ELECTION BALLOT

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TABLE OF CONTENTS

U.S. ICBM VULNERABILITY IN THE 1990s by Art Hobson*, Physics Department, University of Arkansas, Fayetteville, AR 72701

The Midgetman missile is one proposed solution to the perceived problem of U.S. ICBM vulnerability. The system puts some 500 small, single-warhead missiles into a less vulnerable basing mode, possibly either superhard silos, or hardened mobile launchers (HMLs) silos ready to dash on warning. We calculate the vulnerability of each of these three modes, and evaluate the 1990s survivability of the full U.S. ICBM force under a range of assumptions.

The standard theory of silo destruction[1] implies that the "single shot probability of survival" of a silo attacked by one warhead is SSPS = 0.5^x where $x = RD^2/CEP^2$. Here, RD is the radius of destruction for that warhead against that silo, and CEP is the inaccuracy of the warhead, defined as that radius inside of which 50% of an "ensemble" of warheads would fall. We note that SSPS is just a Gaussian in the ratio RD/CEP, and that it is a consequence of a Gaussian assumption for the spatial distribution of an ensemble of attacking warheads.

There is now general agreement that "superhard" silos can be built to withstand nuclear effects right up to the edge of a nuclear crater, but that no silo can survive within the crater[2]. For such silos, RD = RC ("radius of the crater"). Since the crater's volume should be roughly proportional to the energy released, $RC^3 \approx cY$ where Y is the warhead's yield and the proportionality constant c is dependent on the geology in which the blast occurs. U.S. officials have stated that, in favorable (small c) geology, RC ≈ .075 km for Y = 0.5 megatons (MT)[3]. Thus, c ≈ $(0.075)^3/0.5$ = 8.4 x 10^{-4} km^3/MT. Experimentally, the blast pressure (in atmospheres) at distance r (kilometers) from a ground burst[1] of yield Y (MT) is $6.31Y/r^3$. At the edge of the crater, where r = RC, this becomes $6.31Y/RC^3$ = 6.31/c ≈ 7500 atm (110,000psi). Superhard silos, defined as silos that must be inside the crater in order to be destroyed, must be able to withstand this blast pressure. Silos much harder than this are superflous, for they would be destroyed by the crater anyway. For superhard silos,

$$SPSS = 0.5^x \text{ where } x = RC^2/CEP^2 \qquad (1)$$

But the preceding calculation implies RC^3 = 6.31Y/7500, so that

$$x = (6.31Y/7500)^{2/3}/CEP^2 = Y^{2/3}/110\ CEP^2 \qquad (2)$$

More simply, x = L/110, where L = $Y^{2/3}/CEP^2$ is commonly known as the attacking warhead's "lethality."

Today's MIRVed SS-18s and SS-19s (CEP = 0.25 km, Y= 0.5 MT) have L = 10, so SSPS = 94%, a high survival rate. But the older un-MIRVed SS-18 carries 20 MT with the same CEP, implying SSPS = 50%. So superhard silos are vulnerable even today. In the future, the Soviets should attain[4] the .090 km CEP of today's MX. The survival probabilities of superhard silos attacked by several such high accuracy warheads are shown in Table 1. The Table is, of course, only an approximation to the real world. The caption of Table 1 lists the most important of the effects not accounted for in these calculations.

TABLE 1

Single Shot Probability of Survival of a superhard silo attacked by present and plausible future Soviet warheads.

Missile	Fractionation (MIRVing)	Yield Y	CEP	Lethality $L=Y^{2/3}/CEP^2$	SPSS $=0.5^{L/110}$
SS-18 mod 3	1	20 MT	0.25 km	120	.47
SS-18 mod 4	10	0.5	0.25	10	.94
SS-19 mod 2	1	8	0.25	65	.66
SS-19 mod 3	6	0.5	0.25	10	.94
Future SS-18	1	20	0.09	920	.003
	2	7.1	0.09	460	.06
	3	3.8	0.09	302	.15
	4	2.5	0.09	228	.24
	10	0.5	0.09	77	.61
Future SS-19	1	8	0.09	505	.04
	2	2.8	0.09	249	.20

A "superhard silo" means one that must be inside the crater to be destroyed, i.e. hardness = 7500 atm. These survival rates neglect several factors such as fratricide, unreliable attacking warheads, and the possibility that the silo might be destroyed by other effects even if it is outside the crater.

Mobile launchers could be hardened to 2 atm (30 psi) and be capable of moving at 22 m/s (50 mph). If based on large military reservations they will roam randomly over some 10,000 km^2 during peacetime and 20,000 km^2 during alert, prepared to dash off this area in the event of attack. If based at MM silos, they would be prepared to dash onto surrounding access roads and farmland. We denote these basing modes Random Mobile (RM) and Dash Mobile (DM).

The most plausible attack on either mode would be an area barrage, either against the entire RM operating area, or against small regions surrounding each of the 500 DM sites. Simple geometry implies that the number of warheads needed to barrage an area A is $A/4 \, RD^2$, where RD is the radius of destruction of a warhead against an HML. This result assumes a "loose" barrage pattern in which the circles of destruction just touch. This pattern is only 80% effective since 20% of the HMLs are outside all the circles. This calculation also ignores the additional survival of mobile missiles because attacking warheads will not hit their aim points precisely. The number of MIRVed missiles needed is $N = A/4 \, f \, RD^2$ where f is the "fractionation" (number of warheads per missile) of the missile. In practice, for a given missile the individual warhead yield decreases with increasing f roughly in accordance[5] with $Y \approx f^{-3/2}$. Scaling considerations imply $RD^3 \approx Y$, so that $RD^2 \approx Y^{2/3} \approx f^{-1}$. Thus f cancels in the formula for N, i.e. for a given missile, MIRVing has no effect on area barrage, to first order.

As an important example, the number of SS-18 missiles needed for our 80% effective area barrage is calculated to be 7.6 SS-18s per 1000 km^2, assuming that the warheads are airburst at a height that maximizes RD. It is interesting to estimate the implied "exchange ratios" in a Soviet attack. If 500 Midgetmen were spread out on 20,000 km^2, as might be the case, there would be 25 Midgetman missiles (or 25 warheads) per 1000 km^2. If SS-18s are 10-MIRVed, these 25 Midgetmen would be barraged by 76 SS-18 warheads, resulting in the destruction of about 20 Midgetmen (80% of the 25). So the warhead exchange ratio is about 4 SS-18 warheads to 1 destroyed Midgetman warhead. From another point of view, the missile exchange ratio is 1 SS-18 to 2.6 Midgetmen. Whether these ratios are favorable for the Soviets, or favorable for the U.S., or immaterial, depends on many considerations. For example, one consideration is cost: How much do 7.6 SS-18s cost, versus 20 Midgetmen? We leave these questions for others. For example, the recent Defense Science Board Task Force ("Deutch panel") report[4] calculates the cost in dollars per surviving U.S. warhead, and compares basing modes on this basis.

To calculate in more detail the Soviet attack required to barrage the mobile modes, it is most instructive to study the operating area as a function of dash time. We assume that the dash begins from the 20,000 km^2 alert area for RM, and from 500 MM silos for DM. The 20,000 km^2 alert area is reported[6] to be located on 5 separate military reservations. For simplicity, we will assume that these 5 regions are each circles of area 4000 km^2, or radius $R_o = 35.7$ km.

Assuming a constant v = 22 m/s speed during the entire dash, and assuming that the dash can proceed in any direction, the area "generated" after a dash time t is $5\pi \, (R_o + vt)^2$ and $500\pi v^2 t^2$ for RM and DM respectively.

Thus we calculate the two graphs of Figure 1 for the first 10 minutes of dash time, still assuming 7.6 SS-18s are needed per 1000 km^2. The graph is surely optimistic for Midgetman survival, since real-life HMLs would need some time to get moving, would move slower than an average 22 m/s (especially during off-road travel), would be restricted mostly to roads, would require time to deploy, etc. The times graphed should be compared with the 15 minute SLBM flight time to the central U.S. from 200 miles offshore, or 8 minutes with depressed trajectories. This barrage leaves a theoretical 20% survival rate, or 100 surviving Midgetmen in a force of 500. But these 100 survivors will each experience four near-threshold blasts, so their post-attack condition could be questionable. A 100% effective barrage may be shown to require twice as many attacking missiles as the 80% effective barrage. Other factors, such as unreliability of the attacking missiles (i.e. duds), are neglected here. Despite the approximate nature of these results, they show that the mobile modes could be barraged by SLBMs (8-15 minute flight time) with a plausible hope of success. On the other hand, the 30-minute flight time of ICBMs would probably make ICBM barrage unsuccessful. Thus, mobile Midgetmen will have the same "failure mode" as bombers: vulnerability
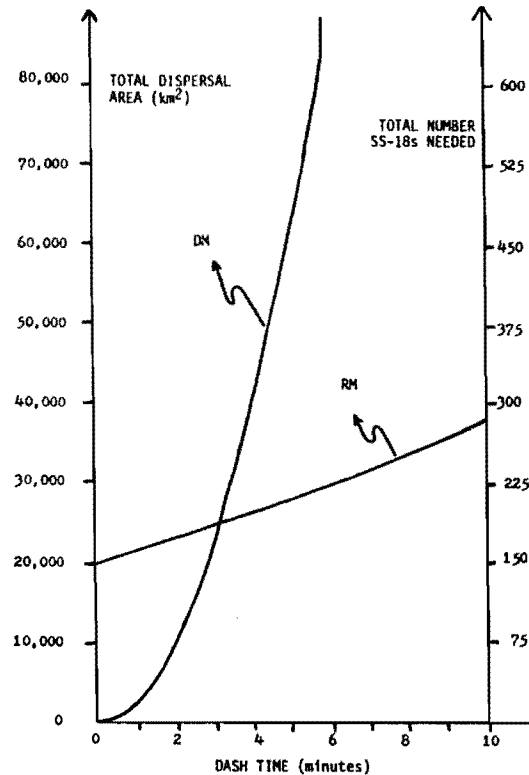

Figure 1. Total dispersal area and total number of SS-18s needed to barrage this area at 80% effectiveness, as a function of HML dash time for the Random Mobile (RM) and Dash Mobile (DM) modes.

How vulnerable would a 1990s ICBM force of 500 Midgetmen plus 1000 MM and MX missiles be under plausible Soviet attacks? We study four plausible Soviet force levels. If one assumes that SALT II constraints are maintained, the 1990s Soviet force might include some 1400 high-accuracy ICBMs and 900 medium-accuracy SLBMs. This force could destroy the full U.S. ICBM force. Under superhard silo basing, some 50% of the Soviet ICBM force would be needed (SLBMs wouldn't do, as they aren't lethal enough to destroy superhard silos). Under the mobile modes, the entire SLBM force would be needed (ICBMs wouldn't do, because the HMLs would have 30 minutes to get out from under an impending ICBM barrage), leaving their ICBM force for other purposes.

