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LETTERS

NUCLEAR ORBIT-TO-EARTH MISSILES

Your September 1986 summaries of the two APS Forum sessions on the Strategic Defense Initiative (SDI) give an excellent overview of the current state of the ongoing debate on ballistic missile defense (BMD) with space-based components, the type most favored by SDI officials.

The Soviets have already indicated that such a defense would be countered by an anti-satellite (ASAT) force including relatively cheap "low-tech" maneuverable space mines for trailing BMD satellites and blowing them up on command. But a truly frightening prospect is that suitably designed space mines could also serve as nuclear orbit-to-earth missiles (NOEMs), using their maneuver rockets to de-orbit (as in the Soviet fractional-orbit bombardment system of the 1960s).

NOEMs are, of course, banned by the 1967 Outer Space Treaty, but Gorbachev warned, at the 1985 summit, that all arms control "will be blown to the winds" if a "Star Wars" defense (banned by the ABM treaty) is deployed.

If BMD satellites should turn out to be survivable in the face of an ASAT attack, so should NOEMs using the same survivability techniques, making them unstoppable by any non-terminal defense. If, on the other hand, NOEMs turn out to be non-survivable, so would BMD satellites, making their defense against ICBMs worthless. In either case, the offense will prevail.

NOEM survivability can be improved without any fuel loss by unpredictable orbit-changing mass exchanges between roughly co-orbital NOEMs using small nuclear powered mechanical or electro-magnetic mass launchers. NOEMs could also be accompanied by (free or tethered) decoys, and be salvage fused to explode on attack, with the resulting signal triggering space mines near enemy BMD satellites.

With only a third of their mass expended as rocket fuel, NOEMs could travel from a 200 km orbit to ground in about 3 min., with a 10-20 sec vertical fast-burn fuel exhaust velocity of 3 km/sec. Since modern positioning and arming systems (used before hostilities begin) could make them quite accurate, they would therefore have a highly destabilizing short-warning first strike potential, particularly if they are seen as vulnerable.

Finally, a purely ground based "pop-up" BMD could be decimated, e.g. in its own boost phase, by a "pop-up" anti-BMD, which can always be up first; or, if the BMD can be made unstoppable, so can any forward-based missile force.

Louis A.P. Balázs, Department of Physics, Purdue University, West Lafayette, IN 47907

CHERNOBYL

The Forum on Physics and Society tries to be alert to occasions in which seemingly esoteric investigations lead to conclusions that have a bearing on our ordinary lives. It therefore distressing that the authors of the pieces on Chernobyl in your January 1987 issue seem to be unaware of the scientific conclusion that "Planet Earth is made of nuclear wastes" (New York Times, July 22, 1986). The direct import of this conclusion is that members of the public are being exposed to controllable levels of ionizing radiation that make the exposures from Chernobyl seem modest by comparison.

The major exposure mechanism is indoor radon, initially thought to exist in U.S. homes at a nominal level of 0.8 picoCi/liter, but now believed to be somewhat higher on the average, and factors of five to fifty times higher in a significant fraction of U.S. dwellings. The U.S. EPA has recently issued a "guideline" for indoor radon (4 picoCuries/liter) which gives a cumulative whole body equivalent lifetime radiological exposure comparable not to the Chernobyl exposures in Sweden, but to the exposures in the 3 to 7 kilometer zone around the Chernobyl plant itself (reported by the Russians as 54 REM on the average). The virtually unanimous reaction of those affected by indoor radon (home owners, utilities involved in home modifications for purposes of energy conservation, and realtors facing radon liability litigation) is not only that the EPA guideline is "safe," but that the references on health effects of ionizing radiation cited by Barbara Levi are nonsense. This is what proponents of nuclear power have been saying all along, but home owners who don't believe that 4 picoCuries/liter of radon in their dwellings will cause death to one occupant in 33 may have more clout.

It is of course true that public opinion does not alter the actual dose-response curve for human exposure to ionizing radiation. But public opinion may encourage scientists who make learned pronouncements about the health effects of ionizing radiation to be less alarmist in their rhetoric and more forthright in placing radiological exposures from different sources in proper perspective.

Henry Hurwitz, Jr., 827 Jamaica Rd., Schenectady, NY 12309

Response:

I certainly agree with Mr. Hurwitz on the importance of placing various risks in proper perspective. That is precisely why I was careful in my article, "Estimating Long-Term Health Effects from Chernobyl: Some Useful Parameters," to compare the Soviet estimate of about 5000 long-term deaths from Chernobyl to the normal occurrence of some 9.5 million deaths from cancer in the same population. The intent of my article was not to alarm (and my language was certainly not "alarmist") but to inform. I aimed merely to provide useful data for conversion among the various radiation units being reported. For that purpose, I drew data from fairly standard, respected and accessible sources (my references 2 through 12). If Mr. Hurwitz has specific evidence to back his claim that those references are "nonsense," I would like to learn about it.

