it to him when he was involved with a meeting. Kissinger and Nixon approved the system, which has greatly contributed to U.S. knowledge of activities regarding strategic weapons, both offensive and defensive. Before his service on PSAC and its various panels, in 1960 Sid was a founding member of the JASON group of scientists advising elements of the U.S. government. JASON's first Summer Study was housed at Bowdoin College, and was focused on space and missile defense. It was the group's introduction to the phenomenology of nuclear explosions in space. As a member of various PSAC panels, I briefed JASON that summer. In 1966 I was invited to join JASON and had the pleasure of working with Sid in the summer studies—in La Jolla for the most recent 40 years or so.

JASON itself was created by senior U.S. scientists (mostly physicists) who had been involved in the developments of WWII—radar and, particularly, nuclear weapons.

Most of them had had experience with PSAC and recognized that there was a gap opening in the scientific expertise applied to military activities, that had been essential in surviving and winning WWII. Ultimately, Charles H. Townes, in a stint as Vice President of the Institute for Defense Analyses, together with the JASON founders—Marvin L. Goldberger, Kenneth M. Watson, and Keith A. Brueckner—recruited their colleagues into what became the current JASON model.

There is a lot of fun in learning new things, and one of the results of the early Study, in addition to considerations of “blackout” or “red-out” as a result of space nuclear explosions, was the Alfven Propulsion Engine (Sid delighted in calling it “the APE in space”). Of course these were serious matters and were taken as such.

JASON was to provide what was missing from high-level advisory committees in the government—fresh eyes on an important problem, backed up by a scientific paper, rather than by hunches and assertions.

At a time when Air Force was tiring of the same old Minuteman missile in silos in the United States, defense intellectuals were prescribing “essential” modifications of the basing—especially of a new missile the “M-X” (with “X” designating experimental). It was well known that the *solution* was the M-X missile, but what was the *problem*? The problem most widely asserted by Paul Nitze and those urging the deployment of the M-X was “Minuteman vulnerability,” because Soviet warheads were assumed soon to be so accurate that they could destroy with high confidence a Minuteman silo with the expenditure of a single warhead from a highly MIRVed Soviet missile.

The M-X missile basing insanity was rampant in 1980 with various high-level official and unofficial panels advocating or criticizing various deployment options, including week-long patrols of diesel-powered aircraft over the United States carrying one or more M-X missiles for air launch, or the buried “racetrack” mode of deployment, in which one or more M-X missiles on transporters would stop at unknown locations in a multi-mile-long racetrack, immune to observation by the Soviets, or the deceptive basing scheme, in which 500 M-X missiles would be deployed in 5,000 silos, with dummy missiles in 4,500 of them, and so on. Ultimately, 50 M-X missiles were deployed in the very same Minuteman silos deemed to be so vulnerable that a new generation of ICBM missiles and bases were required; they have now been removed.

JASON was tasked by William J. Perry, then Director of Defense Research and Engineering in the Carter Administration, to conduct a study of basing M-X missile on small submarines, which would not need to deploy into the vast oceans, and certainly not near the Soviet Union, where the first SLBM short-range missiles were deployed. Sid and I were the leaders of this JASON effort, and I recall that at a certain point, we had done what seemed to be a reasonable study, and then Sid prodded me “Can’t we do more?” We could, and did an expanded study that resulted in the proposal to deploy two or four 100-ton M-X missiles, individually encapsulated, lying horizontally alongside a submarine of perhaps 500 or 1,000- ton displacement. We took into account transients in the launch of the missile, accurate navigation by hundreds of pseudolites on U.S. territory broadcasting GPS-like signals. In typical Sid collaboration mode we arranged with the Draper Laboratory of Cambridge, MA, to send an “observer” to vet the (to Draper, anathema) radio guidance, with the result (one can never be sure) that Draper began to use GPS for scoring its inertial navigation systems in test, part of the way to relying on them for the navigation of the missiles themselves.

The ”Can’t we do more?” resulted in the additional effort to produce from the Secret JASON report an unclassified publication in the MIT *Technology Review*[4] bringing the small undersea mobile—SUM—system into public view and exposing it to criticism, both warranted and unwarranted. Perhaps its most famous moment was this *New Yorker* cartoon. Sid contacted the cartoonist and posted the original in his office at SLAC.

Here is the cartoon, and a view of the 1981 *Technology Review* article.

---

[4] "Basing the MX Missile: A Better Idea," by R.L.Garwin and S.D. Drell, *Technology Review* , Edited at the Massachusetts Institute of Technology, May/June 1981. The authors would have preferred black print on white paper, rather than the artistic white on patterned blue that makes it almost impossible to read the text or view the diagrams