With no arms control constraints, anything is possible. The Soviets could obviously destroy nearly all our ICBMs with a small fraction of their missiles, if the Soviets had enough missiles.

Under the 50% cuts proposed in differing versions by both sides, the Soviets might retain 900 ICBMs and 300 SLBMs. The attack on superhard silos would still be possible, but it would then consume most of the Soviet ICBM force, a bad trade for the Soviets because it leaves their SLBM/bomber force facing the much stronger U.S. SLBM/bomber force. The SLBM threat to RM would vanish due to insufficient SLBMs, but SLBMs could still attack DM in hopes of striking with very short dash time (see Figure 1 for short t). So under 50% cuts U.S. ICBMs might be significantly more survivable in the 1990s than they are today, unless DM basing was chosen.

Finally, a "finite deterrence" regime[7] of say 2000 warheads on each side would make U.S. ICBMs essentially invulnerable, still assuming 500 Midgetmen, for the Soviets would lack sufficient warheads for an effective attack.

Midgetman makes sense with arms control, but is a waste of money without controls that reduce strategic forces significantly below present levels.

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1. For example, K. Tsipis, Arsenal (Simon and Schuster, New York, 1983).
2. E. Ulsamer, Air Force Magazine, January 1984.
3. Defense Daily, 22 May 1985.
4. Defense Science Board, Report of the Task Force on Small ICBM Modernization. (Department of Defense, March 1986).
5. I. Bellany, Nuclear Vulnerability Handbook (Center for the Study of Arms Control, Lancaster, England, 1981)
6. J. Medalia, Congressional Research Service, Report No. 83-106F, 26 May 1983.
7. H. A. Feiveson, R. H. Ullman, F. von Hippel, Bulletin of the Atomic Scientists, August 1985.

THE CHERNOBYL REACTOR ACCIDENT: SCANDINAVIAN PERSPECTIVES

by Allan M. Din, Department of Theoretical Physics, Royal Institute of Technology, Stockholm and Stockholm International Peace Research Institute, SIPRI, Bergshamra, S-171 73 Stockholm, SWEDEN

During the weeks following the Chernobyl accident, Sweden was subject to two somewhat different kinds of exposure, both having rather unpleasant consequences. First, the monitoring stations at the nuclear reactor facility at Forsmark north of Stockholm were able to call, on April 28, the initial alert on unusually high environmental levels of radioactivity coming from abroad. Secondly, Stockholm became for almost a week the number one rallying point of the international press with the result that many non-Swedes probably got the impression that Sweden had become a radioactive wasteland. The director of the National Tourist Board was seen on TV lamenting that American tourist bookings had come down 20% because of the mere fact that Sweden was an open society with an effective environmental monitoring system!

The system for monitoring radioactivity, which consists of 25 measuring stations around the country, including those at or near the 4 reactor sites, worked all right but was nevertheless found to have some flaws. Initially, it was thought that the radioactivity originated from the Forsmark reactor, but after similar readings at other stations it was concluded that the origin was abroad and, probably, in the Soviet Union since the winds were coming from the southeast. Eventually the Swedes deduced that the radioactive fallout originated from the burning reactor in Chernobyl near Kiev.

Later, it was discovered that a number of measuring stations had not been working properly for some years with the result that a complete map of the fallout in the country could not be made until mobile measuring apparatus had criss-crossed certain regions. The levels of radioactivity were generally about 5 times the normal background level of 10 μrem/hour, but there were exceptions. On the islands of Gotland and Oland in the Baltic Sea closer to the Soviet border the levels were a little higher than average as might be expected from regular fallout patterns but, somewhat ironically, in the region of Uppsala and Gavle, not far from the Forsmark site, the levels were more than 100 times normal. The general fallout pattern[1] is displayed in Figure 1. Table 1 shows a list of different isotopes found in the fallout[1].

These irregular patterns were due to the occurrence of a moderate rainfall in the mid-eastern part of the country 3-4 days after the reactor accident. Such a wash-out phenomenon is of course not unexpected since the experience from atmospheric tests of nuclear bombs has often indicated much irregularity in fallout patterns due to special circumstances of wind and precipitation. The countermeasures recommended by the Radiation Protection Authorities were therefore enforced

with a varying degree over the country. People were told not to drink rainwater, not to eat fresh vegetables and to keep cows from grazing until further notice; 3 weeks after the accident these measures were still in force in the most contaminated regions.
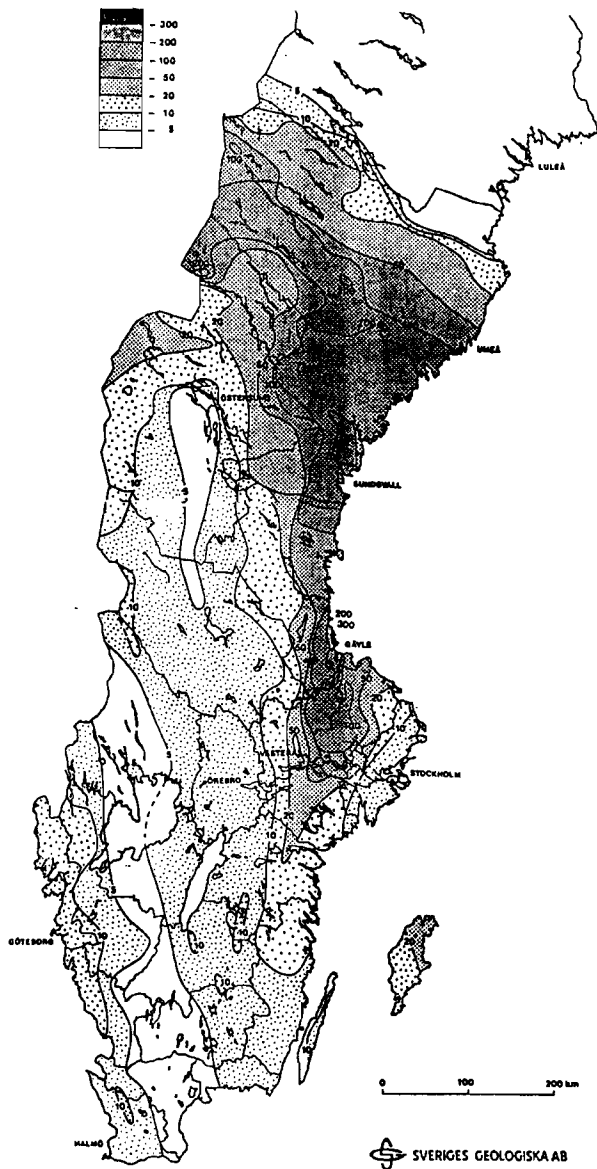

TABLE 1. Isotopes found in the Chernobyl fallout:

Isotope	Half life
Sr-89	50 days
Sr-90	28 years
Zr-95	65 days
Nb-95	35 days
Mo-99	3 days
Tc-99m	6 hours
Ru-103	40 days
Te-132	3 days
I-131	8 days
I-132	2 hours
I-133	21 hours
Cs-134	2 years
Cs-136	13 days
Cs-137	30 years
Ba-140	13 days
La-140	2 days
Ce-141	33 days
Ce-144	285 days
Np-239	2 days
Pu-238	86 years
Pu-239	24,000 years
Pu-240	6,000 years

Figure 1. FALLOUT PATTERN. Computed surface intensity in μR/hour as of May 9, 1986 based on airplane measurements conducted May 9-June 3, 1986.

As in many other countries which were exposed to fallout from the Chernobyl reactor, there has been a lively debate on precisely what will be the effects on public helath and environment. Concerning the possibility of increased rates of cancer, it was generally acknowledged that it is difficult to determine the exact threshold for radiation exposure above which cancers are produced. Lacking precise information on this point, the threshold is pessimistically put quite low, and as a result any increase in radiation above normal background levels may be said to generate so and so many additional cancer cases over a certain number of years.

The uncertainties over thresholds were apparent, for example, concerning the admitted levels of radiation in milk. In Sweden, the allowed limit had been set at 2000 Becquerel per liter of milk, whereas in the European Common Market countries the limit was 4 times lower. Under the threat of adverse effects on food exports, which many other countries have experienced, Sweden was forced to adapt its limits to what had been accepted by a majority of European states. In general, one now sees a trend to impose stricter and more uniform limits on the presence of radioactive substances in food and in the environment. Concomitantly, the preparedness for enforcing emergency measures in case of future alerts is being reassessed.

While the physical effects of the fallout definitely should not be underestimated, it is fair to say that the psychological ones have been dominating the scene. The fact that iodine drugs in Sweden were sold out at pharmacies in a matter of hours is hard to explain by anything else but an eruption of latent fears. Those fears are probably also going to be quite decisive in determining the precise fate of Sweden's nuclear reactor program. According to the result of the referendum in 1980 (following the Three Mile Reactor accident), the present 12 nuclear reactors must be dismantled not later than the year 2010 but, althought this decision was also mandated by parliament, the exact procedure and rate of phasing out nuclear energy were not quite clear.

Put concisely, the message of the referendum was that civilian nuclear energy was not in Sweden going to be the one-way street that it appears to be in most other countries which have developed the nuclear option. With due consideration to national energy needs, alternative energy

resources were to be developed gradually over the next few decades so as to make a phasing out of nuclear energy practically possible. Lately though, the commitment to developing alternative options has not appeared to be very strong and the political community sent out test-balloons with the purpose of allowing nuclear energy to survive.

The Chernobyl accident has, however, underlined the desire of most people to implement the referendum result; also the Energy Minister has recently made strong statements endorsing a dismantling of the 12 reactors and, if both warranted and possible, at an accelerated rate. The problem is particularly acute with the Barseback Reactor situated close to Maimo in Southern Sweden and only 20 km from Copenhagen across the Strait of Oresund. In Denmark, which has no civilian nuclear reactor program, many people have, since the construction of this reactor, been feeling very uncomfortable living in what demonstratively is called the evacuation zone of a reactor situated on foreign soil, and very recently the parliament issued a strong appeal to the Swedish government to get rid of the Barseback Reactor as quickly as possible. These political recriminations joined the chorus of criticism directed towards the Soviet Union for failing to alert their neighbors and the world about the possible danger of radioactive fallout. The Chernobyl accident has certainly been exploited politically, as the Soviet Union has complained and others, including the nuclear reactor industry, would most certainly not like to go too far in the debate. The many different discussions following the accident are, nevertheless, not likely to ebb out quickly. The important thing is that people in the process become more aware of dangers which are manyfold greater than nuclear reactor melt downs, namely the risks of nuclear war. Among others, the risks involved in nuclear attacks on reactor sites[2] deserve to be better known and more studies are warranted which describe the serious long-term consequences such attacks could have to densely populated areas such as Europe.