Barbara G. Levi, Center for Energy and Environmental Studies, Princeton University

ARTICLES

MANAGED VERSUS UNMANAGED 7 YEAR ELECTRIC GROWTH: CALIFORNIANS NEEDED 3 NEW PLANTS, TEXANS NEEDED 11 (1),

by Evan Mills and Arthur H. Rosenfeld,Center for Building Sciences, Lawrence Berkeley Laboratory, University of California, Berkeley, CA 94720

In the early 1970s, electricity demand in the U.S. was expected to continue to double every decade. By under-estimating the potential for conservation, planners and regulators approved the construction of far too many power plants. Had the projected growth materialized, today's $150 billion electricity bill would be far higher and customers would be paying more than they are now to cover construction costs for power plants they didn't need. Growth has declined primarily because conservation turned out to be far less expensive than new supply--3-5 times cheaper than new power plants. Today, energy-efficiency standards like those in California have stretched the demand doubling time from one to three decades, saving billions of dollars annually. However, progress has varied greatly among the states. California and Texas illustrate the effects of regulation versus laissez faire on conservation (2).

Using federal data and simple corrections, we can see how the normalized demand for electricity declines in California while it steadily increases in Texas and across the country. Progress in California has been hastened by mandatory building and appliance efficiency standards. The 1993 refrigerator standards alone (already partially implemented), compared to the 1977 refrigerator,will save 1,200 kWh/household or 15 BkWh for California--the equivalent of three, 1,000-MW base-load power plants. Other California standards and conservation programs target commercial and industrial customers. In contrast, Texas has left matters almost entirely to the marketplace and still has growth rates of 4.5%.

The data in Table 1 show that California, which has 11% of the U.S. population and 12% of the national income, consumes only 8% of the electricity, while Texas, which represents only 7% of national population and income, consumes 9% of the electricity. Californians use less than half as much electricity per dollar of gross state product (GSP) than do Texans, although both have had declining growth in kWh/$GSP. Texas' climate, construction activity, and industrial structure are different from California's. Nonetheless, the *rates* of electricity demand growth, normalized for population growth in the residential sector, floor area growth in the commercial sector, and value-added in the industrial sector, reveal the rewards of energy demand planning in California. The rates of electricity price increases are slightly higher in Texas.

Table 1. Economic Comparison of Texas and California (1984).

	Population (Millions)	%	Income ($B)	%	Electricity (BkWh)	%
US	236	100	3000	100	2278	100
CA	26	11	367	12	175	8
TX	16	7	202	7	208	9

Table 2. Normalized growth in electricity demand since 1977: CA, TX, and U.S. (4).

		U.S.	CA	TX
I.	TOTAL 1984 kWH/capita	9648	6838	13021
	•Δ(kWh/capita)1977-1984	782	-267	1424
	•Annual growth rate	1.2%	-0.5%	1.7%
II.	TOTAL 1984 kWh/$84 $1000 GSP	760	477	1030
	•Δ(kWh/$84 $1000 (GSP)'80-'84	-26	-80	-33
	•Annual growth rate	-0.5%	-2.2%	-0.4%
III.	RESIDENTIAL growth/capita '77-'84			
	•Δ(kWh/capita)	357	136	652
	•Annual growth rate	1.7%	0.9%	2.4%
IV.	COMMERCIAL growth/ft^2 '77-'83			
	•Δ(kWh/ft^2)	1.3	-0.2	0.4
	•Annual growth rate	2.0%	-0.4%	2.2%
V.	INDUSTRIAL growth/$ value-added '77-'83			
	•Δ(kWh/$82 value-added)	0.06	-0.08	0.14
	•Annual growth rate	1.5%	-3.0%	2.0%
VI.	1982 ENERGY PRICES (all sectors)			
	•Δ($82/kWh)1977-1982	$0.010	$0.016	$0.017
	•Annual growth rate	2.6%	3.6%	4.5%

During the seven-year period of 1977-84, the average Californian's electricity use decreased by 267 kWh while the average Texan used 1,424 kWh *more* than in 1977 (see Figure 1 and Table 2.) Industiral conservation efforts have been especially effective in California where, in 1982, energy costs represented only 3.5 cents of each dollar of value-added versus 4.5 cents and 7.1 cents in the U.S. and Texas, respectively. (The cogeneration of electricity and process heat may account for part of the differences between Texas and California). The sum of all the above effects is that during the seven year period California has built or acquired the electricity corresponding to three new plants and Texas eleven (3).