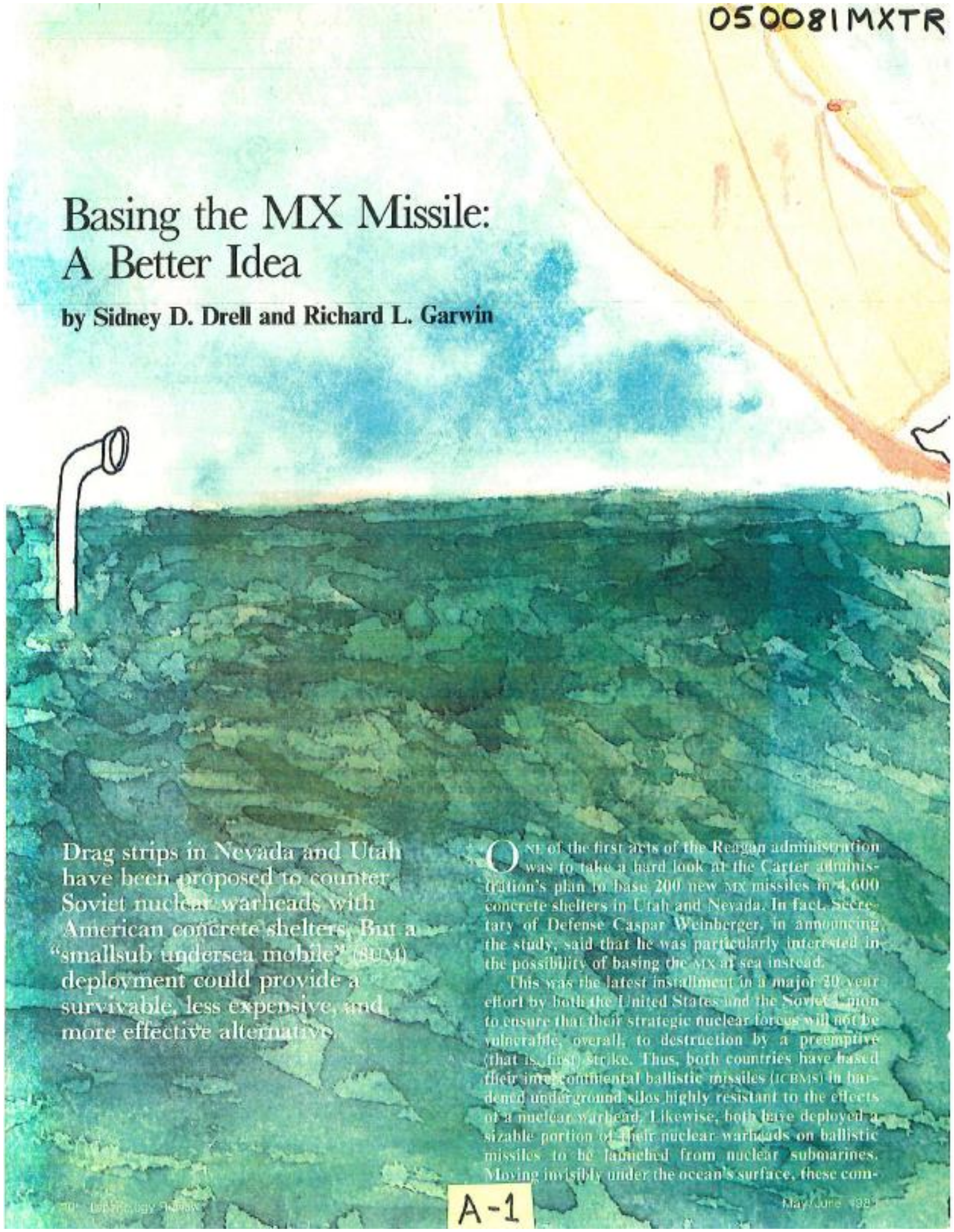
"Ordinarily, I lean toward a land-based-MX system. But when I have a few drinks I lean toward those little submarines."

Dana Fradon (6/1/1981)

Return to Main Menu ►

More technically, this is the open publication Sid and I published in *Technology Review*.

050081MXTR



Basing the MX Missile: A Better Idea

by Sidney D. Drell and Richard L. Garwin

Drag strips in Nevada and Utah have been proposed to counter Soviet nuclear warheads with American concrete shelters. But a "smallsub undersea mobile" (SUM) deployment could provide a survivable, less expensive, and more effective alternative.

ONE of the first acts of the Reagan administration was to take a hard look at the Carter administration's plan to base 200 new MX missiles in 4,600 concrete shelters in Utah and Nevada. In fact, Secretary of Defense Caspar Weinberger, in announcing the study, said that he was particularly interested in the possibility of basing the MX at sea instead.

This was the latest installment in a major 20-year effort by both the United States and the Soviet Union to ensure that their strategic nuclear forces will not be vulnerable, overall, to destruction by a preemptive (that is, first) strike. Thus, both countries have based their intercontinental ballistic missiles (ICBMS) in hardened underground silos highly resistant to the effects of a nuclear warhead. Likewise, both have deployed a sizable portion of their nuclear warheads on ballistic missiles to be launched from nuclear submarines. Moving invisibly under the ocean's surface, these com-

prise, now and for the foreseeable future, a highly survivable force. Finally, to maintain a broad diversity of forces with differing vulnerabilities, operating characteristics, and failure modes, the United States has maintained and repeatedly upgraded a strategic bomber force that would survive by being launched on warning of impending attack.

Minuteman Vulnerability

In the 1980s, two technological improvements threaten fixed land-based systems such as the Minuteman, the bulwark of the American ICBM forces, with obsolescence: the achievement of very high accuracy and reliability for ICBMs, and the extensive deployment of "multiple independently targetable reentry vehicles" (MIRVs) that enable individual missiles to effectively threaten several ICBM targets.

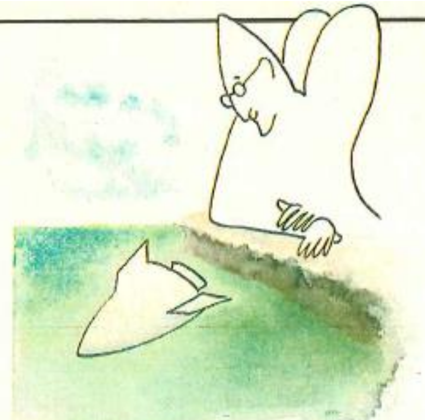
The United States is particularly concerned about the improved accuracy of Soviet missiles and their rapidly growing numbers of MIRVed ICBMs, many deployed with 6 warheads (SS-19s) or 10 warheads (SS-18s). U.S. defense officials have claimed that these weapons, when fully deployed by the early 1980s, could destroy as much as 90 percent of the present U.S. ICBM force. Of course, such an attack would be enormously difficult to execute successfully; it would require nearly simultaneous and very accurate arrival of some 2,000 Soviet warheads at the 1,000 American Minuteman silos, and the Soviet missiles would be flying on trajectories never before flight-tested. Therefore, many experienced observers (both military and civilian) view Minuteman vulnerability as little more than a paper-and-pencil threat. The Soviets nevertheless appear to be headed on a path that will soon reduce U.S. confidence in the invulnerability of

May/June 1981

A-2

The Politics of the MX

by James Fallows



IN the two years since the Carter administration decided to build the MX missile and base it in the Southwest on a "drag strip" (politely known as "linear grids"), arguments have raged about the system's military, economic, environmental, and diplomatic effects. Yet the probability that the system will be built as planned, never high, has dwindled further since the beginning of 1981.