1. From T. Bennerstedt et al., Tjernobyl - nedfall, matningar och konsekvenser, SSI-rapport 86-10, Stockholm

2. S.A. Fetter and K. Tsipis, Catastrophic releases of radioactivity, Scientific American, vol. 244, 33, 1981.

4. UNSCEAR, 1982, p. 220, Table 13 on p. 234.
5. UNSCEAR 1977, p. 141.
6. UNSCEAR 1982, p. 225 and Table 27, p. 240.
7. UNSCEAR 1982, p. 222.
8. UNSCEAR 1982, Table 31 on p. 242.
9. UNSCEAR 1982, p. 220.
10. THE EFFECTS ON POPULATIONS OF EXPOSURE TO LOW LEVELS OF IONIZING RADIATION, (BEIR, 1980, National Academy Press, Washington, DC). Tables V-15, V-17 and V-31.
11. REECOMMENDATIONS OF THE INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, (Pergamon Press, ICRP Report 26, 1977), p. 10-12.
12. BEIR 1980, p. 304. INDUCTION OF THYROID CANCER BY IONIZING RADIATION (WASHINGTON, DC, National Council on Radiation Protection and Measurement, 1985), Table 11.3.

ESTIMATING LONG-TERM HEALTH EFFECTS FROM CHERNOBYL: SOME USEFUL PARAMETERS by Barbara Levi, Center for Energy and Environmental Studies, Princeton University.

In the wake of the reactor accident at Chernobyl, many have made estimates of the long-term health impacts. Among these early assessments is an estimate present by the Soviets as part of their accident report to the International Atomic Energy Agency last August. The Soviets predicted that the roughly 75 million in the Western part of the USSR might receive a collective dose over the next 50 years of about 29 million person rem from external exposure to the radiocesiums released from Chernobyl. The collective dose from ingestion of cesium might be about the same. At roughly 1 cancer death expected for every 10,000 person-rem of exposure, the estimated collective doses might cause about 5000 cancers over and above the approximately 9.5 million deaths in the Western USSR expected from the normal incidence of cancer. Other studies are attempting to evaluate the collective dose to the rest of Europe.

Estimates such as those made by the Soviets are plagued with uncertainly. Even if the distribution of radionuclides were perfectly known, it would still be difficult to calculate the dose imparted through diverse pathways: direct inhalation of radionuclides in the cloud, external irradiation from deposits on the ground and ingestion through the food chain. Several studies, relying primarily on data from atmospheric nuclear weapons tests, have estimated the various transfer functions, from levels of radiation in the environment to levels in the diet, from levels in the diet to levels in the body, and from radiation activity in the body to biological doses. These transfer functions are of course all specific to each radionuclide. They are only estimates, and can vary significantly with the soil and plants of a given region and with the ages, living patterns and diets of residents.

For those who wish to give some perspective to the measured or projected levels of radiation reported in units like Bq/1 in milk or Bq/m^3 in air, we have accumulated here some relevant parameters relating source to dose. They are consistent with those used in the estimates by Cochran and von Hippel.[1] Table I reviews the various units for measuring radiation. The other tables summarize transfer factors for two of the radionuclides which escaped from Chernobyl: iodine-131 and cesium-137. The Soviets have estimated that about 7MCi of I-131 and 1MCi of Cs-137 fell within the Soviet Union alone.

TABLE I: RADIATION UNITS

1 Roentgen	creates 1.61×10^{12} ion pairs/gram in air deposits 88 erg/gm of air at STP
1 rad	deposits 100 erg/gm in any material (gamma exposure of 1 R roughly equals absorption in tissue of 1 rad for photon energies of .3-3 MeV)
1 gray	deposits 10,000 erg/gm or 1 Joule/kg of tissue (1 gray = 100 rad)
1 rem	has the biological effect of 1 rad of x- or gamma radiation
1 Bequerel (Bq)	has 1 distintegration/sec
1 Curie (Ci)	has 3.7×10^{10} distintegrations/sec

TABLE II: RELATIONSHIPS BETWEEN DOSE AND EXPOSURE FOR I-131. Iodine-131 is a beta-emitter with a half-life of just 8 days. There are two primary pathways through which I-131 enters the body: inhalation and ingestion through milk. As it concentrates in the thyroid, iodine can cause thyroid abnormalities. The dose received for a given level of inhaled or ingested activity is significantly higher for infants than for adults. Doses predicted by the factors below assume no mitigation measures. However, exposure to I-131 can be reduced by such measures as restricted consumption of dairy products with high contents of radio-iodine or by timely ingestion of potassium iodide tablets.

From Inhalation:

Thyroid dose averaged over all age groups = 0.7 - 1.2 mrem/(Bq-d/m^3).
where Bq/m^3 is concentration
of I-131 in air

Based on the following data:[2]

Age (years)	Fraction of Population[3]	Dose per Inhaled Activity (mrem/Bq)	Breathing Rate (m^3/d)	Transfer Factor [mrem/(Bq-d/m^3)]
0 - 1	.02	0.13 - 0.41	3.0- 3.2	0.39-1.3
1 - 9	.16	0.13 - 0.32	7.0- 9.5	0.91-3.0
10-19	.20	0.046 - 0.065	13.4-17.3	0.62-1.1
20	.62	0.032 - 0.041	19.9-20.0	0.64-0.82

From Ingestion of Milk:

Thyroid dose averaged over all age groups = 8.5 x 10^{-3} mrem/(Bq/m^2).
where Bq/m^2 gives concentration
of I-131 on the ground

Based on the following data:[4]

Age (yrs)	Transfer from Milk to Thyroid Dose [mrad/(Bq-yr/l)]	Transfer from Ground to Milk [(Bq-yr/l)/(Bq/m^2)]	Overall Transfer Factor [mrad/(Bq/m^2)]
0.5	140.0	6.3 x 10^{-4}	88.2 x 10^{-3}
4	36.0	"	22.7 x 10^{-3}
14	9.8	"	6.2 x 10^{-3}
Adult	4.6	"	2.9 x 10^{-3}

TABLE III: ESTIMATES OF THE DOSE FROM EXPOSURES TO CS-137. Cesium-137 emits both beta and gamma radiation, and has a 30-year half life. It is an alkali metal similar to potassium. After deposition, it leaches into the soil, where it is fixed by ion exchange, with a high fraction in the top 3 cm of soil. Thus it exposes people to external radiation. It can also expose humans to internal radiation through ingestion of contaminated food - - especially grains and meat. Most of the ingested cesium goes to muscle and other soft tissue. The biological half-life for 90% of the ingested cesium is 110 days for adults. The transfer of cesium through the diet is highest in the first year after its deposition and relatively small after that.[5]

External Radiation:
```
    .039   mrad/(Bq/m²) absorbed dose in air
x  0.7   to compute absorption in organs
x  0.4   to allow for a shielding factor of 5
         for buildings and assuming people spend
         80% of their time indoors
         _____
    0.012  mrad/(Bq/m²)⁶
```

Ingestion:
```
    0.009 (Bq-yr/kg)/(Bq/m²) - Transfer between deposition
                                density and diet
x  2.6 (Bq-yr/kg)/(Bq-yr/kg) - Ratio of concentration
                                in body to that in diet
x  0.24 mrad/(Bq-yr/kg)      - Conversion from tissue
                                activity to tissue dose
         _____
    0.0054 mrad/(Bq/m²)⁷
```

TABLE IV: ESTIMATED DOSE COMMITMENTS FROM ATMOSPHERIC NUCLEAR WEAPONS TESTS.

	Total Injection[9] (MCi)	Dose Commitment (mrem/person)[8] Temperate Zones		
		North	South	World
I-131 ingestion	19000	4.8	.7	3.3
Cs-137 external	26	60	17	37
internal		28	7.8	17

TABLE V: CANCER INCIDENCES: LINEAR-MODEL. Relating the dose to a resultant health effect is difficult because so little data on radiation exposure has been accumulated at these low dose levels. A convenient and common, although still controversial, procedure is to adopt the so-called linear hypotheses, according to which the relation of dose to effect is the same at low dose levels as it is at high dose levels. Frequently used dose coefficients are summarized here:

Incidence of Cancers   4-12.5 x 10^{-4} cancers/person rem[10]
Incidence of Fatal Cancers   2- 6 x 10^{-4} cancers/person rem[10]
                                1.25 x 10^{-4} fatal cancers/person rem[11]

Incidence of Thyroid Abnormalities 1 - 6 x 10^{-4} cases/person rem[12]
                                (only a few percent are fatal)

1. F. von Hippel and T.B. Cochran, BULL. AT. SCIENTISTS 42, p. 18 (Aug. 1986).
2. Rev. Mod. Physics 47, p. S99, Table XXVI, 1974. The ranges shown reflect two different sources used for the data.
3. IONIZING RADIATION; SOURCES AND BIOLOGICAL EFFECTS, United Nations, 1982, Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), p. 234.

LEVERAGE AND COUNTERMEASURES: MARGIN CALLS IN STRATEGIC DEFENSE, by Peter D. Zimmerman, Carnegie Endowment for International Peace, Washington, D.C.

The use of leverage and the acceptance of prudent risks are essential to achieving high rates of return on one's investments. In financial terms, leverage often means investing borrowed money so that the profits from a success are a large multiple of the investor's own stake. In military terms, leverage is often a "force multiplier" which confers, for example, the ability to destroy many of the opponent's forces with a single shot. Destroying MIRVd ballistic missiles in boost phase and getting ten warheads is supposed to be just such a force multiplier.

The risk, however, arises from the fact that boost phase defense is, as George Keyworth once called it, the "hinge" on which all the rest of a layered ABM system would turn. Any failures in the boost phase defenses would propagate forward affecting each successive layer, potentially swamping the entire system.

Each of the layers, four in a typical "system architecture", has to be constructed using some assumptions about the threat it faces. Each successive layer has to be designed assuming that the previous ones have done their jobs. A terminal defense system which could engage all of the attacking RV force by itself, for example, would be unaffordably large because it would have to be able to protect simultaneously against extremely determined attacks, everywhere. It would be an intolerably fragile system because a single widespread failure mode could well result in the total collapse of the defense system. Such a wide-area terminal defense would look very much like the Sentinel system of the late 1960's, and would be rejected for the same reasons that Sentinel was.

If mid-course defenses could handle an unattenuated onslaught-- as if there were no earlier tiers--and reduce the number of attackers to where the terminal defenses could handle the remainder, it could logically substitute for the earlier layers.

