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Physics and Society is the quarterly of the Forum on Physics and Society, a division of the American Physical Society. It presents letters, commentary, book reviews and reviewed articles on the relations of physics and the physics community to government and society. It also carries news of the Forum and provides a medium for Forum members to exchange ideas. Opinions expressed are those of the authors alone and do not necessarily reflect the views of the APS or of the Forum. Contributed articles (2000 words maximum, technicalities are encouraged), letters (500 words), commentary (1000 words), reviews (1000 words), and brief news articles, are welcome. Send them, in hard copy plus (if possible) a Mac or PC disk, to the editor: Art Hobson, Physics Department, University of Arkansas, Fayetteville, AR 72701, 501-575-5918, fax 501-575-4580, bitnet ahobson@uafsysb. Typist: Sandra Johnsen. Layout: Page Perfect of Fayetteville.

LETTER

The Forum—Good Folks Indeed

"Form letters" are always less than satisfactory when responding to a kindness, but I'm forced to the expedient because of the very great reaction to the appeal for support of The James Randi Fund. I've heard from folks I've never met and received letters from organizations that recognize the importance of the present battle, and I've been more than dazzled by the response. Over 300 contributions, small and large, have come in so far. Three major payments from The Fund have been made to my legal advisors. In addition, I have launched two suits against publications that have chosen to misrepresent my cause. Of course, no fund money has been used to pay for that service

The opposition has been frantically issuing inane accusations against me and my supporters in an attempt to direct attention away from the issues. In a few cases, those charges have been taken seriously, but I hope that most of you choose to remember who made those allegations, and why. Quite simply, the opposition is unable to attack the facts, so they attack my reputation with wild statements just too nutty to deny. Please bear with me until I'm able to properly discuss and refute the garbage that certain persons have been circulating.

The judge in the case has ruled that Mr. Geller must now prove his psychic powers under deposition.

Things look good. Well, most things. In some desperation, Mr. Geller recently appeared on UK television stripped to his shorts in a performance of the compass-deflecting miracle, thus scientifically proving he had no concealed magnets by which this wonder might be accomplished. He chose to inform the TV audience that the skeptics could now only explain the effect by claiming that he had concealed a magnet in his "goolies." No translation is needed. I hereby offer to determine, with the proper instrument, whether his claim is justified.

The judge in the case has ruled that Mr. Geller must now prove his psychic powers under deposition. *That* should be very interesting to see, don't you think? I can't wait.

The skeptical groups and the academic community have rallied to this cause, expressing their dismay that the situation has been allowed to get so much out of control. However, I am confident that we are now in an excellent position to at last finish the controversy. Our battle will soon be won, and with it some landmark decisions. Your support has made this possible, and I know that you'll enthusiastically share the victory with me.

To those very few who have chosen to accept the desperate rantings of the opposition, I'll only say that I will not, in fact cannot, respond to such nonsense—at present. I'll not play the mud-slinging game to which I've been lured. Let them flounder around in their desperation to escape the situation they have made for themselves. I'll throw them a life-preserver when they're going under. A cement one.

Hang in there and await good news, and please accept my grateful thanks for your needed support and encouragement. You're good folks indeed.

James Randi
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ARTICLE

Limits on the Coverage of a Treaty-Compliant ABM System

Lisbeth Gronlund and David C. Wright

Last fall, the US Congress adopted the Missile Defense Act of 1991, which mandates the Secretary of Defense to "develop for deployment by the earliest date allowed by the availability of appropriate technology or by fiscal year 1996 a cost-effective, operationally effective, and ABM Treaty-compliant" missile defense system, to consist of 100 interceptors based at a single site. This system is seen as the first step toward a multiple-site continental missile defense that would not comply with the ABM Treaty. Thus the Act calls for renegotiation of the ABM Treaty, and if renegotiation is not possible, the Act states the US will "consider the options available—as now exist under the ABM Treaty," which includes withdrawing from the treaty with six months notice. The Act, however, explicitly states that it does not constitute a deployment decision, and that such a decision will require additional approval by Congress.

The Missile Defense Act was carefully worded to allow ABM Treaty supporters to vote for missile defenses in the aftermath of the Gulf War. However, a Treaty-compliant ABM system is not a viable compromise between missile defenses and the ABM Treaty: We show here that a Treaty-compliant system would protect only limited portions of the US even if the system worked flawlessly, leaving uncovered the east and west coasts and the southern US. Building a system that could even in principle adequately cover the coasts would violate the ABM Treaty.

A Treaty-compliant ABM system is not a viable compromise between missile defenses and the ABM Treaty.

Thus, Congressional supporters of the ABM Treaty should realize that making a deployment decision before renegotiating the Treaty implies a willingness either to spend large amounts of money on a treaty-limited system that even in principle can only be marginally effective, or to unilaterally abrogate the treaty, if mutually-agreeable changes cannot be negotiated. Although Russian President Boris Yeltsin has proposed developing joint US-Russian ground-based defenses, he has clearly stated that he will not relinquish the ABM Treaty if the US proceeds with unilateral development and deployment and that, in any case, he is opposed to deployment of space-based interceptors (1).

Of course, any reasoned support for missile defenses requires an assessment of the possible threats and alternative methods of dealing with them. Accidental or unauthorized nuclear attacks by the former Soviet republics would be more effectively addressed by deploying destruct-after-launch systems (2), and the CIA director recently asserted that there will be no long-range missile threats to the continental US from developing countries other than China for at least a decade (3).

Coverage of a battle-management radar at Grand Forks

Since there have been contradictory statements in recent months about the capabilities of a treaty-compliant ABM system, we describe below how to calculate the coverage of this system. Specifically, we consider the limits on the coverage provided by a ground-based ABM radar; other factors will further limit the capabilities of a treaty-compliant ABM system (4).

The assumptions made about the direction and apogee of the trajectories of incoming missiles are critical, and it is important to check the sensitivity of the results to variations in these assumptions. For example, coverage results presented in SDIO briefings often assume that missile attacks originate in central Russia, against which a site at Grand Forks has the best coverage, and that the missiles will be flown on standard "minimum-energy" trajectories. We show below that the defended area can change considerably if the trajectories are depressed slightly. Flying on such trajectories might degrade the accuracy of the missiles slightly, but flying existing missiles on such trajectories would not be difficult (5). Table 1 lists all relevant trajectory parameters for the cases we consider.