The Carter administration embraced the drag-strip system less out of conviction than because of political constraints. Because he had cancelled production of the B-1 bomber and the deployment of the neutron bomb, Jimmy Carter was not eager to give his opponents another item for their list of his steps toward a weaker defense. Because his administration had staked its political and ethical capital on passage of the SALT II treaty, Carter was willing to take the steps necessary for a favorable vote in the Senate on the treaty, steps generally thought to include increasing the defense budget and proceeding with the MX.

But from the moment the plans for the basing system were announced, they met with lukewarm support and determined opposition. Paul Nitze of the Committee on the Present Danger, who had warned strenuously about "Minuteman vulnerability," said that the drag-strip system would be clumsy and conceptually inelegant. He recommended instead that the United States build hundreds of new silos in the far West and then move missiles secretly from one silo to another in a process known as the "shell game." Others said that the quickest solution would be to put MX missiles into existing Minuteman silos and then build an antiballistic missile system—in violation of the SALT I treaty—to defend the missile fields. Such support as the drag-strip system won was generally of the better-than-nothing variety.

As for opponents, announcement of the basing system shifted the focus of their concern. The main political objection to the MX had been that its greater accuracy would appear to give American missiles the ability to destroy Soviet forces in a surprise first strike, thereby destabilizing the balance of nuclear deterrence. Afterward, complaints changed from the missile itself to its basing system. Environmentalists warned about the damaging impact on the topography and scarce water supplies of the Great Basin region. A govern-

---

its land-based strategic forces.

The loss of the Minuteman force would not mean the loss of the entire U.S. retaliatory capability. The seaborne and airborne components of our strategic triad are considered both highly survivable and capable and are continually being improved at great cost. For example, of the 31 Poseidon submarines operating for the last decade, each with 16 14-MIRV Poseidon missiles with a range of 2,500 nautical miles, two have already been refitted with 16 8-MIRV Trident I missiles with a range exceeding 4,000 nautical miles and warhead yields in the 100-kiloton range. The longer missile range greatly increases the subs' ocean operating area. Soon the first 24-missile Trident submarine will join the fleet, carrying the same Trident I missiles but capable of carrying a much larger 6,000-nautical-mile Trident II, although no decision has yet been made to develop and produce Trident II. In 1982 the bomber force will begin to carry thousands of long-range air-launched cruise missiles that will substantially increase the bomber's firepower and remove the need to overfly and penetrate the extensive Soviet air defenses.

The loss of Minuteman would not compromise the U.S. retaliatory capacity for assured destruction. Even today, loss of the ICBM force would leave intact about three-fourths of the total number of nuclear warheads in the currently deployed U.S. strategic forces and about two-thirds of their total throw-weight. However, a fundamental question remains: Should the United States accept a decrease in its margin of safety as a result of new Soviet deployments? Both Congress and the executive branch agree that to simply ignore the growing vulnerability of our Minuteman force is not an acceptable policy for the United States. Thus, the issue is not whether but *how* to respond to the growing threat.

The MX Missile System

The Carter administration responded to this problem by recommending the deployment of a large new MX missile in a land-based "multiple-aimpoint" system. At 92 inches in diameter, 71 feet in length, and a design weight of 192,000 pounds, the MX is the largest missile consistent with the provisions of SALT II. (Although this treaty has not yet been ratified by the U.S. Senate, the Reagan administration has stated explicitly that it will abide by these provisions so long as the Soviet Union also complies, pending the estabment official calculated that building the shelters and drag strips would consume a substantial fraction of all the cement the United States could produce in a decade. Official estimates of the cost rose from $30 billion to $50 billion within a few months, and opponents threatened to tie up the system for years with environmental impact statements and endless litigation.

Ronald Reagan came to office more sincerely committed to the missile than Jimmy Carter had probably ever been, but he encountered new obstacles to proceeding with Carter's basing plan. In postponing ratification of the SALT II treaty, Reagan altered the fundamental logic of the MX, which had rested on careful calculations of how many warheads the Soviets would have to fire against it. A series of government reports, including one from the Office of Technology Assessment, emphasized the gravity of the environmental effects and the greater technical feasibility of putting the MX missiles on ships or submarines instead of land. Secretary of Defense Caspar Weinberger said that he was attracted by the idea of putting the MX to sea and thereby avoiding the environmental tangles, and that the drag-strip plan "has an element of the unreal in it. There's no doubt about that."

Weinberger also began one of the two processes that seem likely to determine the system's fate. In March he appointed a 15-member panel composed largely of military officers and scientists and headed by Charles Townes, a Nobel-laureate physicist from the University of California at Berkeley, to review the basing plan. The panel is supposed to report its findings by July 1, and Weinberger has said he will then make up his mind.

The other process is being played out among the people and politicians of Utah and Nevada, the states that would house the missiles and could thereby become, in the infelicitous phrase of Air Force Chief of Staff Lew Allen, a "nuclear sponge" during a Soviet attack. Three of the states' four senators are prominent Republicans—Orrin Hatch and Jake Garn of Utah, and Paul Laxalt of Nevada, a close friend of Reagan's. (The other senator, Howard Cannon of Nevada, is a Democrat but has been more enthusiastic than the others about the basing plan. Nevada's Democratic representative, James Santini, has been the most vigorous opponent.) All three Republicans say that opinion in their states is deeply divided, that of course they and their constituents will patriotically bear the burden if the nation's security is at stake, and that they hope like crazy that the experts will decide to put the missile elsewhere.

Senator Garn says that his preference is to put the MX in Minuteman silos and defend them with an ABM system. If it comes to the drag strip, he and the others have supported a "split-basing" plan that would locate half the missiles in New Mexico and Texas. They cite the precedent of the Minuteman missile, which was deliberately dispersed among half a dozen states to minimize the impact on any one. But there has been little enthusiasm from New Mexico and Texas for such a plan.

"We feel that it's the worst of the alternatives," a spokesperson for Senator Garn said. "We just hope it doesn't turn out to be the only practical choice." □

James Fallows is Washington editor of The Atlantic.

lishment of a long-term U.S. arms-control policy.) The MX payload is MIRVed into 10 warheads (also a SALT II limitation), each with an explosive yield in the range of 300 to 500 kilotons. The missile is carried in a heavy steel capsule, requires little maintenance, can remain unattended for many months, and is ready to be launched at any minute.