The capability of any layer is limited; it can be saturated or exhausted. The extra margin built into each layer to handle the possibility that the preceding ones do not reach their design specifications, or that the offense employed more missiles or more effective countermeasures than anticipated, cannot be large. For the second and third layers of a four-layer defense, one can hope to build in a factor of no more than two excess capacity; a margin of ten would be very difficult to achieve.

Perhaps a factor of four margin could be built into ground-based terminal defenses, remembering that, if the layered defense scheme works, only a few warheads would be expected to get that far. However, the terminal defenses must have this excess capacity everywhere, lest the attacker concentrate his forces on less-well-defended, but valuable, targets.

Since the defense knows or thinks it knows how many missiles its opponent has, and since the offense surely knows how many satellites the defense has, the boost phase part of the defense will have very little excess capability.

Some Quantitative Examples

If the layers of a four-tiered defense system are assumed to be statistically independent,[1] and characterized by a kill probability P_{ki}, where the subscript i refers tro the layer number, the number of missiles surviving to reach their targets is:

$$N = N_0 * (1-P_{k1}) * (1-P_{k2}) * (1-P_{k3}) * (1-P_{k4})$$

where N_0 is the number of missiles, or multiple warheads, launched. The quantities in parentheses are often called the 'leakage rates' for each layer. If the second tier refers to the flight segment when MIRVs are being dispensed, the situation is more complex. A missile intercepted when there are few warheads remaining to be dispensed is a less valuable target than one intercepted with most of its warheads still to be released. For simplicity I assume that if a missile is intercepted in boost phase all of its warheads are destroyed, but that P_{k2} refers to the destruction of a single warhead in

the second tier. The capacity of the second tier is, therefore, given in terms of the number of MIRVs expected to leak through the boost phase defenses. The P_{ki} are not single shot kill probabilities, but are instead the likelihood that a warhead will be destroyed by a layer, which may be capable of taking more than one shot at a given target.

In general, the number of warheads, N_s, passing through a given layer of finite capacity is:

$$N_s = N_a * (1-P_k) \qquad N_a > N_{max} \qquad (2a)$$

or

$$N_s = (N_a - N_{max}) + N_{max} * P_k \qquad N_a <= N_{max} \qquad (2b)$$

where N_a is the number of missiles entering the layer and N_{max} is the maximum number of targets which can be engaged by the layer.

For numerical convenience, assume that the attacking force ("Orange") actually launches ICBMs, each carrying 10 MIRVs. Suppose that the defense, "Blue", has a four layer defense, and that each layer has a P_{ki} of 0.9. If Orange has 1,000 ICBMs, each with 10 warheads, only one warhead would reach its target, surely an effective defense even for populations. It appears that such a defensive system would be hard to beat just by increasing the number of Orange missiles. After all, if Orange must add 10,000 new warheads to destroy one additional target with confidence, the defense "must be cost-effective at the margin". This is one source of the confidence expressed by the supporters of strategic defense that the proposed systems can prevail.

But the defense is cost-effective only through leverage, and Orange can make a "margin call". The layers of the defense are so tightly linked that if the threat is increased by only a small amount, or if countermeasures are even moderately effective, the defense will collapse.

Hidden Boosters

Suppose Orange is able to launch more boosters than Blue counted on, and suppose that the effects of saturation and exhaustion are modeled by assuming that each layer can destroy 90% of an attack up to its maximum capacity--and that for the post-boost and mid-course layers, the maximum capacity is twice the expected threat. A factor of four excess capacity is allowed for the terminal defenses. Above that level of attack, all of the Orange forces leak through a given layer. This is a simplification, since saturation effects are not usually so sharply defined; but the "cookie-cutter" approach illustrates the principle (Effectively. For a Blue system designed to handle 10,000 Orange RVs distributed among 1,000 ICBMs, the effect of Orange adding missiles is shown in Fig. 1. Curve 1 represents the case where P_{ki} is set at 0.9 for all layers; curve II takes a perhaps more reasonable view of the effectiveness of the defenses, setting P_{ki} to 0.8 while maintaining the same factors of two and four excess capacities for the second, third and fourth layers. Each of the upper layers is thus much bigger and more costly than if a P_{ki} of 0.9 had been achieved.

FORUM ELECTIONS

Now is the time for all good Forum members to elect their officers. This year elections are being held for the office of Vice-Chairperson and three Executive Committee Members. This issue of Physics and Society features a centerfold which contains the candidates' statements and a ballot for the Forum elections. Indicate your choices on the ballot, which can then be folded and mailed to the address shown on reverse side. Please return it before February 15, 1987. The nominations committee was chaired by Mark Sakitt.

BARBARA G. LEVI: VICE-CHAIRPERSON

BACKGROUND: Barbara Levi is a member of the Research Staff, Center for Energy and Environmental Studies, Princeton University, working on arms control. Her background includes a Ph.D. in particle physics from Stanford University, teaching at Fairleigh Dickenson University and George Tech, consultant to the US Congressional Office of Technology Assessment, and a consulting editor of *Physics Today* since 1970. In the past year Levi has co-authored a *Scientific American* article on verifying a fissile-material production cutoff, and a *Physics Today* article reviewing the nuclear winter calculations. From 1984-86, she served on the Executive Committee of the Forum, chairing the Forum Awards Committee.

STATEMENT: The very name of the "Forum" describes what the primary goal of our organization should be -- to promote the open discussion of subject areas where the discipline of physics and the interests of society overlap. Our special role as physicists should be to master and convey the deepest possible understanding of the technical facts and principles underlying science and society issues. The Forum activities - - topical sessions at APS meetings, the newsletter, special study groups -- attempt to facilitate this process of self-education. We should strive to maintain a high quality and objectivity in all of these activities. Our influence as a Forum will continue to grow with the quality of our products.

I applaud the current trend to make the newsletter even more substantive. I would like to see the newsletter become a more heavily travelled two way street, through which Forum members may both learn and teach. We should encourage wide membership contributions to regular features such as book reviews, sample student problems, brief technical papers, point-counterpoint essays on selected issues, etc. Similarly, I would like to encourage presentation of well-researched papers at Forum contributed paper sessions. The dominant theme of Forum activities in the past few years has been the nuclear arms issue. While that certainly is a high-priority issue, we must not forget the ever-expanding list of areas where science impacts on society or vice versa.

PETER D. ZIMMERMAN: VICE-CHAIRPERSON

BACKGROUND: Peter Zimmerman is a Senior Associate, Carnegie Endowment for International Peace, directing the SDI Technology and Policy Program, and he is a Professor of Physics, Louisiana State University. His background includes a Ph.D. in intermediate energy nuclear physics from Stanford University, Visiting Scholar at the US Arms Control and Disarmament Agency and Advisor to the START negotiating delegation in Geneva (1984-86), postdoctoral fellow at DESY, UCLA and Fermilab. Zimmerman has recently published an article on SDI Policy in *Foreign Policy*. From 1984-present, he has been the Secretary-Treasurer of the Forum, chairing the APS-Forum Fellowship Committee and serving on the Forum Awards Committee.

STATEMENT: In the past decade the APS has become deeply involved in public affairs in fields ranging from environmental and energy policy to arms control and national security. The Forum and POPA, the Panel on Public Affairs, have played complementary roles, with the Forum presenting symposia at Society meetings and POPA organizing large-scale, well-funded, studies. More recently, the Forum has begun to sponsor its own studies conducted by volunteer members; the project on Civil Defense has been completed, and one on ICBM basing methods is in progress.

I believe that these studies are valuable for two reasons: they provide good papers on important topics where physics and society interact; and they permit physicists who have not yet had the opportunity to work in this challenging area with a chance to break in. I believe that more projects, covering a wider range of topics, and involving more people, should be undertaken. The Vice-chair of the Forum serves as a member of POPA, where he or she has an opportunity to seek support for Forum projects from the APS and to suggest new projects for the Society, building when possible, on work done in the Forum.

Our experiment of organizing Symposia for Divisional and sectional meetings has been successful and should be extended. I am happy to see that our newsletter seems to be evolving into a journal of physics and society and I want to encourage all members of the Forum to consider publishing it.

DON'T FORGET TO VOTE!

ALEXANDER DeVOLPI: EXECUTIVE COMMITTEE

BACKGROUND: Alex DeVolpi is a physicist at Argonne National Laboratory and Principle Investigator of the Arms Control Project on On-Site Inspection. His background includes a Ph.D. from Virginia Polytechnic University, Co-founder and Co-chairperson of the concerned Argonne Scientists, Lieutenant Commander USNR (retired), and Executive Committee of Chicago Alliance to End Repression. DeVolpi has authored a book on nuclear-weapons proliferation *(Proliferation, Plutonium and Poilicy)* and co-authored one on government secrecy *(Born Secret)*.

STATEMENT: We have become increasingly dependent on technology for our existence and security. To deal with the human consequences of this dependence, the coordination and organization of scientists are increasingly important. Physicists have an especially important share of responsibility, and organizations such as the Forum that exchange information and viewpoints can help individuals and local groups amplify their role in the interface between science and society. Therefore, through the Forum -- its sessions and organized activities, newsletters and publications, membership and representatives, studies and positions -- we have an opportunity to contribute to public education and informed action.

ROBERT EHRLICH: EXECUTIVE COMMITTEE

BACKGROUND: Robert Ehrlich is Chairman of the Physics Department, George Mason University. His background includes being the Organizer of the 1986 George Mason University Nuclear War Education Conference and he has taught interdisciplinary courses on the nuclear arms race for 5 years. Ehrlich has authored the text *Waging Nuclear Peace*, co-authored two chapters in the Forum's study, *Civil Defense: A Choice of Disasters*, and is now editing *Nuclear War Education: A Variety of Perspectives*.

STATEMENT: I see the following as high priorities for the Forum: Continuing a strong emphasis on arms control issues, welcoming diverse points of view so as not to foster the impression that only those on the left care about arms control, sponsoring (with other organizations) short courses and symposia, promoting college-level nuclear war education, encouraging young people (especially physics majors) to consider careers in the area of national security/arms control.

MARTIN B. EINHORN: EXECUTIVE COMMITTEE

BACKGROUND: Martin Einhorn is a Professor of Physics, University of Michigan, working in Elementary Particle Physics. His background includes a Ph.D. in Theoretical Physics from Princeton University, member of the High Energy Physics Advisory Panel to DOE, Director of the Theoretical Advanced Study Institute in Elementary Particle

Physics, and he has taught a course on the nuclear arms race for the past 6 years. Einhorn has published an article in *International Security* on Strategic Arms Control Through Test Restraints.