The ABM treaty allows deployment of 100 interceptors at a single site (chosen by the US to be at Grand Forks, ND), and requires that the ABM battle-management radars, which track incoming missiles and guide the interceptors to their targets, be located within 150 kilometers of the ABM site (Articles III, VI). The treaty restrictions on the location of ABM radars were formulated specifically to limit the capability of the ABM system to provide a nationwide defense, since this was a central objective of the treaty.

The distance at which a battle-management radar can see an incoming missile is limited by the inability of the radar to see around the curve of the earth (6). For this reason, a radar at Grand Forks would be unable to see missiles aimed at large portions of the US from a wide range of directions (7). This fundamental limit means that a treaty-compliant ABM system would be unable to defend the majority of the US population, regardless of the range or flight time of the ABM interceptors.

The radar coverage problem is illustrated in Figure 1. We assume a new radar capable of looking in all directions would replace the existing radar at Grand Forks left over from the Safeguard system, which looks only north. The bold line shows the lower limit of the radar field-of-view of an ABM radar at Grand Forks out to several thousand kilometers (calculation of the radar field-of-view limit is discussed below). The lighter lines show the flight paths of two SLBMs on standard (mini-

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mum-energy) trajectories with ranges of 3000 and 7400 kilometers (km) launched from the Atlantic Ocean and targeted on Washington DC. The dashed line indicates the flight path of an SLBM on a 3000 km range depressed trajectory with an apogee of 150 km.

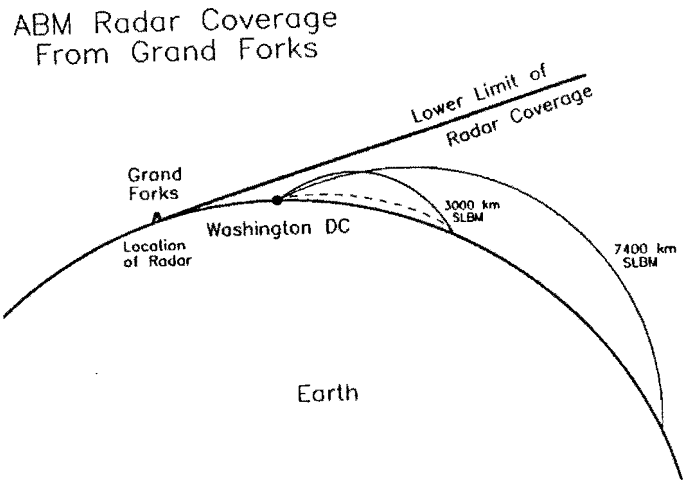

Figure 1. The lower limit of the coverage of an ABM radar at Grand Forks, ND. The distance between Grand Forks and Washington DC is roughly 1900 km. (Washington DC, New York, Boston, San Francisco, and Los Angeles all lie 1900-2300 km from Grand Forks.) Also shown are flight paths of two SLBMs launched from the Atlantic Ocean on standard (minimum-energy) trajectories with ranges of 3000 km and 7400 km; both stay below the region of radar coverage throughout their flights. The dashed line is the flight path of an SLBM on a 3000 km range depressed trajectory with an apogee of 150 km; such a trajectory could underfly the radar field-of-view to attack targets far inland.

As Figure 1 shows, the radar would be unable to see these missiles at any point during their flights, and thus would be unable to guide the interceptors to attack the missiles. As is also evident from Figure 1, regions hundreds of kilometers inland from Washington would also not be covered by the radar. Similarly, a radar based at Grand Forks would never see SLBMs launched from most of the Atlantic and Pacific Oceans against the east and west coastal areas, and all of the southern US (8). Thus a Grand Forks ABM system could not protect those regions of the continental US containing most of the population from such an SLBM attack. (There would also, of course, be no coverage of Alaska or Hawaii.)

Building a system that could even in principle adequately cover the coasts would violate the ABM Treaty.

For a single-site system, the Grand Forks radar is nearly optimally located to detect missiles aimed at the continental US from the former Soviet republics, and could in theory provide coverage of the central US against such attacks. However, ICBMs launched from missile fields near Moscow on standard, or in some cases slightly depressed, trajectories could underfly the radar to attack New York and northeast coastal areas, as could ICBMs launched against San Francisco and northwest coastal areas from missile fields in far eastern Russia. Yeltsin recently announced that Russia would no longer target the US, removing the possibility of an accidental attack. However, if Russia once again targets the US, it could be expected to reprogram its missiles to fly on slightly depressed trajectories to avoid US defenses if they were built, and thus the ABM radar would be unable to detect even an accidental launch of one of these missiles. Moreover, an unauthorized attack would presumably be targeted to avoid US defenses.

Similarly, missiles launched from China against San Francisco and the northwest coast of the US would never enter the ABM radar's field-of-view.

A radar at Grand Forks would also provide coverage of only a limited part of the US against hypothetical missile attacks from developing countries. If a country in the Middle East were able to acquire an ICBM in the future, the radar would not be able to see such a missile launched against Boston, New York, Washington or other targets on the east coast. Similarly, this system would not cover San Francisco and the northwest coast against a hypothetical future ICBM launched from North Korea. The radar could not see hypothetical missiles launched from countries in South or Central America or the Caribbean region against large portions of the continental US. Any country with only a few missiles would target cities, many of which would be left uncovered by the radar. In the case of a country with a small arsenal, partial coverage of the US is equivalent to no coverage.

Treaty compliance issues

The most obvious way to increase the coverage of an ABM system would be to build multiple ABM sites. Doing so is unambiguously prohibited by the treaty, as is deploying additional ABM radars outside of Grand Forks.

Cuing the Grand Forks ABM radar from early-warning radars or other sensors would not alleviate the radar coverage problem discussed above since we consider the extreme case in which the missile or RVs *never* enter the field-of-view of the radar.

Since in these cases the RV is never seen by the radar, extending the coverage of a single-site system to include missiles on these trajectories would require developing intelligent interceptors that could guide themselves to their target using onboard sensors after being cued by other sensors, such as satellites or ground-based sensors at other sites. However, any such approach would involve some sensor substituting for the ABM radar, and thus would be a clear violation of Agreed Statement D of the Treaty.