The MX basing scheme finally proposed by the Carter administration would take the form of 200 "drag strips" in the valleys of Utah and Nevada. Accessible from each strip of roadway would be 23 hardened concrete shelters housing 1 genuine MX missile and 22 high-quality dummy missiles. If they simulated all the observable characteristics of a real MX (such as weight, vibration modes, propellant vapors, and nuclear radiation) in each shelter or on the move between shelters, the dummies would force the Soviet Union to use at least 4,600 (not 200) warheads to destroy 200 MX missiles.

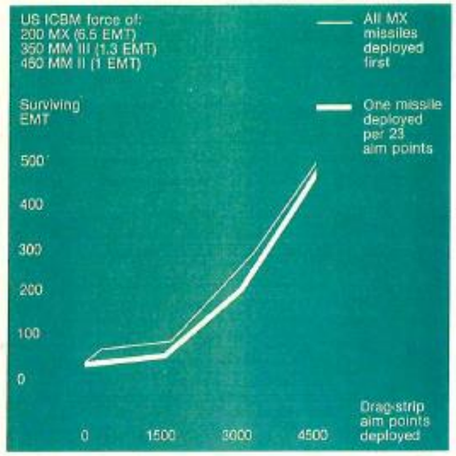
In advocating such a "multiple protective shelter" (MPS) basing mode for the MX missile, the Carter administration argued that the United States must maintain a land-based deterrent force to preserve the diversity of its current triad. Although both the cost and effectiveness of this basing scheme are still being debated, the missile itself is in engineering development. Its first flight test is scheduled for 1983, and regular production of the missile should begin in 1986.

Problems with the Land-Based MX

Because the drag-strip basing mode presents severe operational and strategic problems—it is vulnerable, essentially the entire system must be deployed before it contributes survivable megatonnage, and secrecy, deception, and simulation must be maintained—we do not regard it as a satisfactory response to the threat.

To ensure that some of the deployed missiles in a system of multiple protective shelters will survive, the total number of shelters must exceed the number of threatening warheads. Current U.S. assumptions of survival of 100 of the 200 MXs to be deployed in 4,600 shelters depend on somehow limiting the number of threatening warheads the Russians will deploy. Thus, if one imagines a force of 3,000 accurate, perfectly reliable Soviet reentry vehicles (RVs) available for attack on the MX MPS alone, there would be no survivors until 3,000 silos had been deployed. Indeed, until the number of shelters exceeded considerably the number of available Soviet RVs, the deployment of the

MX-MPS Survivability. It is assumed that 5,000 Soviet RVs (each with a destruction probability of 0.8 against a silo or shelter) are used against the system. The Minuteman II missiles are assumed to have 1-megaton warheads, the Minuteman III to have 3 MIRVs, each of about 200-kiloton yield, and the MX to have 10 warheads of about 400-kiloton yield. (The effectiveness of a submegaton warhead against large targets is determined by the ground area subject to destructive overpressure, while that of a highly accurate force against silos is determined only by numbers of warheads. Thus, the EMT of a force is obtained—as a compromise—by summing the megatonnage of each warhead raised to the 0.5 power).



200 MX missiles would constitute a "silo-killing" force in a vulnerable basing structure—something defense leaders from the Carter administration specifically criticized as unacceptable and provocative.

More realistically, the figure on this page shows the number of surviving U.S. ICBM equivalent megatons (EMT) as a function of the number of MX aimpoints deployed. It demonstrates quantitatively the very limited effectiveness of the first half of the 4,600-shelter force, the first breaks in the curves coming as the Soviets can no longer apply two RVs per shelter, so that 20 percent of the shelters attacked will survive instead of 4 percent. The surviving EMT then rises linearly to 500 EMT when all 4,600 shelters exist. Even this result assumes that deception can be maintained—that the Soviets do not know which of the 23 shelters in a cluster is occupied by a real MX missile.

Such concealment for survivability is necessary if we insist on a survivable land-based missile force within the SALT II limit of 820 MIRVed ICBMs. Cooperative operational procedures are included in the design requirements of the drag strip to give confidence to the Soviets that no more than the stipulated number of missiles (200 MXs) are deployed in the guise of decoys (totaling 4,400). These procedures, including barriers on access roads and removable plugs in ceilings of assembly buildings and shelters to allow for periodic satellite viewing, may provide confidence that no more than 200 real missiles are present. But they do *not* keep the system owners from rapidly deploying hundreds of additional missiles in hardened, prepared, accurately surveyed launch points, should they abrogate the treaty or fail to renew it. This potential for rapid expansion will be a particular concern for the United States if the Soviet Union responds by deploying its own multiple-aim-point system.

The United States, with its open society, can hardly compete with the closed Soviet society in maintaining secrecy and deception, and the Soviets have a much larger land mass in which to "hide" mobile ICBMs. If Soviet tendencies to follow the United States' lead in weapons programs are any guide, the United States would essentially be choosing Soviet home turf for a competition almost bound to occur.

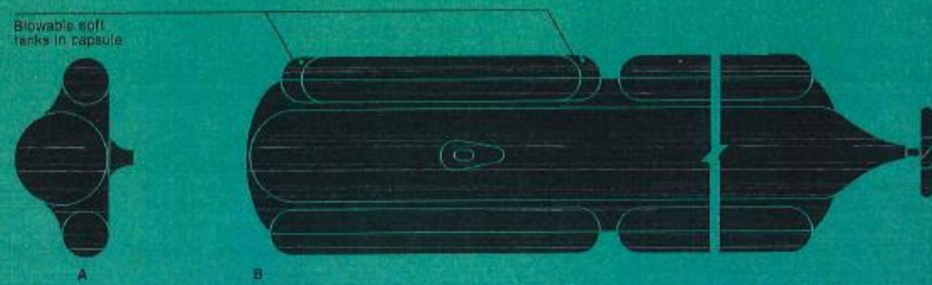
In the absence of current or future SALT limitations on the maximum number of Soviet warheads, a multiple-aimpoint system provides no assurance of eliminating ICBM vulnerability; it may lead to nothing more than an open-ended race between Soviet warheads and U.S. concrete shelters. Former Secretary of Defense Harold Brown has testified that such competition may be advantageous to the United States, but we fail to see any advantage in balancing concrete holes against additional Soviet warheads, nor do we relish political battles aggravated by questions of environmental impact. Indeed, it would be to our benefit to *ban* land-based mobile ICBMs, the stated U.S. inclination in SALT I, rather than undermine arms control and national security with a program of deceptive basing of land-based missiles.