STATEMENT: A non-partisan Forum is an essential to the APS in promoting the exchange of ideas and information about issues affecting our professional lives. I support the current initiatives, expecially upgrading the newsletter into an even more valuable resource. One subject which should be disconcerting to APS members is the apparent disaffection among youth with physics as a career. This is all the more remarkable in view of the vitality of physics research and the expanding professional opportunities which can be anticipated in the future. The number of undergraduate majors, the decline in graduate enrollments in physics, especially among U.S. citizens, and the failure to attract more women and minorities into the profession ought to be topics of great concern.

ANTHONY FEINBERG: EXECUTIVE COMMITTEE

BACKGROUND: Tony Feinberg is a Senior Analyst at the Congressional Office of Technology Assessment, working on a feasibility study of the SDI. His background includes a Ph.D. in Experimental Particle Physics from the University of California, Berkeley; Staff Physicist at Brookhaven National Laboratory (1978-83) working on nuclear safeguards and nonproliferation, APS Congressional Fellow with Sen. Jeff Bingaman (1983-84), Research Assistant Professor at Syracuse University, and post-doc at the University of Turin, Italy. Feinberg co-authored the OTA report *Ballistic Missile Defense Technologies*.

STATEMENT: The Forum and *Physics and Society* have become integral parts of the U.S. physics community, in great part due to their activities in disseminating information on issues dealing with the arms race, with energy and the environment, and with human rights for physicists. These activities should be intensified because of the increasing impact of military research on the physics community.

Physics and society interact mutually with each other; physics affects society, but physicists often forget that the reverse also occurs. The current severe fiscal crisis may produce draconian budget reductions over the next few years. Non-military science research may be especially vulnerable. If not moderated, the effects of cutbacks will change the face of U.S. research and graduate education in physics for many years to come. The Forum could be an ideal vehicle for dealing with this issue, which is likely to become very serious in a very short time. Symposia and workshops should be organized which bring together representatives from both sides to discuss a) the effects drastic changes in research funding would have on U.S. physics and on the U.S. in general and b) ways of moderating the effects of such changes if they cannot be avoided. Finally, I would note that, in order to maintain its effectiveness and credibility in the community, the Forum must continue to present opinions from all parts of the scientific and political spectra.

MICHAEL J. HARRISON: EXECUTIVE COMMITTEE

BACKGROUND: Michael Harrison is a Professor of Physics at Michigan State University. His background includes a PhD from the University of Chicago, Dean of the Lyman Briggs College at Michigan State, consultant to the University Development Commission in Bangkock, Thailand, and teacher of a course on the nuclear arms race. Harrison has published on nuclear arms education in the *Journal of College Science Teaching* and in *Physics and Society*.

STATEMENT: Our strengths and integrity as physicists and educators arise from our scientific and technical capacities for carefully evaluating and examining complex issues which have both physics and societal components. These issues extend beyond nuclear arms race and enviornmental concerns into many aspects of economic and social life. Our potential for first educating ourselves, and subsequently others, receives important support from Forum activities, particularly short courses and invited paper symposia and sessions at APS meetings. The Newsletter of the Forum can also play a strong supportive role in sharing summaries of substantive Science and Society investigations by individual physicists with the readership at large. Accordingly, the Forum should seek to develop greater interest and involvement of the considerable talent embodied in the membership of the APS, while continuing to actively identify important new oncoming issues in which physicists can make knowledgeable contributions in the early formulation of problems. Our goals should be to strengthen the educational role of Forum sessions, symposia and short courses, develop the research potential of topical study groups, and cooperate more broadly with other parallel groups in the APS, AAPT and AAAS.

FORUM ON PHYSICS AND SOCIETY 1987 ELECTION BALLOT

Please place an X in the box for the candidates of your choice

For VICE-CHAIRPERSON (Vote for one):
☐ Barbara Levi
☐ Peter Zimmerman

EXECUTIVE COMMITTEE (Vote for three):
☐ Alexander DeVolpi
☐ Robert Ehrlich
☐ Martin Einhorn
☐ Anthony Feinberg
☐ Michael Harrison
☐ Anthony Nero

Please fold and tape this ballot and return to Paul Craig by February 15, 1987. The reverse side is already addressed

ANTHONY V. NERO, JR: EXECUTIVE COMMITTEE

BACKGROUND: Tony Nero is a Senior Scientist and Principal Investigator in the Indoor Environment Program at Lawrence Berkeley Laboratory. His background includes a Ph.D. in nuclear physics from Stanford University, Physical Science Officer in the Non-Proliferation Bureau at U.S. Arms Control and Disarmament Agency (1978), Assistant Professor at Princeton University (1972-75), Lecturer in the Energy Resources Program at Berkeley, Chair of the POPA Subcommittee on Studies and consultant to the National Academy of Sciences and the World Health Organization. Nero has authored the book *A Guidebook to Nuclear Reactors*, and articles on indoor radon in *Technology Review* and *Science*.

STATEMENT: The physics community, through its research, makes a fundamental and long-term contribution to the future of our society and has a corresponding capability and responsibility for considering important technological issues and for influencing associated societal choices. During recent decades, physicists have taken the lead on important questions in arms control, energy, and the environment. The Forum has been an essential contributor by raising issues, airing them in its sessions at APS meetings and in its publications, exploring them in informal groups, and encouraging the APS as a whole to examine them in detail. I expect that Forum invited-paper sessions will continue to advance these purposes, Further I hope for an increased level of Forum activity in three respects. First, Forum publications, including the newsletter, should serve even more frequently as an avenue for substantive papers on key issues. Secondly, the Forum should lend more encouragement to the formation of working groups on important topics, since it is the joint efforts of capable and didicated scientists that can yield the greatest result and wield the most influence. Finally, physicists, through the Forum, ought to examine to a greater degree, not only well-defined topics in arms control or energy and the environment, but the underlying question of how a nation such as ours can make effective decisions on difficult technological questions that ultimately affect the way we live or whether we live at all.

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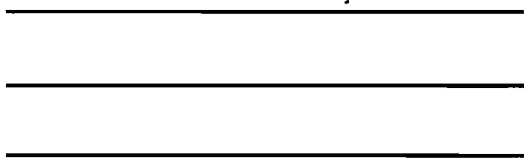
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PAUL CRAIG
Dept. of Applied Science
University of California
Davis, CA 95616

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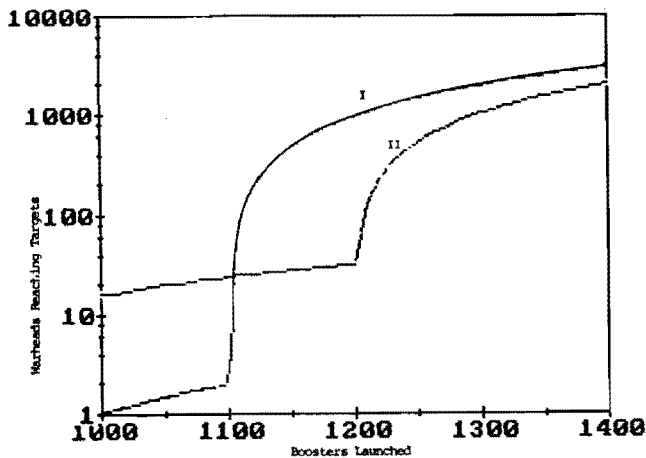**PLEASE SEAL ONE EDGE WITH A PIECE OF TAPE. THANKS!**

Figure 1. Warheads reaching their targets for boosters launched beyond the nominal attack size of 1,000. Curve I shows results for a kill probability of 0.9 in each layer; curve II shows the results for a kill probability of 0.8. In each case layers 2 and 3 have a factor of 2 excess capacity while layer 4 has a factor of 4 excess. For the case of P_{ki} of 0.8 the absolute capacities of layers 2,3 and 4 are, however, much higher than in the case for P_{ki} of 0.9 because lower kill probabilities imply higher absolute numbers of missiles and warheads penetrating each layer.

An increase of just 400 Orange missiles brings about a total collapse of the defenses. No reasonable expansion of the terminal layer can cope with such a situation; only expanding layers one and two offers any hope. However those layers are precisely the most expensive to reinforce and require the most lead time to build.

Countermeasures

Proliferating Orange forces to overwhelm Blue is a possibility, but Blue could expand its defenses to match additional Orange deployments. On the other hand, Orange can (and probably will) add countermeasures in secret. If the United States is assumed to be Blue, Orange can be expected to have a fairly detailed knowledge of Blue's weaknesses. Consider a situation where Orange is limited in total strength -- perhaps through a new Strategic Arms Reduction Agreement -- but can add countermeasures to some ICBMs so that they are capable of penetrating the boost phase defense layer with only small losses.

Reasonable countermeasures might include the use of ceramic coatings, booster rotation to defeat some lasers, or the use of fast-burn boosters which will defeat neutral particle beams, x-ray lasers and kinetic energy interceptors -- or some combination of speed and hardening.[2] The situation is sufficiently complex that a simple model loses some important features: the use of any countermeasures will reduce the throwweight of an ICBM, but not inordinately; no countermeasure will guarantee that every missile will penetrate the defenses perfectly.

But let us estimate[3] that a booster with countermeasures might carry 8 warheads, instead of 10, and that against such a booster the kill probability of the first layer is reduced to between 0.7 and 0.1. (For comparison, a 10% kill rate, corresponding to a 90% leak rate, is roughly as good as the best air defenses have ever achieved, even after significant experience against real opponents.). Figure 2 illustrates the behavior of Blue's defenses when confronted with a numerically constrained Orange force as a function of the number of boosters Orange equips with countermeasures of varying effectiveness. Note that no special countermeasures are used on RVs to reduce the effectiveness of the second, third and fourth layers of the defenses. Such countermeasures would only increase the already large number of warheads reaching their targets.
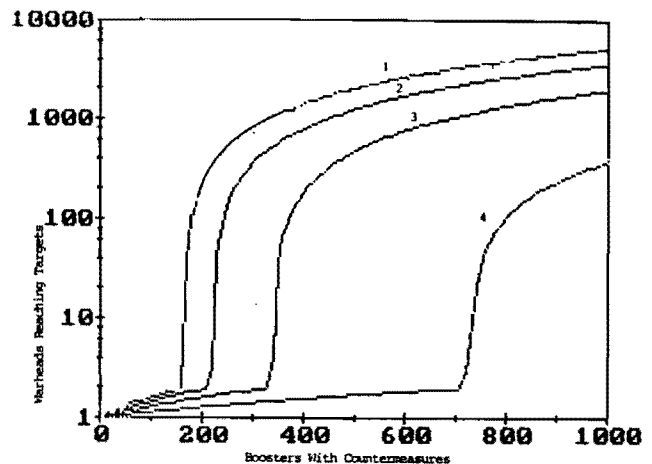

Figure 2. Warheads reaching their targets for a fixed number of boosters (1,000), but with a varying fraction equipped with countermeasures of varying effectiveness against the boost-phase defenses. The kill probabilities achieved against countermeasure equipped boosters are: curve 1, 0.1; curve 2, 0.3; curve 3, 0.5; and curve 4, 0.7. Catastrophic failure of the defense occurs for all cases. The absolute capacities of layers 2, 3 and 4 are the same as for curve I of Fig. 1, and the kill probability for each of the upper layers is assumed to be 0.9.