Calculation of radar coverage

The radar field-of-view is assumed to extend down to inclination angles of 3^{o} above the local horizontal (9). Due to the decrease in atmospheric density with increasing altitude, radar waves bend toward the earth slightly as they propagate through the atmosphere. This effect was accounted for using the standard method of calculating the radar propagation in the absence of an atmosphere, but assuming the earth's radius is 4/3 its actual value (10). This refraction effect was included until the beam was above 100 km altitude; at higher altitudes atmospheric effects are negligible and the beam was extrapolated linearly.

Since in general the radar, target, and launch point will not lie in a plane (Figure 2), we use the following method to determine whether a missile on a particular trajectory (with a given range and apogee) approaching a target from a particular direction can be seen by the radar. Given the relative location of the radar and target, and the particular trajectory of interest, we change the direction of the attack by increasing the angle ϕ (see Figure 2) until the trajectory first intersects the radar field-of-view at ϕ_o. Thus, the radar will never see a trajectory launched from a direction ϕ that is less than ϕ_o. This method actually over-estimates the directions of attack that an ABM system would be able to defend against since our criteria is that the trajectory intersect the radar field-of-view at a single point, and the radar would actually have to see the RV for a longer period to be able to direct an interceptor to attack it.

Details of the Calculation

We choose the origin of our coordinate system to be at the center of the earth, with the z-axis pointing at the radar (assumed to be at Grand Forks, ND). The x-z plane contains the radar and the target (Figure 3), and ψ is the range angle between the radar and the target, defined as the range between them divided by the radius of the earth (Re).

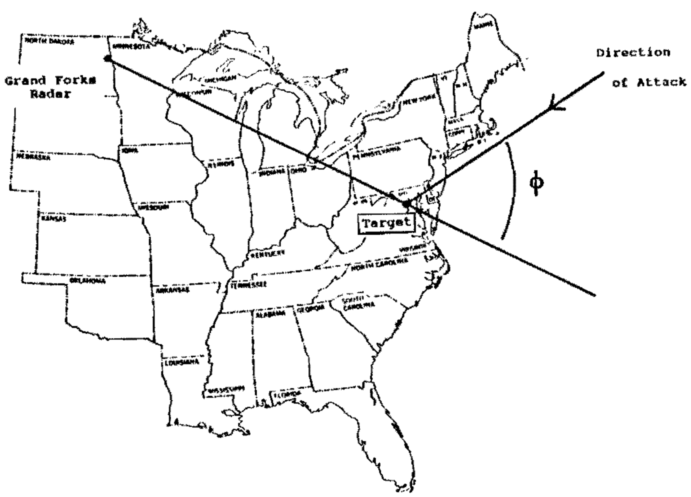

Figure 2. The direction of attack ϕ, as measured from the line connecting the Grand Forks radar and the target (in this case, Washington, DC).

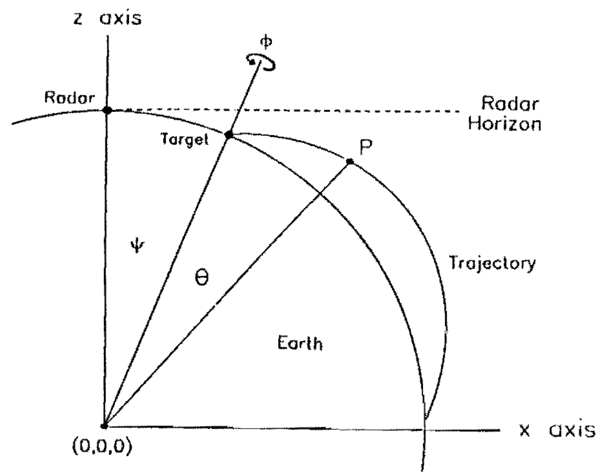

Figure 3. Coordinate system and angles used in the radar coverage calculation. The figure shows a cross-sectional view of the earth, with the x-z plane containing the radar and the target. The y-axis points into the page.

In the region of interest for this calculation, we find that the net effect of the 3^o inclination angle and the bending in the atmosphere is to give a lower limit of the radar field-of-view that can be approximated by a plane perpendicular to the z-axis, defined by all points with $z = Z_R \approx R_e + 40$ km.

We then consider the particular trajectory of interest (with specified range and apogee) lying in the x-z plane and terminating at the target, and choose a point P on this trajectory. P can be specified by its height h above the earth and its range angle θ from the target, and has coordinates $(x,y,z) = ((h+R_e)\sin(\psi+\theta), 0, (h+R_e)\cos(\psi+\theta))$. A right-handed rotation of the trajectory by an angle ϕ about the line from the center of the earth to the target can be performed by rotating P using the rotation matrix M:

$$M = \begin{bmatrix} \cos^2\psi\cos\phi+\sin^2\psi & -\cos\psi\sin\phi & \cos\psi\sin\psi(1-\cos\phi) \\ \cos\psi\sin\phi & \cos\phi & -\sin\psi\sin\phi \\ \cos\psi\sin\psi(1-\cos\phi) & \sin\psi\sin\phi & \sin^2\psi\cos\phi+\cos^2\psi \end{bmatrix} \quad (1)$$

The rotated point P' = MP will intersect the radar's field-of-view when the z-component of P' equals Z_R. This will occur at a value of ϕ given by:

$$\cos\phi = [\cos\psi\cos\theta - Z_R/(R_e+h)] / \sin\psi\sin\theta \quad (2)$$

By examining all points P on a trajectory using this method, one can determine the rotation angle ϕ_o for which the trajectory first intersects the radar field-of-view at a single point. A missile approaching the target on this trajectory along a direction given by ϕ that is less than ϕ_0 will never be seen by the radar. For each target, the orientation of the target relative to the radar must be taken into account, since the angle ϕ given in Equation (2) is measured with respect to the line between the target and radar. Table 1 gives our results for several launch points and targets.