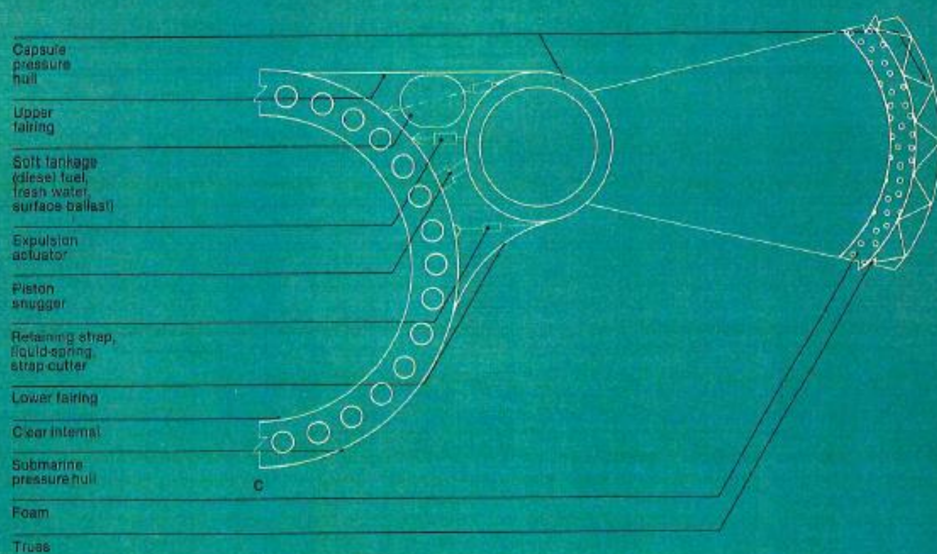
The SUM Alternative

We favor an alternative basing scheme—a mobile sea-based deployment of the MX on small submarines. We call this the smallsub undersea mobile (SUM) force. SUM retains the major desirable characteristics of the current ICBM force and therefore preserves a healthy diversity in the U.S. strategic deterrent.

SUM would be a deployment of small non-nuclear-powered submarines operating within 600 miles of the continental United States and in the Gulf of Alaska. This concept can be adapted to a wide variety of missiles with ICBM range, but we assume that each submarine will carry two encapsulated MX missiles, mounted horizontally, external to its pressure hull. Limited operating range, short mission duration (no more than four weeks), and a small crew (of about 20 to 25, consistent with safe, efficient operation aided by automation) make possible the concept of small

A-5





Figures A and B show side- and plan-view sketches, respectively, of the MX-carrying submarine, while figure C shows a cross-section illustrating how fuel, freshwater, and surface ballast are carried outside the pressure hull in soft tankage. One sees also a detail of the capsule structure, stiffened by an internal truss, and the missile within the capsule, supported gently against impulsive shock load by resilient foam between the missile and the capsule.

submarines with hull displacements of no more than about 1,200 tons. The total displacement of a SUM boat carrying two encapsulated missiles is about 1,700 tons. This is comparable to World War II submarines and about one-tenth the size of the new Trident missile submarines.

SUM consists of four subsystems: the encapsulated MX missile itself; the submarine carrying the missile; the missile guidance system; and specialized command, control, and communications to the vessel.

The primary function of the crew would be to maintain sovereignty over the nuclear-armed MX missiles; guard against piracy, sabotage, and interference; perform safety checks and maintenance; and, of course, operate the submarine. Full power of decision to launch the missiles would reside with the president (or his successor as national command authority), and orders would be transmitted by encrypted communication to the missile. The submarine commander would retain veto power in the event of a failure, as indicated by on-board instrument checks.

With their limited range and duration, SUM submarines have very modest power requirements, so nuclear propulsion is neither necessary nor desirable. Various (relatively inexpensive) propulsion schemes are feasible, including diesel-electric and electric-drive fuel-cell systems. We foresee an initial operation with familiar, tested diesel-electric power, with the submerged submarines patrolling at a speed of about four knots. As in all modern diesel-electric submarines, air would be taken in through a conventional "snorkel" tube for a few hours each day to operate the diesel engine to recharge the battery. This system could evolve in the mid-1990s to one that utilizes fuel-cell propulsion, thereby avoiding any need to snorkel. The technology of fuel-cell propulsion has been extensively tested, but at-sea use of the required fuel and oxidizer still requires further development.

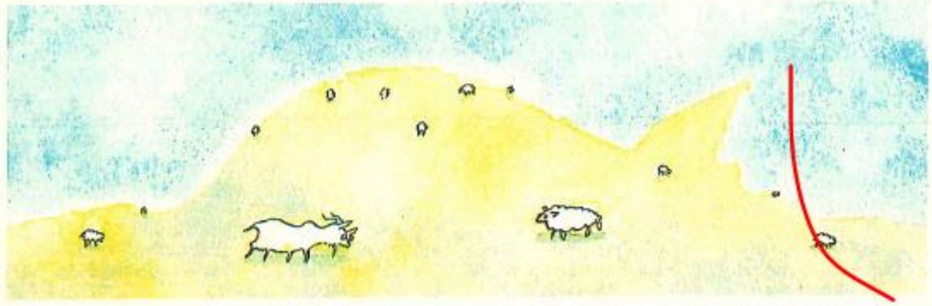
A conservatively designed SUM boat (state-of-the-art for missile capsule and hull) operating at a 200-to-300-foot depth in deep water would be safe from the shock effects of a 1-megaton detonation at distances greater than four miles. By this criterion, more than 20,000 megatons—a number that far exceeds the total Soviet arsenal—would be required to barrage a total SUM deployment area of 1 million square miles. And further fractionation (MIRVing) of their ICBM force would not increase the threat to SUM.