Countermeasures against boost phase defenses are clearly a useful way to make sure that the defense is overwhelmed. In order to ensure that Blue suffers a catastrophe, only a relatively small fraction of Orange's boosters need to be so equiped. It is often suggested that because a layered defense can engage targets several times, each time using different techniques, that each RV or booster has to be able to parry every type of defensive weapon; this is clearly not true and indeed brings only a small improvement in offensive performance. The ability to skip specialized countermeasures greatly reduces the penalties exacted by the defense. Furthermore, if Orange employs about 200-300 boosters with very effective counter-measures, he can remain confident of his ability to attack a large subset of Blue's hard target set, because Orange knows that nearly 50% of the RVs on those missiles will reach their targets.

Reasonable cross-targeting will ensure Orange's ability to deprive Blue of his C^3 sites, missile control centers and national command centers. Since some boosters without countermeasures will get through, unhardened boosters can carry warheads aimed at industrial and civilian targets.

Blue's counter-countermeasure is obvious; merely expensive and complex. Each layer of the defense must be greatly expanded; but this kind of response is clearly limited in practice. A layered defense is feasible only if the demands on each layer are modest and if each layer is truly independent of all of the others. But the layers cannot be statistically independent because they are encountered in a specific order, and only in that order. A weakness in an early layer translates instantly into more stringent demands on the later ones.[4]

A leveraged defense can collapse if the offensive strategy and hardware change even a small amount. The real case is apt to be worse for the defense than even the above models suggest, because ICBMs can be rigorously tested in peacetime; and a layered defense can never be tested realistically. The leverage which makes the layered defense scheme attractive makes it inherently fragile; the fragility cannot be beaten by simple fixes, but is intrinsic to the achievement of otherwise implausibly high effectiveness. At great cost to the defense and relatively little to the offense, offense dominance will remain even in a defended world.[5]

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1. To the best of my knowledge Ashton Carter was the first to suggest that the tiers of a layered defense might not be statistically independent and that this could have grave consequences for the defense. See his Directed Energy Missile Defense in Space -- A Background Paper (Washington, D. C.: U.S. Congress, Office of Technology Assessment, April, 1984). The "Fletcher Report", The Strategic Defense Initiative: Defensive Technologies Study (Washington, D. C.: Department of Defense, March, 1984) concluded that a layered defense, and only a layered defense, could provide "the means of rendering" ballistic missiles "impotent and obsolete".
2. Countermeasures are discussed in many places; one of the most authoritative in the unclassified literature is Ballistic Missile Defense Technologies (Washington, D.C.: U.S. Congress, Office of Technology Assessment, September, 1985), pp. 170-178. The fast-burn booster is perhaps the most effective generic countermeasure; it stresses the boost-phase intercept system by reducing the time available for engagement after the launch of the booster is detected and a track file established. By ensuring that more missiles survive the boost-phase intercept phase, it also reduces the effectiveness of all the other layers. Indeed, fast-burn boosters may completely negate many defensive schemes.
3. See R. L. Garwin's letter, Physics Today, 39, No. 3 (March, 1986), pp. 13-15.
4. The September, 1985 OTA report cited above states (p. 145) "The leakage rates of the individual layers of a layered defense can be multiplied together to give the

total leakage rate only if the individual layers are totally independent and share no common elements" (emphasis in original). The situation is clearly more desperate than the OTA report indicates, since even layers without common elements cannot be independent.
5. This paper is a mathematical extension of the work originally presented in Foreign Policy, issue number 63, summer, 1986, under the title "Pork Bellies and SDI".

WERNER HEISENBERG AND THE GERMAN ATOMIC BOMB by Lawrence Badash, Professor of History of Science, University of California, Santa Barbara, CA 93106

The US-UK "Manhattan Project" invented nuclear weapons which were used during World War II. Nazi Germany did not. Yet, nuclear fission was discovered in Germany in 1938, and German scientists investigated reactor and bomb concepts with not inconsiderable success. Why, then, this inability to produce a weapon? The reasons are numerous, well discussed in the historical literature, and highly instructive about the workings of a scientific community, both internally and in its relationship with the government. The most controversial explanation offered has been that German scientists were too moral; they could not create a weapon of mass destruction for Hitler. This interpretation has been widely criticized, but it refuses to vanish, perhaps because some ambiguous evidence supports it, and because of lingering incredulity that Germany, believed to be supreme in science in the 1930 s, could have bungled the job so badly.

When Frederic Joliot's team in Paris reported, in April 1939, that about 3.5 neutrons were emitted per fission of a uranium nucleus, the attention of physicists in several countries was riveted upon the possibilities of a chain reaction. In Germany, Wilhelm Hanle and Georg Joos of Gottingen contacted the Reich Ministry of Education, which appointed the president of the Physikalisch-Technische Reichanstalt to coordinate an investigation, while almost simultaneously Paul Harteck and Wilhelm Groth of Hamburg wrote to the War Office. Long before the famous Einstein letter to President Roosevelt was sent, Germany banned the export of uranium and officially backed studies of the uses of fission. Upon the outbreak of war the military assumed charge, but failed in its attempt to consolidate the research, leaving each professor as prince of his provincial institute instead of a mere courtier to some scientific king in Berlin. This desire to protect one's prestige, coupled with rivalry between theoreticians and experimentalists, plagued the project from the outset.

Harteck was one of the most creative and energetic of the scientists, but as a physical chemist he was lower in the pecking order than physicists and had difficulty in obtaining scarce materials. Nevertheless, he soon acquired uranium hexafluoride gas for thermal diffusion separation of U-235 and, on the instigation of Hans Suess, designed a reactor, or uranium burner, consisting of layers of uranium fuel and

heavy water moderator. Others initiated measurements of nuclear cross-sections and studies of various processes, while Werner Heisenberg of Leipzig began a theoretical study of the possibility of a chain reaction. In December 1939 he reported to the War Office that ordinary uranium could be used in a reactor, with heavy water or carbon as moderator, but that the reactor's size could be smaller as the enrichment of U-235 was greater; for an explosive, enriched U-235 was necessary.

By mid-1940 German scientists recognized the value of a lattice arrangement in a reactor, saw that plutonium also would be suitable for an explosive, had at their disposal a huge supply of high-grade uranium from the conquest of Belgium, had the potential for increasing their heavy-water supply through the conquest of Norway, and were abreast of developments abroad from the uncensored American journals. And by the year's end Heisenberg (commuting from Leipzig and effectively replacing the Dutchman Peter Debye as head of the Kaiser Wilhelm Institute of Physics) was building with some colleagues a uranium oxide-paraffin reactor in Berlin.

Optimism turned to despair in 1941. Walther Bothe of Heidelberg determined that plentiful graphite was unsuitable as a moderator and no one presumed to confirm the validity of the distinguished professor's work. Only near the war's end was his error recognized, due perhaps to nitrogen in the air. Heisenberg's pile and subsequent modifications never achieved criticality--too many neutrons were absorbed by the paraffin and impurities. Had Harteck not been denied an adequate amount of uranium oxide for an experiment with dry ice (available in great purity) as moderator the year before, the proper neutron absorption value for carbon very likely would have been measured. A natural uranium reactor now depended solely on heavy water as moderator and needed tons of it, but was denied this by Allied air raids and sabotage. Research was tied to a trickle of the liquid. And yet, by early 1942, using uranium metal instead of oxide at Leipzig, R. Depel and Heisenberg obtained such an improvement in the neutron multiplication factor that they were convinced this approach would work.

The alternative, a reactor using carbon or paraffin with enriched U-235, fared poorly. Thermal diffusion proved to be unsuitable for highly corrosive uranium hexafluoride, there were no other gaseous compounds of uranium, and other separations techniques had not been pursued actively since problems had not been anticipated. Erich Bagge now concentrated on his idea of an isotope sluice, Groth pursued the ultracentrifuge, and by the end of 1941 seven different enrichment processes were under consideration (but, curiously, not gaseous diffusion through a porous barrier). However, by this time Fritz Houtermans had made calculations on fast-neutron chain reactions, critical masses, and especially the superiority of plutonium over U-235; a Pu-producing reactor would be far more efficient than any isotope separation technique. The urgency for isotope separation thus dissipated (without any formal decision), and the project sank into a state of marking time for the construction of a heavy-water reactor. At this point, I conjecture, the reactor was viewed more as a source of explosive material than as a source of energy.

In early 1942 most uranium research was transferred from War Office control to the weak Reich Research Council. The German economy was nearing a breaking point and only projects certain to benefit the war effort in the near future could be considered. The prospect of both a weapon and an energy source kept uranium research alive, but not flourishing. In June, Minister of War Production Albert Speer reviewed the work and thenceforth permitted support only for a program limited to an energy source. Had a chain reaction been achieved by that time, Heisenberg might have urged a massive effort involving personnel, construction, and raw materials. Indeed, the relatively small requests by the scientists seem to have convinced the government that they had little confidence in a successful outcome. Another interpretation is that the scientists felt it futile to expect the German economy to support uranium work on the scale needed (yet at this very time mass production of the V-1 flying bomb was authorized), and the best they could hope for was to keep young scientists out of military service and perhaps develop an energy source that would be useful in postwar Germany. Allied air raids on Berlin caused the project to move to rural Bavaria in 1944 and 1945, where a pile was constructed in the village of Haigerloch. Lack of materials, particularly uranium of necessary purity, prevented this reactor from achieving criticality by the time American troops arrived.