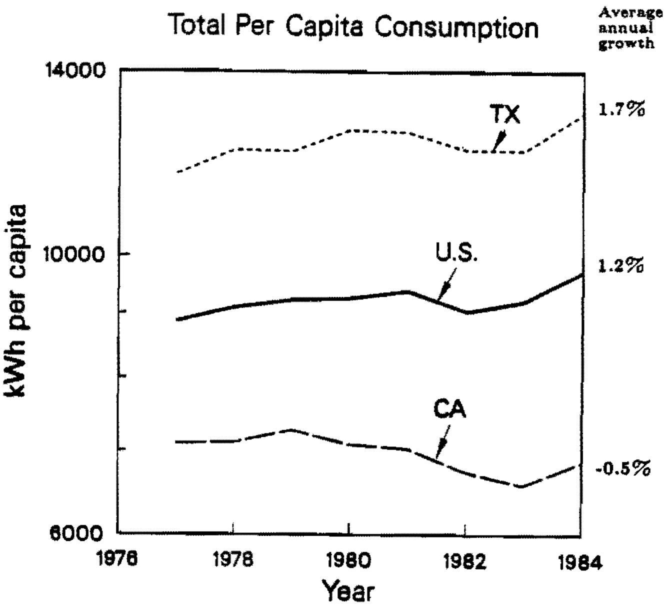

Figure 1. Total electricity consumption by all customers for CA, TX, and U.S. Annual electricity consumption is normalized to per-capita use in the same year. In the seven years 1977-1984, California population grew by 2.0%/year, Texas by 2.8%/year, and the U.S. by 1.0%/year. The y-axis is logarithmic.

Texas is now following in California's footsteps, advancing a range of conservation and load management initiatives. The Texas Public Utilities Commission is planning to "construct" an 800 MW "conservation power plant" for the city of Austin by deploying a package of residential retrofits that will cost several times less than new generation capacity. Texas is also pursuing load management strategies, such as thermal storage for cooling commercial buildings as a means of avoiding the construction of new plants. One-third of new commercial floor space in Dallas now employs thermal storage, which shifts 20-25% of new cooling load to off-peak times (5).

As a result of conservation efforts, the overzealous projections of demand growth and the accompanying construction plans of the early 1970s have not become a reality. From the data presented here we cannot tell precisely how much of the difference between California and Texas is due to regulation, but it is clear that California has demonstrated more of a will to conserve at both the government and private levels.

REFERENCES AND NOTES

1. The work described in this report was funded by the Assistant Secretary for Conservation and Renewable Energy, Office of Buildings and Community Systems, Building Services Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.
2. Readers interested in receiving copies of the full report with data tables and figures may contact the authors at Building 90/3125, Lawrence Berkeley Laboratory, Berkeley CA, 94720. Ask for LBL-22932.
3. A 1000-MWe power plant sells roughly 5 BkWh per year.
4. Sources for Tables 1 & 2: Electricity-Electric Power Annual 1984, Energy Information Administration (EIA),U.S. Department of Energy EIA-03048, Table 45, pages 127-31, September 1985. Energy Prices--State Energy Price and Expenditure Report 1970-1982, EIA-0376, pages 17, 67, and 457. Population, Industrial Value-added and Income--1986 Statistical Abstract of the United States, Table 12, page 12; Table 1336, page 750; and Table 735, page 440 respectively, U.S. Depasrtment of Commerce. (1977 income, 1978 Statistical Abstract, Table 725, page 449). (Income data are used as a proxy for GSP). Commercial floor space--1985 NBECS Survey DOE/EIA-0246(83) (data by Census Region) and DOE/EIA-0453 Model Documentation: Commercial Sector Energy Model, August 1984.
5. Personal communication, Leo Stambaugh, Texas Utilities, January 1987.

THE TECHNOLOGICAL FEASIBILITY OF STRATEGIC DEFENSE by Dietrich Schroeer, Department of Physics and Astronomy,University of North Carolina at Chapel Hill

Introduction

The current debate about strategic defense is ultimately political. None the less, there are underlying questions about the technological feasibility of such a defense. The first question is whether specific weapons might be able to produce sufficient energy to destroy offensive strategic weapons. The second question is how effective the weapons might be as part of an operational defensive system.

Physicists may not be particularly competent to judge the capabilities of defense systems. But they can analyze the capabilities of weapons *per se*, particularly with respect to the minimum technical requirements that must be met by the weapons if they are to be incorporated into the defensive systems.

This note will review the capabilities required for several weapons that might be useful as components of certain specific defensive systems. Based on past rates of technological improvements, current weapons capabilities will be projected into the future, to estimate when sufficiently capable weapons might be available for deployment. Building strategic defense systems will be more difficult than developing individual weapons. The availability of sufficiently capable weapons therefore is a minimum but not sufficient prerequisite for effective strategic defense. The date for the projected availability of prototypes of specific defensive weapons will therefore be a minimum estimate for the availability of adequate strategic defenses.