The SUM force can reliably achieve high accuracy comparable with that envisioned for the land-based MX. To correct errors in flight parameters, the missile would receive radio signals during the boost from the Navstar-satellite global positioning system (GPS) or a network of onshore transmitters forming a ground beacon system. Line-of-sight contact with a large and inexpensive network of such beacons could be achieved for submarine launches as far as 500 miles offshore. The duration of missile flight in radio line of sight with ground stations and below ionospheric regions would be sufficiently long that this information would not be distorted by high-altitude nuclear detonations. The ground stations would consist of many unmanned, relatively inexpensive transmitters supplemented by even more inexpensive decoys, and would be turned on only if Navstar were destroyed, minimizing system vulnerability to enemy attack. The SUM submarines themselves would not need a good inertial navigation system but would rely on the very capable guidance system of the MX for accurate locational data, supplemented with occasional radio signals.

The current U.S. submarine missile force has a robust and redundant command, control, and communications (C-3) system, but it is ordinarily viewed as providing less confidence and security than the bomber and land-based ICBM components of the triad. These reservations do not apply to SUM. Because of its coastal deployment, SUM need not rely only on worldwide communication networks. Existing very-low-frequency (VLF) transmitters can be supplemented by equipment at dispersed survivable ground stations or by airborne transmitters much less powerful than those now carried by the navy TACAMO (take-charge-and-move-out) aircraft. Ultimately, other means of communication are available, such as ultra-high frequency (UHF) from satellites, with improved techniques for *receiving* these communications as well. For example, a system of expendable buoys has been proposed for SUM and other submarine-launched ballistic missile systems. A new buoy would be ejected every few hours from the submarine and float awash, while the submarine paid out a fine, slack, insulated wire or fiber-optic thread to receive the signals relayed by the buoy.

The SUM system would maintain about 55 boats with 110 missiles at sea, corresponding to the design goal of survivable warheads for the proposed land-based drag-strip deployment of MX. Although SALT II would limit any land-based MX to 10 MIRVs, it would permit submarine-launched ballistic missiles to have up to 14 warheads per missile, and the SUM-MX could carry 11 to 14 assorted Trident I and Mk-12A

Defense of Land-Based ICBMs



AN alternative prospect of defending the real MX missiles with a deceptively based (mobile) antiballistic missile (ABM) system has been discussed. This would require abrogating the limitations on ABMs in SALT I—an even less attractive prospect than the drag strip—and ABMs would not, in fact, provide an *enduring* force. After a first attack, the Soviets could determine the location of the defense as well as the surviving shelters and attack them too. Against such a threat, ABMs would increase the number of Soviet warheads needed to destroy an MX by 10 percent or less.

Ironically, effective defense of the MX or Minuteman force *is* available, and probably allowed under SALT I, in less technologically advanced forms of ballistic missile defense. This would consist of a modest-sized (100-kiloton) nuclear explosive buried some tens of meters underground about one kilometer north of each Minuteman silo. Its detonation would project some hundred kilotons of earth into the air, rendering it impossible for a Soviet warhead to penetrate and explode within lethal range of the silo. In addition to this individual defense, the dust raised to the troposphere would so abrade the protective heat shield of Soviet reentry vehicles (RVs) that their survival to ground level would be doubtful and their accuracy, even if they penetrated, would be impaired.

Individual nuclear defenses would be armed by presidential decision and triggered by small radars a few kilometers north of each silo facing the incoming RVs. Although there is no technical criticism of this system, it is scorned with the comment that "no president will detonate nuclear weapons on U.S. soil until Soviet nuclear bursts have occurred there." The result is that no president has ever been asked whether he wants to develop and deploy such a defense.

A cratering defense of silos not only provides several hours of Minuteman invulnerability after detonation (until the wind carries the high-altitude dust cloud from the Minuteman fields), but it is economical and has a low peacetime environmental impact. Furthermore, even if the system were operated, the radioactive fallout from the cratering explosives would be very small in comparison with the fallout avoided from the enemy RVs. The detonation of 1,000 such bombs would thus contribute less radioactive fallout than 10 nominal Soviet RVs; the defense would need to be no more effective than 1 percent to provide a net reduction in fallout.

Such a cratering defense is both inexpensive and rapidly deployable. The weapon and its emplacement can be bought for $1 million, leading to a price tag for the system (aside from command and control) of $1 billion. It is difficult to understand why this defense has not been sought if we are seriously concerned with Minuteman vulnerability and early remedies.—*R.L.G.* □

warheads.

The encapsulated MX missile makes it possible, as foreseen in the massive Defense Department strategic systems study (STRAT-X) of the 1960s, to provide a clean interface between missile and submarine. The figures on page 25 show the exterior of the submarine, with capsules 3.4 meters in diameter, housing a missile of 2.3 meters, and strapped to a submarine of 6.1 meters. With the missile control center and sophisticated inertial navigation system contained in the missile and capsule, the submarine is a simple electrical relay center for radio signals. These are transmitted from the submarine directly to the missile capsule, where the signal is decrypted and, if verified, launching takes place.

The actual launch consists of freeing the capsule from the submarine, pushing on the capsule with the expulsion actuator to give it a horizontal velocity of a few feet per second, and blowing water from "soft tankage" in the front of the capsule by means of a contained gas generator. The capsule then becomes buoyant and accelerates through the surface of the water. As the capsule broaches, explosive cutters free the forward and rear dome-retaining clamp bands. The missile booster then fires, and the missile emerges from the capsule as from a normal land

A-8

The drag-strip basing mode is vulnerable, essentially the entire system must be deployed before contributing survivable megatonnage, and deception must be maintained.

launch. A gas generator in the capsule then inflates an airbag so that it cannot sink and collide with the submarine. The submarine refairs to its initial shape by inflating a rubberized fabric fairing with seawater to about two-pounds-per-square-inch overpressure.

Many problems are avoided by carrying a neutrally buoyant capsule rather than one that is positively buoyant. Thus, no reballasting of the submarine after caspule ejection is required. There is no need for large hard tanks to prevent loss of the submarine if a capsule floods, because the capsule can be ejected if flooded. The fabric water bag weighs a few hundred pounds and is essentially rigid at submarine speeds up to 10 knots, saving the weight, maintenance, and design of a metallic refairing system. The required resistance to shock loading is obtained for the submarine-capsule structure by the arrangement of liquid springs, hydraulic pistons, and multiple retaining bands. Such a system, carrying two missiles, would have an overall submerged displacement of 1,700 tons, a maximum speed of 10 knots, an electric-drive submerged patrol speed of 4 knots, and a 28-day mission duration.