Heisenberg has explained this failure as due to the inability of wartime German industry to mount the huge effort needed, and has noted that even the American project was not concluded until after the European war ended. Moreover, given the Nazi leadership's attitude that weapons were needed quickly, the scientists were not about to make promises they knew they could not keep. German physicists attempted to keep control of the project (in contrast to America, where the Army was in charge), and, as things turned out, "they were spared the decision as to whether or not they should aim at producing atomic bombs."[1]

Journalist Robert Jungk, in his bestselling <u>Brighter Than a Thousand Suns</u> (1958), chose to emphasize the personal attitudes of the German scientists, who he claims opposed the regime and "were able successfully to divert the minds of the National Socialist Service Departments from the idea of so inhuman a weapon."[2] Heisenberg and his colsest friends, Jungk maintains, endeavored to control the research because they feared "that other less scrupulous physicists might in different circumstances make the attempt to construct atom bombs for Hitler.[3] Jungk reports (unforunately without footnotes) that Heisenberg, Carl Friedrich von Weizsacker, and Houtermans agreed to keep the government as ignorant as possible about the possibility of atomic bombs, particularly of plutonium.[4] Further, he quotes Max von Laue's consoling words to an anguished Houtermans: "no one ever invents anything he doesn't really want to invent."[5] And, of course, Jungk tells the familiar but still confusing story of the October 1941 encounter between Niels Bohr and Heisenberg. The latter claimed that he tried to convey the message that German scientists would not make nuclear weapons if Allied scientists similarly refrained, but Bohr went away convinced that the Germans intended to progress as far as they could.[6]

The basic thesis of Jungk's book is the following:

It seems paradoxical that the German nuclear physicists, living under a saber-rattling dictatorship, obeyed the voice of conscience and attempted to prevent the construction of atom bombs, while their professional colleagues in the democracies, who had no coercion to fear, with very few exceptions concentrated their whole energies on production of the new weapon.[7]

The fundamental problem with this interpretation is the lack of evidence for it. Jungk explains this away by saying that the Germans had to be very circumspect, fearing the Gestapo. But this alleged role-playing, in which Heisenberg and Weizsacker only appeared as sympathetic to their government, has not been seen by Allied scientists as mere acting.[8] Samuel Goudsmit, scientific director of the American "Alsos" mission to determine how far the Germans progressed, saw no reason to credit the Germans with ethical behavior. Instead, he found them lacking in vital teamwork because they held each other in contempt, and were without the Allied motivation to succeed because they smugly believed that no one could be further advanced than they.[9]

British journalist David Irving, author of the most comprehensive study of the German uranium work, likewise saw little reason to ascribe an ethical explanation to the German failure to produce an atomic bomb. In a nutshell, he remarked that they :never came far enough to have to make a decision on the bomb."[10]

My own strong inclination is to agree with Goudsmit and Irving, both for the many arguments they present and for the following reason. Ten nuclear scientists captured by the Allies were interned in a country estate near Cambridge, England, during the last half of 1945. Unknown to them, their conversations were recorded in an attempt to learn if Germany had made progress beyond what they admitted to their captors. Although the British government has denied my request for a copy of the transcripts (presumably they do not with to admit to anything so unsporting as eavesdropping), excerpts have been published by Irving (who doesn't reveal his source) and others. Upon learning of the bombing of Hiroshima they expressed a wide range of emotions. Of particular interest, Weizsacker asserted: "I believe the reason why we didn't do it was that all the physicists didn't want to do it, on principle. If we had all wanted Germany to win the war, we could have succeeded." This suggestion of sabotage upset some of the others, and Bagge of Leipzig thought it "absurd for von Weizsacker to say he did not want the thing to succeed: that may be so in his case, but not for all of us."[11] These two quotes exemplify the ambiguity mentioned in the opening lines of this essay. The overwhelming evidence shows virtually no morally-based hesitation to work on nuclear weapons, but here and there a comment (not always self-serving) suggests the opposite. Yet, if such hesitation did exist, we are without evidence that it was acted upon and that it set back the German project. The only "evidence" is circumstantial-- Germany made no atomic bomb--but that is inadequate for historical purposes. Far more concrete is the fact that they never reached the point where such a decision might be needed.[12]

1. W. Heisenberg, "Research in Germany on the technical application of atomic energy," Nature, 160 (16 Aug. 1947), 211-15.
2. R. Jungk, Brighter Than a Thousand Suns: A Personal History of the Atomic Scientists (New York: Harcourt Brace Jovanovich, 1958; originally published in German in 1956), p. 88.
3. Jungk, p. 91.
4. Jungk, p. 96.
5. Jungk, p. 94.
6. Jungk, pp. 100-102.
7. Jungk, p. 105.
8. See, e.g., review of Jungk by E. U. Condon in Science, 128 (26 Dec. 1958), 1619-20, and Jungk's reply in Science, 129 (1 May 1959), 1192. See also, an anonymous review in the (London) Times Literary Supplement (20 June 1958), 337-38; review by C. P. Snow in the New Statesman, (14 June 1958), 771-72; review by Hans Bethe in the Bulletin of the Atomic Scientists, 14 Dec. 1958), 426-28; review by Robert Wilson in Scientific American, 199 (Dec. 1958), 145-49.
9. S. Goudsmit, Alsos (New York: Schuman, 1947), ch. 15.
10. D. Irving, The Virus House: Germany's Atomic Research and Allied Counter-measures (London: Kimber, 1967), p. 268. The book was published in America as The German Atomic Bomb (New York: Simon and Schuster, 1968).
11. Irving, pp. 11-17.
12. Useful reviews of Irving, by Eugene Rabinowitch, Heisenberg, and Hans Suess, may be found in the Bulletin of the Atomic Scientists, 24 (June 1968), 32-39.

ASSESSING THE EFFECTS OF ACIDIC DEPOSITION ON LAKES USING DIATOM AND CHRYSOPHYTE ALGAL REMAINS by

Donald Charles, Department of Biology, Indiana University, Bloomington, IN 47405

Scientists and policy-makers are very interested in learning how acidic deposition (acid rain) has affected lake water chemistry and biota during the past 100 years. If we knew more about these changes we would be better able to evaluate the potential benefits from alternative strategies for control of sulfur and nitrogen emissions. Unfortunately there is little good-quality historical data on acidification related changes. Because of this, there has been widespread interest in detecting changes in aquatic ecosystems using the paleoecological approach: analysis of the chrono-stratigraphic record contained in lake sediments. Among the various sediment characteristics, the remains of diatoms and chrysophytes provide the best data for quantitatively reconstructing past lakewater pH and alkalinity[1,2]. They have been used to analyze acidification trends in lakes in several countries including the U.S., Canada, Norway, Sweden, Finland, West Germany, Netherlands, England and Scotland[2,3].

Diatoms make up a large group of single-cell freshwater and marine algae (division Bacillariophyta). They have silicious cell walls and are formed of two halves or valves. Chrysophytes (Chrysophyceae; Mallomonadaceae) are primarily freshwater plankton. Its members have flagella and an external covering of overlapping siliceous scales and bristles.

Diatom assemblages in sediment are good indicators of past lake pH because (1) diatoms are common in nearly all freshwater habitats, (2) distributions of diatom taxa are strongly correlated with lakewater pH, (3) diatom remains are preserved well in sediment and can be identified to the lowest taxonomic level, (4) their remains are usually abundant in sediment (10^4 to 10^8 valves/cm^3 of sediment) so that rigorous statistical analyses are possible, and (5) many taxa are usually represented in sediment assemblages (20 to 100 taxa per count of 500 valves is typical) so that inferences are based on the ecological characteristics of many taxa.

Some disadvantages in using diatoms as pH indicators are that (1) diatom identification requires considerable taxonomic expertise, (2) occasionally diatoms are not well preserved because of dissolution (e.g., in some peaty and some calcareous sediments), (3) sometimes the number of taxa is low (e.g., in some bog lakes), (4) calibration data sets (the current relationship between water chemistry and surface sediment diatom assemblages) are not always available for the lake region studied, and (5) good ecological data are not always available for all dominant taxa.

In general, the use of chrysophyte scales for pH reconstructions involves the same advantages and disadvantages as for diatoms[3], except that the number of chrysophyte taxa in a sediment assemblage is in the range of one-tenth the number of taxa of diatoms. Most chrysophyte taxa are euplanktonic (normally suspended in the water).

Techniques for Determining pH Trends

Several techniques based on diatom assemblages have been used to assess trends in acidification and to derive equations for inferring lakewater pH.

The simplest and most straightforward approach is to count sediment-core diatom and chrysophyte assemblages and prepare depth profiles of percentages of the dominant taxa. Changes in the profiles are then interpreted in light of the ecological data available on the taxa. An example is the diatom stratigraphy of Big Moose L. in the Adirondack Mountains, N.Y. (Figure 1) At the present time, this is the only technique used to analyze chrysophyte scale data.

Friedrich Hustedt (in 1939) made one of the first significant steps toward establishing a more quantitative approach for using diatoms as pH indicators, by defining the following pH occurrence categories:

Acidobiontic (ACB)--optimum distribution at pH below 5.5

Acidophilic (ACP)--widest distribution at pH less than 7

Circumneutral/indifferent (IND)--distributed equally above and below pH 7

Alkaliphilic (ALK)--widest distribution at pH greater than 7

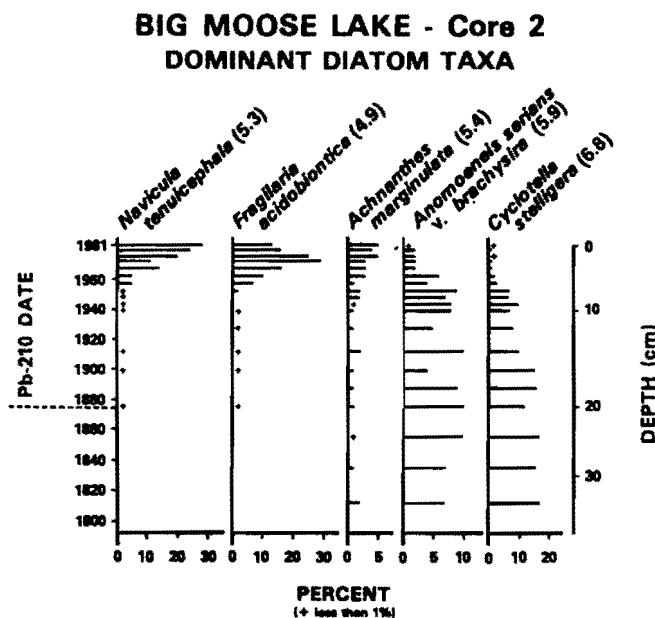Alkalibiontic (ALKB)--occurs only at pH greater than 7

BIG MOOSE LAKE - Core 2
DOMINANT DIATOM TAXA

Figure 1. Dominant diatom taxa in a sediment core from Big Moose L., Adirondack Park, New York. The numbers in parentheses indicate abundance weighted mean (AWM) pH values for each taxon,

$$pH_{AWM} = \sum_{i=1}^{56} P_i(Xi) / \sum_{i=1}^{56} P_i \; ;$$

Pi = the percentage occurrence of the taxon in the sediment assemblage from lake i; xi = the mean air-equilibrated surface sample pH of lake i (determined from mean of H+ concentrations) calculated from distribution of the taxa in 56 Adirondack lakes. Pb-210 dates determined by Stephen Norton, Univ. of Maine, Orono. Dates below dashed line are extrapolations of Pb-210 dates.