Table 1. Radar coverage of a trajectory of the listed range and apogee launched against the target from the launch point.[a]

Launch point and target	Range of trajectory (km)	Direction of attack ϕ (deg)	Apogee of trajectory (km)	Min radar coverage ϕ_0 (deg)	Trajectory seen by radar? ($\phi_0<\phi$?)
Moscow to:					
Wash. DC	7800	110	1400	60	yes
			1200	72	yes
New York	7400	88	1350	64	yes
			1100	79	yes
			900	92	no
Boston	7100	79	1350	67	yes
			1100	81	no
Svobodnyy to:					
L.A.	8500	104	1450	82	yes
			1200	91	yes
			1000	100	yes
San Fran.	7800	90	1400	79	yes
			1200	88	yes
			1100	92	no
Seattle	7100	58	1350	67	no
Luoning to:					
San Fran.	9500	87	1500	86	marginal
			1300	92	no
N Korea to:					
San Fran.	8500	82	1450	82	marginal
			1200	91	no
Libya to:					
Wash. DC	7800	61	1400	60	marginal
			1200	72	no
Boston	7400	51	1350	64	no
Iran to:					
Wash. DC	10,000	94	1500	74	yes
			1200	88	yes
			1000	97	no
Boston	9500	74	1500	79	no

Note:
a. The trajectory is never seen by the radar if $\phi_0 > \phi$. Launches from Moscow refer to the missile fields in the Moscow region. Svobodnyy is a missile field in far eastern Russia. Luoning is a missile field in eastern China. Approximate ranges are used since the radar coverage depends more on the apogee than the range of the trajectory. For most pairs of targets and launch points, we consider two or more trajectories with different apogees. In each case, the highest apogee trajectory listed is the "minimum energy" trajectory for that range. As the apogee is decreased, it becomes more difficult for the radar to see the trajectory.

References and notes

1. Don Oberdorfer and R. Jeffrey Smith, *Washington Post*, 2 February 1992, A26; Aerospace Daily, 4 February 1992, 183.
2. Sherman Frankel, *Science and Global Security*, Vol. 2, November 1990, 1.
3. Robert M. Gates, Hearing before the Senate Committee on Governmental Affairs, 15 January 1992; also Lora Lumpe, Lisbeth Gronlund, and David C. Wright, *Bulletin of the Atomic Scientists*, March 92.
4. See e.g. Anthony Fainberg, *Arms Control Today*, April 1989, 17.
5. Lisbeth Gronlund and David C. Wright, *Physics and Society*, January 1991, 13; *Science and Global Security*, to be published.
6. Over-the-horizon backscatter (OTH-B) radars, which "bounce" radar energy off the ionosphere in order to see around the curvature of Earth, are unsuitable for ABM battle-management for a number of reasons, including their long wavelength and performance limitations imposed by their ionospheric propagation.
7. Early-warning radars would detect incoming missiles, but are not capable of serving as ABM battle-management radars.
8. A radar at Grand Forks could detect Russian SLBMs launched from bastions north of Russia.
9. Gen. John C. Toomay (ret.), in *Managing Nuclear Operations*, ed. by A. B. Carter, J. D. Steinbruner, and C. A. Zraket (Brookings Institution, Washington DC, 1987), 298.
10. J. L. Eaves and E. K. Reedy, *Principles of Modern Radar* (Van Nostrand Reinhold, New York, 1987), 54. Refraction in the ionosphere, which is important for radio waves with frequencies less than 30-50 MHz (Eaves and Reedy, 63), is ignored in our calculation since the frequencies of interest are several hundred MHz (Toomay, 284).

REVIEW

Teller's War, by William J. Broad

Simon & Schuster Publishers, New York, 1992, 350 pp.

When I served as a William C. Foster Fellow at the Arms Control and Disarmament Agency and held most of the appropriate clearances (you never know if you hold *all* the appropriate clearances, because you usually don't know of the clearances you don't have) it was part of my job to follow the progress of the Excalibur x-ray laser project. Over the course of a year it became clear to me that the hard experimental data coming from holes under the Nevada desert could not be reconciled with the optimistic pronouncements radiating from the Oval Office. Somebody, it seemed, was lying to the president. Surely the data did not support the notion that one could begin the engineering design on real anti-missile weapons. Or else I was missing something, and so were the scientists from Livermore who briefed us.

Teller's War recounts an American scientific tragedy, with a great scientist, Edward Teller, as the protagonist who remains unredeemed in the end, and an unassuming hero, Roy Woodruff, riding from a small state university to do battle in the name of scientific honesty—no more and no less. Bill Broad, the author, traces both men from childhood to the fields of battle, Livermore, Mercury, Nevada, and the White House. In American mythology there would have been no contest; Teller would have been vanquished for his undoubted arrogance, slick tales, and super salesmanship. In real life, Woodruff came within a microsecond of being annihilated, and was saved only by the success of a grievance case. Teller continues to hold a dominant position in the nuclear weapons community.

> *Teller's War recounts an American scientific tragedy, with a great scientist, Edward Teller, as the protagonist who remains unredeemed in the end.*

According to Broad, in 1984 Teller told Robert McFarlane, President Reagan's national security adviser, that the x-ray laser might be "accomplished in principle" by 1987. The bearded Lowell Wood, Teller's sidekick, counseled a kind of caution, saying that even large amounts of money might not bring proof of principle until 1990, at which time engineering work could begin on a "baseline" weapon with 1,000 separately aimed beams. When Woodruff became convinced that Teller and Wood had significantly exaggerated the results obtained in "down hole" tests, he took quiet steps to set the record straight—writing letters, giving briefings, speaking within the chain of command.

As the Associate Director for Defense Systems of Livermore, Woodruff was the scientist who carried responsibility for all weapons development work done at the lab, including x-ray lasers. In fact, Teller wielded the power to make and break not merely associate directors, but even directors such as Roger Batzel and John Nuckolls. The situation was made worse by criticisms from without that Woodruff and his deputy would not rein in Wood; Roy wrote that it "did not help to respond with the fact that Lowell Wood does not report to me." The conflict went critical on October 31, 1985 when Roy Woodruff, having found, in Broad's words a "vacuum at the top" in the form of laboratory director Roger Batzel, resigned. Woodruff's troubles were just beginning.