Criticisms of SUM

Charge: *SUM would not be available before the 1990s.*

Some defense analysts allege that construction of a naval base for berthing, maintaining, and resupplying a portion of the SUM force (one-third, if three bases are built) would take more than 12 years, but there is no technical support for this claim. Our own analysis based on conservative practice (allowing 7 years until deployment of the first SUM boat) leads us to conclude that initial system deployment can be realized by 1988, with full deployment completed by 1992.

It is important to realize that each SUM boat contributes to survivable megatonnage for the U.S. deterrent. This is not the case for the drag strip, which will add significantly to the survivable U.S. megatonnage only when it presents so many targets that they cannot all be destroyed (*see the figure on page 24*). The current drag-strip schedule calls for initial deployment in late 1986, with full deployment by 1990. However, this schedule is threatened by serious delays; litigation by citizens' groups in Nevada and Utah on this huge project's environmental impact during both construction and operation, and a proposed congressional requirement that the drag-strip basing include Texas and New Mexico, will surely delay the completion date. Thus, SUM is likely to be a more timely response to the problem of Minuteman vulnerability than the drag strip, and it has a relatively modest environmental impact, particularly if its initial deployment is at an existing naval base.

The SUM system requires no major technological advances like the innovations for developing nuclear submarines and solid-fuel submarine-launched ballistic missiles. It involves a substantial change in *operational* concept, relying on small crew size and efficient operation, but only modest advances in *technology*, such as radio guidance improvements for accuracy. The allegation that SUM could not be available until the 1990s is not only unsubstantiated, it denies the capabilities of our industrial and defense establishments to respond quickly to national needs. Consider that the entire nuclear submarine revolution, including the development of solid-fueled submarine-launched rockets, required only 11 years from the 1949 go-ahead for the *Nautilus* to deployment of the first Polaris boat in 1960.

Charge: *SUM will be more expensive than the drag strip.*

We recognize the inaccuracies and uncertainties of cost estimates for so large a system. Nevertheless, cost *differences* can be assessed with greater confidence because they are computed on the basis of the same set of assumptions. In this context, we estimate that SUM is at least $10 billion less expensive than the drag strip for deploying and operating 850 survivable and effective warheads. We assume here, along with the Defense Department, that SALT II will limit the number of threatening Soviet ICBM warheads. Otherwise, the drag-strip deployment would be even larger and more expensive or require an active and costly ballistic missile defense (in conflict with the SALT I treaty limiting such deployments).

More specifically, a SUM system consisting of 72 submarines, each with 2 MX missiles (but buying 250 missiles and capsules), 1,000 ground-based navigational transmitters, and 3 SUM operating bases, would cost less than $30 billion. This inclues submarines with average displacements of 1,700 tons, including the allowance of 50 tons for defensive systems, with considerable potential for growth in mission duration, propulsion systems, and the like. The $30 billion also includes full cost of operation for 10 years. A lower-cost system could be obtained by deploying the SUM-

SUM retains the major desirable characteristics of the current ICBM force and therefore preserves a healthy diversity in the U.S. strategic deterrent.

MX with 14 warheads (saving about $6 billion), choosing a submarine with less growth potential, and building only 2 bases. SUM will not only be less vulnerable, less obtrusive, and less threatening to arms control but less costly as well.

Charge: *SUM would have no advantage relative to the Trident force. It would mean abandoning the triad in favor of a less desirable dyad and, by putting too much of our deterrent at sea, making it potentially vulnerable to the possibility that the "oceans will become transparent."*

There are major differences, both technical and operational, between SUM and Trident with respect to antisubmarine warfare. Operational advantages include the very much larger number (55) of SUM boats at sea, which gives SUM a major edge against any attempt at continuous trailing of the entire force. Moreover, SUM's proximity to U.S. shores would not concede a benign operating environment to Soviet antisubmarine forces; U.S. naval assets could obviously be used more extensively and aggressively. Physical advantages of the SUM boats include their relative silence (because of electric-drive propulsion) and their much smaller size (displacing 1,700 tons, as opposed to the 18,000 tons by the nuclear-powered boats). On the other hand,the Trident submarines have the advantage of a much larger operating area—17 million square miles as opposed to 1 million—and they don't have to snorkel.

The near-coastal waters of the SUM deployment are a complex operating medium for antisubmarine warfare, which relies, at present, almost entirely on acoustics. Much of these waters are acoustically "shallow": they do not support long-range propagation of low-frequency sonar without loss of signal from repeated bounces off the occan bottom. Moreover, the SUM deployment area can readily be filled with decoys and noise by generators, making the quiet submarines even more difficult to find (although submerged diesel-electric submarines are regarded as virtually impossible to detect).

However, diesel-electric submarines are relatively noisy while snorkeling to recharge their batteries, and they may also be viewed by radar while at the surface. This raises the possibility that a fraction of the SUM force could be vulnerable to future Soviet antisubmarine capabilities. If it should emerge as a threat to SUM, this concern could be addressed by eliminating the need to snorkel—converting to fuel cells for submarine propulsion. This option should be available in the mid-1990s and could be implemented as individual boats are overhauled.

Both Trident and SUM will be highly survivable for the foreseeable future. In an era in which "stealth" technology is supposed to render our aircraft unobservable to radar, it is certain that analogous techniques could help hide submarines. Vice-Admiral Charles H. Griffiths, commander of the U.S. Submarine Force, recently commented that the oceans are a great place to hide because "they're becoming more opaque as we understand more about them."

A specific advantage of SUM relative to Trident for limited strike options is that the launch of 1 MX missile exposes the location of only 1 additional missile on the same boat, as opposed to 23 for a Trident boat. Similarly, in the planned MX-MPS deployment of a single MX missile in a 23-shelter complex, the launch of each missile reduces by 23 the number of reliable, effective Soviet RVs required to destroy the remaining MX force.

An advantage of a mixed deployment of SUM and Trident systems is that they have very different characteristics, including operating areas and numbers of ships. Hence, Soviet antisubmarine efforts could not be concentrated against one or the other alone, and together they preserve an important diversity for the U.S. deterrent forces.