Weapons Requirements

The requirements for defensive weapons depend on the goal of the strategic defense system of which they are to be a part. Table 1 lists a set of possible goals for strategic defenses, together with some of the weapons that might have to be a part of each defense. The revolutionary nature of the strategic defenses proposed in President Reagan's "Star Wars" speech is most visibly symbolized by directed-energy weapons (DEW). Therefore, Table 2 lists one representative DEW system for each of these goals, and outlines the technical requirements it might have to meet (1,2).

Table 1. Possible objectives of strategic defenses.

Strategic Objective	Defensive Strategy	Weapons	DEW Deployment Date
Deterrence by threat of retaliation	Preferential defense, to preserve retaliatory capability	Terminal ground-based lasers or charged-particle beams or ground-based ABMs	1995
Deterrence by denial	Terminal defense plus 25% area defense, to disrupt first strike	Some space-based DEW boost-phase plus two-layer ABMs	2000
Transition to defensive regime	90% effective area defense, damage limitation	DEW boost, DEW and KEW mid-course, two-layer ABMs	2000-2030

Table 2. Requirements for several laser weapons symbolic of different defensive objectives.

	Terminal defense	Boost-phase defense	Midcourse defense
Laser type	DF-chemical	HF-chemical	free e^-
Wave length	3.8×10^{-6}m	2.7×10^{-6}m	0.5×10^{-6}m
Laser location	ground	space	ground
Target distance	10 km	3000 km	75,000 km
Mirr diameter	4 m	10 m	50/26/2m
Laser output	2 MW	20 MW	1000 MW
Kill energy	150 kJ/cm^2	20 kJ/cm^2	50 kJ/cm^2
Kill time at max range	0.16 sec	8 sec	0.66 sec

(i) In many ways, short-range ABMs are the logical weapons for a terminal defense system that is to protect ICBM silos against attack in order to preserve the retaliatory capability necessary for maintaining deterrence by the threat of mutual assured destruction. However, a study of DE weapons indicates that a 2-MW DF laser with a 4-m focusing mirror might be useful for such a terminal defense.

(ii) A space-based laser system for boost-phase intercept might be usable as part of a defensive system to maintain a posture of deterrence by denial, by denying the opponent any military advantage through a first strike. A space-based 20-MW HF laser with a 10-m diameter mirror might be useful for such a defense.

(iii) A 1000-MW ground-based free-electron laser (fel) with a 50-m focusing mirror and a 25-m geosynchronous reflector mirror might be useful in an extensive midcourse strategic defense that is designed to limit the damage to populations from a small-scale nuclear attack.

The problems faced by these DE weapons are symbolic of the technical difficulties of developing effective components for these different defensive strategies. Other weapons, such as particle beams, x-ray lasers, and electro-magnetic railguns, are not likely to be much easier to develop, although they may have unique attractive features. But similar evaluations could be made of the requirements imposed on these alternative weapons.

Weapons Availabilities

Given that these DE weapons must satisfy the performance parameters listed in Table 2, when might they be available for incorporation into defensive systems? It is risky to extrapolate past technological developments into the future. But it is also risky to have no notion of when some technological goal might be achieved. Therefore it makes sense to perform such extrapolations, with the understanding that they are only estimates to which other projections can be compared. Table 3 displays projections for some DE weapons.

Table 3. Estimates of times when the feasibility of various strategic-defense weapons might be established, and when they might be available for deployment.

Defense	Weapon	Range	Parameter	Feasibility	Prototype
Terminal	DF laser	10 km	2 MW laser 4 m mirror	1987 1990	1992 1995
Terminal	e^- beam	10 km	10 kA at 500 MeV	2006	2011
Boost-phase	HF laser	3000 km	20 MW laser 10 m mirror	1995 1996	2000 2001
Mid-course	fel laser	75,000 km	1000 MW laser 50 m mirror	2012 2027	2017 2032
Mid-course	H^0 beam	3000 km	5A at 500 MeV	2001	2006

The current maximum power output of HF lasers is 2 MW, as projected for the *Alpha* laser for 1987. Historically the maximum power output of the best lasers at any moment has doubled roughly every 2.5 years (3). Hence the 20-MW power output necessary for space-based boost-phase defense might be demonstrated in 1995. Historically, within this envelope of maximum power output, different types of lasers have undergone more rapid development rates, sometimes with a power-doubling period as short as 1.5 years. However, once this maximum power envelope has been reached, the development times then have fallen to 2.5 years. The current maximum power output of free-electron lasers is 5 kW. At a growth rate of 1.5 years, fels could catch up with HF lasers by 2000. With a doubling period of 2.5 years thereafter, they might develop a power output of 1000 MW by 2012.