It was not uncommon at Livermore for scientists to rise to executive positions and then return to scientific work. They retained their salaries, their prestige, and generally became part of an influential old-boys' network. Woodruff, however, had his salary reduced, his office became a cubbyhole, and his in-box was perpetually empty. But it slowly became clear that the x-ray laser experiments had largely been failures. The critical test, as Broad describes it, was Goldstone, conducted on 28 December 1985.

Goldstone was political science as well as experimental science. A host of dignitaries ranging from Lieutenant General James Abrahamson, head of the Strategic Defense Initiative Organization, up to Secretary of State George Schultz and Ambassador Paul Nitze, were limousined in to watch the mountain jump. The graded area on top of Pahute Mesa did, indeed, recoil, but the instrument canister of the test device has been bent, Broad reports, when the bore hold was stemmed. Although many of the experiments reportedly failed to register properly, Broad indicates that at least one did. For the first time the brightness of an x-ray laser flash was measured; the results were devastating. In Broad's words, "all the top-secret hoopla about the various forms of Excalibur eventually being a million, a billion, or a trillion times brighter than a hydrogen bomb had been dealt a devastating blow. The claims Teller made to the White House now seemed almost comical. The simple fact revealed by Goldstone was that the laser's brightness was about ten times less than previously believed. In short, the laser was extremely inefficient. It was relatively dim. —It was like the owner of a new car suddenly discovering that his engine produced 10 horsepower instead of the 100 advertised by the dealer." Despite the millions spent on the x-ray laser since Goldstone, despite a delicate attempt by the General Accounting Office to paper over the failure, the nuclear laser sword would be returned to its resting place in the stone, but the blood of reputations ruined would dampen the Nevada sand.

For Roy Woodruff the battle for reputation and status would continue, eventually culminating in a successful grievance suit and an eventual move to a new job in the arms control program of Los Alamos. One wag commented that Livermore had not proved 'big enough for (name deleted) and Roy; the wrong one left."

Teller's War tells a tale of two scientists, but it might as well have included a third, J. Robert Oppenheimer, father of the fission weapon if Teller is father of the fusion one. I was struck by the similar flaws in the careers of these two giants of mid-century nuclear physics. Each was world class, and was recognized by his peers as such from the start of his career. Each founded a weapons laboratory which would carry on in his own spirit. And neither made that single great discovery that would place by their names the only honor that, I think, counted for both—Nobel Prize winner. The seeds of their troubles, those of Oppenheimer and Teller alike, lie in that simple fact. Woodruff, who never aspired to such an honor, is the improbable hero of this tale, a brilliant physicist without a Ph.D., a man to whom scientific truth and personal integrity were worth more than position and title. He is deserving of great respect in our profession. Bill Broad should have earned a third Pulitzer Prize for this new book which recounts Woodruff's story.

Honesty compels me to point out that the observant buyer of *Teller's War* will find that I provided a laudatory quote for the dust jacket of the book. Yes, I did see it in proof form; and I liked it well enough at that early stage to praise the technical and journalistic detective work of its author. The completed book is far better than the galleys were. Bill Broad has a magnificent ability to capture the sounds and sights of physicists at work. As he demonstrated in *Star Warriors*, his earlier book on Lowell Wood and the "O" Group at Livermore, he understands how we work and think, what motivates us. His two books on SDI and the creators of the x-ray laser provide insight into the bright and dark sides of our profession; any physicist with an interest in the interface where physics meets policy should own both volumes.

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NEWS

John Dowling

John Dowling died of cancer on 14 September 1991 at the age of 53. He served the Forum on Physics and Society in many capacities including editing *Physics and Society* for 6 years and chairing the Forum's first study group, on civil defense. At the time of his death, he was a professor of physics at Mansfield State University where he had taught since 1970. Dowling dedicated his professional career to promoting public understanding of the impact of physics on vital social issues. In the physics community, he constantly urged physicists to apply their technical expertise to such important areas of physics as the nuclear arms race and the national energy supply.

Dowling obtained his undergraduate degree in physics from the University of Dayton in 1960, and completed a M.S. in 1962 and a Ph.D. in 1964, both at Arizona State University. Following a postdoctoral appointment at the University of Florida, he taught for four years at the University of New Hampshire before being hired by Mansfield State University. In 1975, he received a State of Pennsylvania Distinguished Teaching Award. He served as chair of the Physics Department from 1981-84.

Dowling was an expert on the use of films in physics instruction. He edited *A Cinescope of Physics* which was published in 1978 by the American Association of Physics Teachers. He reviewed films for several science publications including serving as film review editor of the *Bulletin of the Atomic Scientists* (1979-84) and the *American Journal of Physics* (1976-82). In the late seventies, he became concerned about the unchecked buildup of nuclear weapons and became a nationally recognized expert on media used to present arms race issues to students. He published the *War Peace Film Guide* in 1980 and co-authored the *1984 National Directory of AV Resources on Nuclear War and the Nuclear Arms Race* with Karen Sayre. He also lectured widely on teaching about the technical aspects of the nuclear arms race to groups both within and outside the physics community.

In 1980, he accepted the job of editing *Physics and Society*, the newsletter of the Forum on Physics and Society. Under Dowling's six years of leadership, the quarterly newsletter became a medium for sometimes heated discussion of technical issues which impact society. In particular, Dowling promoted widespread discussion of the technical and political aspects of the Strategic Defense Initiative.

During 1983-87, Dowling chaired the Forum's study group on civil defense, and established the pattern followed by all subsequent studies. The report of the study, *Civil Defense: A Choice of Disasters*, which he co-edited with Evans Harrell, was published by the American Institute of Physics in 1987. Dowling then joined the Forum's energy study where he worked actively and authored two chapters on agriculture and hydroelectricity in the final report of the study, *Energy Source Book*, published by AIP in 1991. He presented a summary of the results of the study on energy resources not related to fossil fuels at an invited session of the American Physical Society in April 1991, shortly before his illness forced him to curtail his activities.

Those of us who had the privilege of working with John will especially miss his common sense and personal kindness that seemed rooted in the Pennsylvania farm on which he loved to work, as well as his seemingly unlimited supply of really terrible physics-related jokes.

Ruth Howes
Ball State University
Muncie, Indiana

Anthony Fainberg
Stanford University
Stanford, California

A Review Editor for *Physics and Society*

Physics and Society is delighted to announce that its board of editors will soon double in size, from one to two.