The United State could soon lose an element of this diversity in its strategic forces as a result of the growing vulnerability of fixed land-based ICBMs. By moving to the drag strip, the United States would be deploying a system with great and unavoidable operational problems. The SUM system, on the other hand, would present only a modest technical challenge and maintain security on the basis of mobility and relatively simple operational procedures at sea.

Sidney D. Drell is deputy director of the Stanford Linear Accelerator Center and Lewis M. Terman Professor at Stanford University. **Richard L. Garwin** is a fellow at the IBM Thomas J. Watson Research Center and professor of public policy at the Kennedy School of Government at Harvard University. Both authors have been members of the President's Science Advisory Committee and consultants for many years to the Arms Control and Disarmament Agency and the Department of Defense.

The SUM system was a serious answer to a rhetorical question.

Two more facets of the Drell saga—nuclear weapon safety, reductions, and potential elimination

In 1990, in response to concerns about the safety of U.S. nuclear weapons, Sid was asked to form a congressional panel to analyze the problem and to recommend solutions. This was no easy task in such a highly classified and sensitive area, and to do a proper job, Sid recruited fellow physicists Charles H. Townes, and John S. ("Johnny") Foster, II, former Director of the Lawrence Livermore weapons laboratory, former DDR&E-- a highly respected and vigorous participant in many national security activities. Sid also had the good sense to recruit Bob Peurifoy, who had recently retired from Sandia National Laboratories, which provides the arming, fuzing and firing systems for U.S. nuclear weapons, and much of the engineering of the nuclear weapon itself. Peurifoy provided technical support and was the keeper of a mine of unclassified technical information with which he was intimately familiar.

Here I present several of the slides illustrating the 01/12/18 lecture by Raymond Jeanloz at SLAC recounting the Drell-Townes-Foster Nuclear Weapon Safety Study.

101st Congress 2d Session	COMMITTEE PRINT	No. 15

NUCLEAR WEAPONS SAFETY

REPORT

OF THE

PANEL ON NUCLEAR WEAPONS SAFETY

OF THE

COMMITTEE ON ARMED SERVICES
HOUSE OF REPRESENTATIVES

ONE HUNDRED FIRST CONGRESS
SECOND SESSION

DECEMBER 1990

J. 36-661

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON : 1990

For sale by the Superintendent of Documents, Congressional Sales Office
U.S. Government Printing Office, Washington, DC 20402

REPORT

of

THE PANEL ON NUCLEAR WEAPONS SAFETY

of

The House Armed Services Committee

SIDNEY D. DRELL, *Chairman*

JOHN S. FOSTER, JR.

CHARLES H. TOWNES

DECEMBER 1990

(III)

Beyond the very important content and conclusions of the Study, there was a big legacy within the JASON group, in the relationship of trust and mutual respect created by the Drell-Townes-Foster panel with the U.S. nuclear weapon laboratories—Los Alamos, Livermore, and Sandia. This stood the nation (and JASON) in good stead in continuing to maintain nuclear weapons reliable and safe despite the cessation of nuclear explosion testing in 1992 and helped lay the basis for the Comprehensive Nuclear Test Ban Treaty—CTBT—signed in 1995 but never ratified by the United States or China. Sid spearheaded JASON work with the White House and with DOE and DOD, and the creation of the National Nuclear Security Administration—NNSA—within the DOE, although his goal was a much more nearly autonomous NNSA than turned out to be the case.

Sid led the charge within JASON in helping to define the Science-Based Stockpile Stewardship Program—SBSSP—and to put reality behind the name. Over the years from 1994 to the present (more than a quarter century since the cessation of nuclear testing in 1992), Sid's work and that of his colleagues in the labs and in Washington has led to a better understanding of the U.S. nuclear weapon stockpile than we ever had before or could have had with reliance on nuclear explosion testing. Raymond Jeanloz provided insight on Sid's work in arms control and nuclear weapons at the SLAC memorial for Sid Drell, from which I use slides by permission.[5]

[5] 01/12/18 Raymond Jeanloz, SLAC Presentation, "Sid Drell: Beyond the Blackboard, *Physics of Nuclear Weapons,"* https://conf.slac.stanford.edu/siddrellsymposium/sites/siddrellsymposium-conf.slac.stanford.edu/files/Jeanloz.pdf

Science Based Stockpile Stewardship

S. Drell, Chairman

November 1994

JSR-94-345

Approved for public release; distribution unlimited

JASON
The MITRE Corporation
7525 Colshire Drive
McLean, Virginia 22102-3481
(703) 883-6997

NUCLEAR TESTING

Summary and Conclusions

Sidney Drell, Chair

JSR-95-320

August 3, 1995

(UNCLASSIFIED)
Cleared for release August 4, 1995

JASON
The MITRE Corporation
7525 Colshire Drive
McLean, VA 22102-3481
(703) 883-6997

"Stewardship" of US nuclear weapons

Objective: Provide technical basis for US adopting Comprehensive Nuclear Test Ban Treaty (CTBT)

The CTBT helped remove a considerable spur to proliferation of nuclear weapons and a path to the refinement of nuclear weapons and to the extension of fission weapons to the more economical and far more powerful thermonuclear weaponry.

But Sid was not slow to realize that these accomplishments alone would not suffice, but that active arms control and reduction and even the elimination of nuclear weapons were goals to be prized. His deep involvement with Andrei Sakharov in advocacy of human rights and arms control, and Sid's continual search for levers to achieve these aims, encouraged his involvement in organizing the "Gang of Four"—George P. Shultz, Sam Nunn, William J. Perry, and Henry A. Kissinger—and in creating its initial focus on "Reykjavik revisited" on the 20'th anniversary of the Reagan-Gorbachev summit. At their meeting in 1986, where President Reagan hoped to eliminate "fast fliers" (nuclear-armed ICBMs) and legitimize his Strategic Defense Initiative, USSR General Secretary Gorbachev countered with the elimination of all nuclear weapons world-wide. Gorbachev's insistence on confining SDI research "to the laboratory" and the U.S. team's studied lack of imagination that this might be a space laboratory killed this improbable initiative, that Sid and the Gang of Four revived in 2006.

As in his physics, Sid Drell has left an admirable legacy of conduct and substance that we should try our best to emulate.