Kenneth S. Krane, Professor of Physics, Chair of the Oregon State University Department of Physics, and an experienced textbook author, will edit reviews. He hopes to expand our quarterly's coverage of books, and to expand that coverage to include films, articles, and other items.

The Forum has long felt *Physics and Society* should focus on the scholarly discussion of science-and-society issues. Books certainly stand at the center of this focus. With the able assistance of Professor Krane, *Physics and Society* will now be able to play a fuller role in this area.

Welcome aboard, Ken!

Forum Chair's Report for 1990-91

It was a privilege to serve the Forum as Chair in 1990-91. I appreciated the support of many of you, and learned much from ideas offered throughout the year. The experience reaffirmed my longstanding sense that the dynamism of the Forum depends on the commitment and active participation of its membership, rallying around the concept that we, as physicists, can see and constructively influence the interactions of our work with the concerns of society as a whole.

Activities

The forum sponsored an active program of sessions at APS meetings in 1990-91, under the effective leadership of Vice Chair Ruth Howes. We continued two relatively new approaches of the previous year, namely actively seeking opportunities to co-organize or co-sponsor sessions with other divisions or committees of the APS, or colleague professional societies. We also sought to broaden our attention to areas of societal interest beyond the arms control matters in which the Forum plays such an important role. Both approaches may serve to help build the base of APS membership interest and participation in the Forum.

Our committee structure was regularized to insure better participation and continuity in our important functions of recognizing leadership, through the prestigious Szilard and Forum awards, nomination to APS fellowship, and nomination for Forum offices. The Executive Committee and others were asked to suggest Committee nominations to broaden the participation in Forum leadership by relatively unrepresented groups and younger members, and we succeeded to some extent in this.

Our awards activity produced a memorable session at the Washington meeting, with the Szilard Award presented to Dr. John Gibbons, Director of the Congressional Office of Technology Assessment, and the Forum Award to Victor Weisskopf, of MIT. Professor Weisskopf was unable to attend due to illness, but Professor Hans Bethe accepted the award for him. In the Awards session, Professor Bethe gave a uniquely insightful tribute to Dr. Weisskopf's role in the movement within physics to make those in our profession active participants in influencing society's applications of our work. Dr. Gibbons' acceptance speech was equally memorable, particularly stressing the evolution of institutional mechanisms to understand implications of technology. The Forum was privileged to have these leaders with us for the evening, reminding us of how important it is to help build recognition of the societal implications of our science.

The Gulf War stimulated a healthy debate within the Forum on the impact of the new generation of sophisticated non-nuclear weapons, and the role of the physics community in leading professional and/or public discussion of them. The initial Forum Newsletter article on the matter provoked concern about balance, but also stimulated the debate in a way which a more bland approach would have failed to do. The various ideas and energy of the debate participants have resulted in the formation of a working group aimed at defining a Forum Study on the implications of such non-nuclear weapons technology. All in all, I believe that this discussion has been in the best tradition of Forum activities: timely, lively, and important for physicists and society as a whole.

The Forum's Energy Study was published during the year by AIP. The many contributing authors as well as Editors Ruth Howes and Tony Fainberg deserve much recognition for their efforts.

The Forum also presented an excellent Short Course, "Global Warming: Physics and Facts," at the 1991 Spring APS meeting in Washington, DC. Dave Hafemeister and Barbara Levi led the organization of the course, with the cooperation of Georgetown University. It continued the Forum tradition of excellent and timely short courses to enhance the activities of APS meetings.

A new Forum "Information Sheet" was produced with the help of the Executive Committee. It summarizes the purpose and goals of the Forum, as well as its activities such as the meeting sessions, books and short courses. It is designed for use as handout at Forum sessions, meeting registration desks, or for mailing. *The Forum's information sheet appears on a separate page in this newsletter, for you to photocopy and hand out and post! Help the Forum grow—only 10% of the APS members belong to the Forum !*

Because of changes in the APS constitution and bylaws, certain revisions are required in the Forum bylaws. Heinz Barshall led discussion of the needed changes, and a committee was formed to draft these.

The Forum proposed candidates for election to APS Fellowship, and three were elected (Rochlin, Zimmerman, and Allen). The APS Council also passed, at Forum Executive Committee suggestion, a special resolution of commendation in October for the Newsletter Editor, Art Hobson.

Unsolved Issues

Two issues of great concern to me as I left the Chair were that of increasing the Forum membership, and broadening the active group within that membership. The finances of the Forum as well as its recognition depend on a large membership within APS, and with the high level of APS activity in public affairs, we should be able to increase the Forum enrollment. Moreover, if we are to keep the Forum at the cutting edge of the impact of physics on society, we must bring new and younger members into the group, and be sure we fully represent various points of view and new issues. An active membership committee is needed, with a strategy to increase and broaden membership.

A last area of concern is seeking an endowment for the Forum and Szilard prizes. We have had a distinguished group of winners through the years, and can build on the unique impact of this year's Award session. However, in the long run, it is probably not viable to try to squeeze the prize awards and expenses out of regular revenues. These important awards must be safeguarded by finding an endowed basis for their expenses.

Thomas H. Moss
Chair, Forum on Physics and Society, April 1990-April 1991

Join the Forum! Receive *Physics and Society*!

Physics and Society, the quarterly of the Forum on Physics and Society, a division of the American Physical Society, is distributed free to Forum members and libraries. Nonmembers may receive it by writing to the editor; voluntary contributions of $10 per year are most welcome, payable to the APS/Forum. We hope that libraries will archive *Physics and Society*; Forum members should request that their libraries do this.

APS members can join the Forum and receive *Physics and Society* by mailing the following information to the editor or to the APS office:

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THE FORUM ON PHYSICS AND SOCIETY

A division of the American Physical Society

The Forum of Physics and Society is a division of the APS, organized in 1971. It is dedicated to providing APS members with an outlet for activities and discussions related to the interface of physics and the concerns of society as a whole. Its publications and sponsored symposia are not meant to represent the positions of the APS as an organization but to provide a lively setting for technically well-grounded discussions among scientists who may differ widely on policy implications of scientific data.

APS SESSIONS

Over the past four years, the Forum has held 39 public sessions at APS meetings, plus four topical short courses. Our goal is to provide a timely forum to discuss and debate technical issues of broad national interest. For example, at the 1984 Plasma Physics meeting, the Forum sponsored a debate between government panelists and the Union of Concerned Scientists on the SDI, years before formal APS and other studies. Forum sessions promote understanding of technical foundations of policy issues, and include speakers spanning the range of responsible policy positions. Topics have included: acid rain, SDI, fusion power, ozone hole, DOD production reactors, mobile ICBMs, nuclear test ban verification, nuclear winter, conventional weapons, Challenger disaster, CTB, Chernobyl, big/little physics, Nevada Test Site, born secret, renewable energy, solar cells, EMP, on-site inspection technologies, and stable force configurations.

PHYSICS AND SOCIETY

Over the past 18 years, *Physics and Society*, the Forum's newsletter/journal, has been upgraded in content and style to include original research articles, letters, and regular book reviews as a substantial quarterly. It has become a lively and technically credible forum for expression of a wide range of views on physics and society.

SHORT COURSES

- Nuclear Arms & National Security: San Francisco APS Meeting 1982, Baltimore APS 1983, Baltimore APS 1988.
- Energy: Baltimore APS 1985.
- Global Warming: Washington APS 1991.

BOOKS

- *Physics Careers, Employment and Education*, Perl, AIP 1977.
- *Physics, Technology, and the Nuclear Arms Race*, Hafemeister/Schroeer, AIP 1983.
- *Energy Sources: Conservation and Renewables*, Hafemeister/Levi/Kelly, AIP 1985.
- *Acid Rain: How Serious and What to Do*, Hafemeister, AAPT 1985.
- *Civil Defense: A Choice of Disasters*, Dowling/Harrell, AIP 1987.
- *Nuclear Arms Technologies in the 1990s*, Schroeer/Hafemeister, AIP Volume 178
- *The Future of Land-based Strategic Missiles*, Levi/Sakitt/Hobson, AIP 1989.
- *The Energy Sourcebook*, Howes/Fainberg, AIP 1991.

FORUM STUDIES

- Civil Defense, chaired by J. Dowling and E. Harrell, 1984-86, AIP book 1987.
- Land-Based Strategic Missiles, chaired by B. Levi, 1985-88, AIP book 1989.
- Energy, chaired by R. Howes, 1988-90, AIP book 1991.

MEMBERSHIP

Forum membership is free to APS members. Just check off "Forum" on your annual membership form, or mail in the form that appears in every Forum newsletter.

APRIL 1992/10

COMMENT

Nuclear Proliferation and Limited Nuclear War

Evgeny N. Avrorin (October 1991) has drawn attention to the need to maintain constructive cooperation in the area of US-USSR nuclear arms control and disarmament. However, in this author's opinion, nuclear proliferation also deserves our most serious attention.

The root of proliferation concerns is the fear that nuclear weaponry is a grave and mounting threat to global stability. This threat could materialize in at least four ways. Foremost is the clear danger that nuclear weapons will actually be used. It is fairly clear that the statistical probability of use increases with the spread of nuclear weapons, other things being equal. Second, newly established nuclear powers (India, Pakistan, China) could enter a nuclear arms race which might be politically destabilizing and, in itself, increase the likelihood of a nuclear war. Third, the expanding quantity and distribution of weapons will increase the opportunities for theft, illicit sale, and sabotage. Finally, proliferation will further destabilize the present unstable structure of the international political system as the acquisition of weapons alter the distribution of power.

The case of Iraq demonstrates that the technical and economic barriers to proliferation are declining as accessibility to nuclear weapons material and technology becomes more widespread. Thus, the choice of acquiring a nuclear weapons capability or not will hinge on whether a state views such a capability as being, on balance, in its self interest. Several states on every list of potential new nuclear weapons states (Argentina, Iraq, Israel, North Korea, South Korea, Taiwan) have reasons to fear direct attack or long-term security deterioration vis-a-vis regional adversaries. Recent events in the Near East and Eastern Europe make such considerations even more cogent. Countries such as Poland and Czechoslovakia may find it advantageous to develop their own, albeit limited, nuclear deterrence capability against both Germany and USSR. In addition, there is the perception by many states that they have more options to pursue national objectives as a nuclear state than as a non-nuclear state. France is an example of this reasoning. Lastly, aside from its symbolic significance, a nuclear weapon capability will augment real national military and political power.

It is, therefore, clear that states have many reasons to try to develop nuclear weapons. If this conclusion is correct, it follows then that efforts to draft and promulgate nuclear proliferation treaties will only have the limited effect of slowing down the spread of nuclear weapons. This is a valuable endeavor because it allows the development and establishment collective security measures that may dissuade states that would otherwise have developed nuclear weapons programs from doing so. A major component of any collective security agreement must be economic arrangements that give states an interest in maintaining peace. It is my opinion that the history of US-USSR nuclear arms control may be viewed as the history of efforts to formalize and institutionalize a nuclear stalemate between two industrialized, integrated states that had nothing to gain by a nuclear war. Such considerations need not hold for new and future nuclear weapons states.

Unfortunately, the global trend toward the diffusion of global power and the erosion of bipolar alliance systems and great power security arrangements tend to increase proliferation incentives. Furthermore, these trends will make the task of negotiating and ratifying collective security arrangements quite formidable. It is safe to assume that progress in this area will be slow. On the other hand, the creation and maintenance of an economic peace interest requires relative stability in the world economy. The world economy, however, has been in a state of perpetual crisis since 1973. It is hard to imagine how an economic peace interest can be cultivated with a fragile and unstable world economy.

In the absence of any long-term coherent effort to stabilize the world economy, and in the light of the profound restructuring that has been going on in the world economy, many states will have no stake in preserving the political and economic *status quo*. Iraq was one such state but she will not be the last. Therefore, sooner or later, a newly nuclear state will challenge the economic and political *status quo*. This challenge need not be addressed directly to any of the major global nuclear powers, but instead only to her neighbors. In fact the disperse, rural population of such states makes them less vulnerable to the effects of a limited nuclear war. While urban populations may perish, sufficient number of smaller cities and villages may survive to carry the war to victory, or at least, to continue it at a lower level.

It seems plausible, then, to expect a limited nuclear war between the newly nuclearizing states. This possibility raises many problems and issues for which adequate answers do not yet exist. For example, if such an event transpires, should it be treated as a matter of concern only to the combatant states? Or should other states intervene militarily to stop the fighting? How should governments deal with the consequent global problems of radioactive fall-out? Are there any plans, by international relief agencies, to deal with the massive medical problems caused by a limited nuclear war between, say, India and Pakistan? The present author does not pretend to know the answers to these questions. But must we do nothing until a catastrophe hundreds of times worse than Chernobyl befalls us?

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Editorial: Global Warming

Suddenly everybody is talking about ozone.

The ozone problem began in 1930 when CFCs were created and manufactured. For 43 years, atmospheric chlorine concentrations rose as we enjoyed our air conditioning. Plenty of scientific brainpower went into increasing profits but somehow nobody bothered to look into possible side effects. Finally, in 1973, a few scientists happened on the little fact that CFCs were probably harming the ozone shield that made life possible on Earth. But the theory wasn't yet confirmed by atmospheric measurements, and the business losses from a CFC phaseout were put into the balance scale opposite the uncertain risks of ozone depletion. Air conditioning won and Earth lost. Chlorine concentrations continued rising for 12 more years. In 1985, scientists discovered the Antarctic ozone hole. By 1990, humankind finally decided to phase out CFCs.

The phase-out was a little like buying fire insurance after your house is already on fire. Chlorine levels will continue rising. We are likely to reap unwelcome ultraviolet energies for nearly a century.

Even after 1985, there was surprisingly little discussion of this problem. As long as you weren't a penguin, or a phytoplankton that photosynthesizes in Antarctic seas, it seemed you had little to worry about.

Now, suddenly, there is the threat of a deep ozone hole over the Arctic, extending far enough to affect us right here in the good old USA. Recent Arctic chlorine monoxide levels are higher than ever. Mid-latitude and tropical depletions are also more probable, due to natural stratospheric sulfuric acid and ice aerosols that help convert CFCs into ozone-destroying chlorine monoxide. The problem is no longer in the realm of theoretical chemistry, but something that can give you skin cancer next summer on the beach. So now everybody is talking about it.

There are lessons here that we must learn, as Earth approaches its greenhouse century.

Carbon dioxide concentrations are nearing 360 ppm. The highest concentration during the past 160,000 years was 300 ppm, a level reached 120,000 years ago. The correlation between CO_2 and temperatures over these years indicates that the transition from an ice-age to an interglacial period is associated with about an 80 ppm change in CO_2 concentrations. Since 1750, humankind has increased CO_2 concentrations by just this amount, and we may soon vastly exceed this figure.

CO_2 is only a trace amidst atmospheric N_2 and O_2. But, because of this triatomic molecule's vibrational modes, CO_2 has considerable leverage over Earth's radiation balance. This tenuous gas plays a key role in maintaining Earth as we know it. And yet, during the blink of an eyelash, the industrial age has pumped enough CO_2 to raise its concentration from 280 ppm to 360 ppm.

If someone gratuitously pumped a gas, of unknown human effect, into your living room, you would probably be concerned. But few seem concerned about the gas we have pumped into Earth's energy apparatus for 250 years. The topic was hardly mentioned until recently. Apparently, the problem is too abstract, too remote in time. The temperature hasn't started rising yet, or it hasn't yet risen far enough. It is like ozone depletion, before 1985.

The dimensions of global warming dwarf those of ozone depletion. The problem is not particular industries such as air conditioning, but rather fossil-fueled industrialized living itself. The Environmental Protection Agency (EPA) estimates that, in the absence of a slowdown in emissions of greenhouse gases, an "effective" CO_2 doubling (that is, accounting for other trace gases in addition to CO_2) will occur between 2030 and 2040. A doubling, to an effective CO_2 level of 560 ppm, would be an unprecedented global experiment.

Maybe a doubling will turn out to be harmless. Maybe business as usual will work out just fine, this time. Maybe insurance won't be needed, this time. But sometimes the house does burn down. And judging from recent temperature readings, our greenhouse is already on fire.

What would it take to put a lid on CO_2 levels? The EPA estimates that, to hold CO_2 to its present level, a 50-80% worldwide reduction in fossil fuel use would have to occur during the next few decades. This is a tall order, especially since the recent fossil-fuel growth driver has been the developing countries, where per capita fossil fuel consumption is only beginning to rise and where populations are exploding.

And yet we continue commuting in single-occupant gas-guzzlers, pricing gasoline far below its true cost, building residential estates miles from our workplaces, shipping by truck rather than train, and designing cities around the automobile. As we devote billions to the car, we neglect rails, buses, bicycles, and walking. We build jet planes instead of trains. We generate electricity from coal and we underprice it. Our market economy, unresponsive to the true value of its goods and services and thus subsidized by the future and by the environment, burns the fossils of the past as though there were no tomorrow.

Although the United States was an ozone leader, it is a greenhouse laggard. Maybe this reflects the US love-affair with the automobile, an inheritance from our cowboy past, from the myth of the lone horseman. Or maybe it reflects differences between the US chemical industry, which eventually had the good sense to become an ozone leader, and the US automobile industry, which has difficulty doing anything that is in its own long-term interest.

But the problem lies deeper than automobiles and profits. It lies in the hearts of all of us, and in the scientific age since Copernicus. It is a classic moral problem of power, knowledge, and responsibility. Science confers a power that we exercise every time we switch on a TV set or an automobile. This power stems from scientific abstractions such as force and energy, from inventions such as radios and heat engines. Yet few know anything about force, energy, radios, or heat engines. Few are willing to teach it, or learn it, or study its side effects. The scientific age demands much more education than we seem prepared to either give or absorb.

The modern age wants the power of science, but not the mental work of understanding it. Science, founded upon rationality, is being used irrationally. That contradiction is destroying the ozone layer along with much else that is precious.

As Einstein and others have observed, the nuclear age changed everything save our modes of thinking, and thus we drift toward disaster. But the problem started well before the nuclear age. It goes back to Copernicus, and the power of science.

Art Hobson