Assignments of diatom taxa to categories can be based on literature references and on the distribution of taxa within waters of particular geographic regions. Changes in the percentages of diatom valves in each pH category in a sediment core can be used to estimate trends in lakewater pH.

Several types of equations have been developed to use in calculating lakewater pH from diatom data using these categories. Predictive equations are calibrated for a study region using measured lakewater pH and surface sediment diatom assemblage data for at least 20-30 lakes within the region (see Figure 2). The most successful approach has been use of multiple linear regression analysis of measured lakewater pH with percentage of diatoms in each Hustedt pH category[4]. The r^2 values for the best sets of equations range from 0.80 to 0.94; standard errors of estimates from ± 0.4 to ± 0.25 pH units.
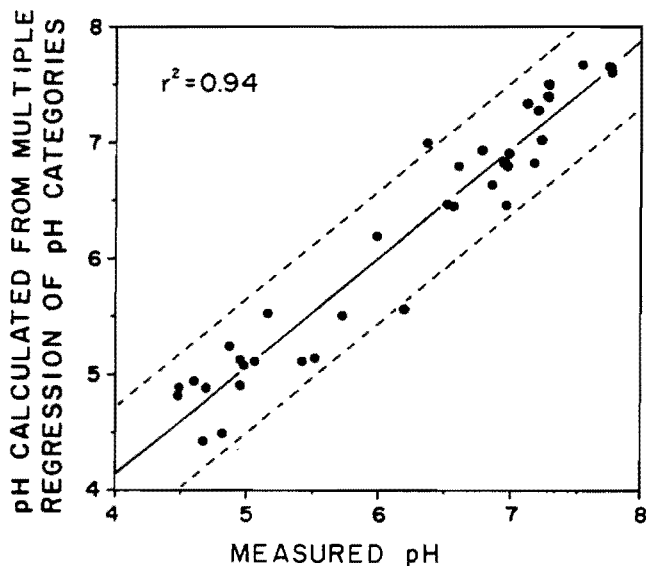
Figure 2. Diatom inferred lakewater pH vs. measured pH for 37 Adirondack lakes, and 95% confidence intervals for an individual prediction of pH from diatom data; pH = 8.14 - -0.041 ACB -0.034 ACF -0.0098 IND -0.0034 ALKF; r^2 = 0.94, SE = ± 0.28 pH units.

Figure 3. Diatom inferred pH for Big Moose L., Adirondack Mountains, N.Y., using the predictive relationship described in Figure 1. Horizontal bars represent standard error estimate of pH; vertical bars are standard deviation of Pb-210 dates (Michael Binford, Harvard School of Design, Personal Communication).

Predictive equations can then be applied to diatom assemblage data from lake sediment cores (usually dated using Pb-210) to infer past pH changes (Figure 3). Trends within cores can be analyzed statistically using, for example, change-point analysis to determine the significance of trends. The inferred pH data can be compared with stratigraphies of other lake sediment characteristics such as pollen, charcoal, coal and oil soot, polycyclic aromatic hydrocarbons, Pb, Zn, Cu, V, Ca, Mg, Ti, Al, Si, S, and others which provide a record of atmospheric inputs of materials associated with the combustion of fossil fuels and of watershed disturbance. With these data, in addition to knowledge of watershed events and some historical information on regional to the atmospheric emissions of S and N, it is often possible to assess with reasonable certainty whether lakes have been affected by acidic deposition, and to what extent. For example, paleolimnological data is some of the best evidence indicating recent acidification of Adirondack lakes[2]. Sediment analysis has also demostrated recent acidification in other countries with acid sensitive lakes. Paleolimnological studies involving diatom and chrysophyte analysis will no doubt continue to be a primary and increasingly important tool in lake acidification studies.
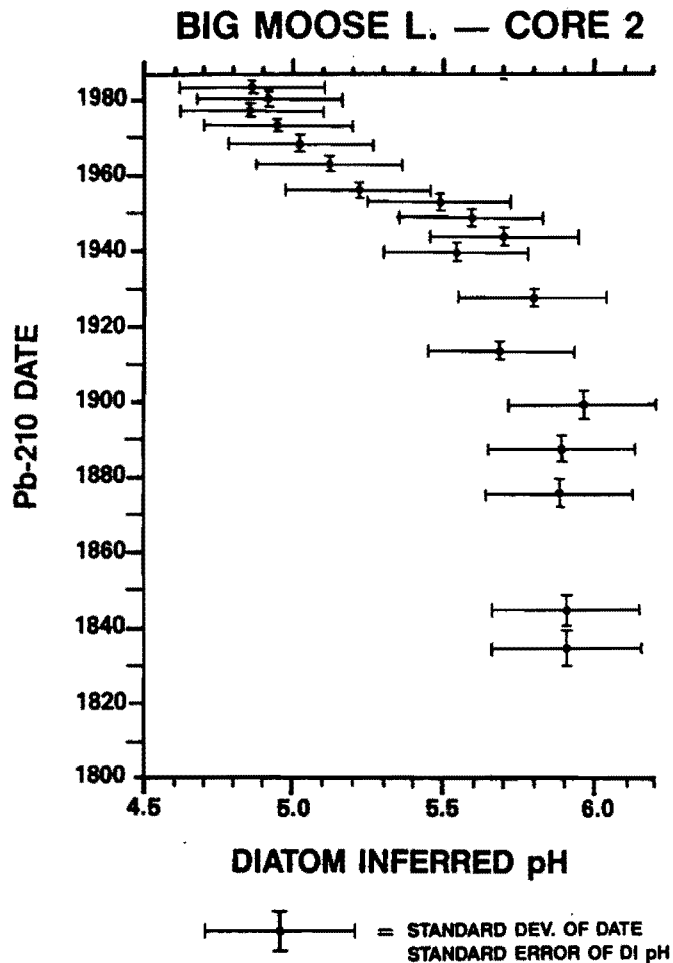
1. Battarbee, R. W., 1984. "Diatom analysis and the acidification of lakes." Phi. Trans. R. Soc. Lond. B305:451-477.
2. Charles, D. F. and S. A. Norton. 1986 "Paleolimnological evidnece for trends in atmospheric deposition of acids and metals." Chapter 9, Pages 335-431 in Acid Deposition: Long-Term Trends. Natl. Academy Press, Washington, D. C.
3. Smol, J.P., R.W. Battarbee, R.B. Davis and J. Merilainen, Editors. 1986. Diatoms and Lake Acidity. Dr. W. Junk, Publisher, Dodrecht, The Netherlands.
4. Charles, D. F. 1985. "Relationships between surface sediment diatom assemblages and lakewater characteristics in Adirondack lakes." Ecology 66:994-1011.
5. Charles, D. F., D. R. Whitehead, D. R. Engstrom, B. D. Fry, R. A. Hites, S. A. Norton, J. S. Owen, L. A. Roll, S. C. Schindler, J. P. Smol, A. J. Uutala, J. R. White, and R. J. Wise. 1987. "Paleolimnological evidence for recent acidification of Big Moose L., Adirondack Mountains, N. Y. (U.S.A.)" Biogeochemistry (in press).

FORUM NEWS

EDITORIAL

"It isn't what you don't know that makes the difference; it's what you do know that ain't so". Pud'nhead Wilson.

If you're like most APS members, you think that while the Forum is a good idea, it really isn't very helpful in terms of personal rewards and recognition. For the most part, you're right. However: You probably don't realize that the Forum, like all APS Divisions, has the authority to recommend APS members as Fellows of the American Physical Society.The Forum makes recommendations to Council, which makes the election to Fellowship. Fellowship is an honor the APS bestows on members who have made significant contributions to the physics or to the objectives of the APS.

Fellowship is not exactly the Nobel Prize. For one thing, it doesn't pay as well. The prestige is modest. Still, you do get a " * " next to your name in the APS membership list. The honor may impress your Department Chairman, Dean, or boss. Who knows, as a Fellow you might even get another promotion.

For APS members working in non-physics areas the Forum is often the best route to Fellowship. We can nominate you for activities which go far beyond physics. Teaching, administrative service, popularizing of physics, and service on advisory committees are examples. The only requirement is that your work be a contribution to physics and society - which is a pretty broad category. There are no limitations on the areas. You might work on energy, environment, the arms race, space, or developing nations. You might be a dove, a hawk, an owl, or a platypus. The criteria the APS uses will be your contributions.

If you respect a physicist, and would like to help her win this honor, please let any Forum Board Member know. If you think your own contributions have not been adequately recognized let us know that, too.

The Forum Newsletter is making a big transition. This is the second and last issue edited by Dave Hafemeister on a transitional basis. As you saw in the last isue and will see again in this one, Dave is emphasizing substantive articles which you'll probably want to save. Starting with the next issue, Art Hobson of the University of Arkansas, will be taking over as permanent editor. Art has lots of good ideas for strengthening the Newsletter. The end result of these changes will be that the Newsletter will become much more useful to you through its substantive articles and its current awareness function.

Those of you who know Mark Twain probably will tell me that I got my quote wrong, and that besides, it isn't really Pud'nhead Wilson's anyway. You're probably right. But it sounds good to me. And it's the sort of thing Pud'nhead might have said.

Paul P. Craig
Chairman

ART HOBSON: NEW EDITOR OF P & S

The Forum has concluded its national search for the position of editor of PHYSICS AND SOCIETY. The Forum is delighted to anounce that Art Hobson, Professor of Physics at the University of Arkansas will be our next editor. Hobson has had considerable experience in both physics and in science and public policy, writing books in both areas: CONCEPTS IN STATISTICAL MECHANICS (Gordon and Breach, 1971) and PHYSICS AND HUMAN AFFAIRS (Wiley, 1982). Recently, Hobson was a Visiting Researcher at the Stockholm International Peace Research Institute, working on such topics as the Midgetman Missile (see page 2 of this issue of P & S). Along with his interests in physics, Art is a talented jazz musician.

SCIENCE & PUBLIC POLICY FELLOWSHIPS

This year the American Association for the Advancement of Science has established two new Fellowships in Science, Arms Control, and National Security. Applications are invited from candidates with some experience in arms control/national security from the science-related professions. Fellows will work in appropriate Executive Branch agencies, the Congress, or non-profit institutions. The deadline for receipt of all applications materials is February 23, 1987. Contact Dr. W. Thomas Wander, Science, Arms Control, and National Security Fellowships, AAAS, 1333 H St. NW, Washington, D. C. 20005.

Other fellowships available in Washington are:
APS, February 13, 1987, Mary Shoaf, APS, 335 E. 45 St., New York, NY 10017
OTA, January 31, 1987, Personnel, OTA, Congress, Washington, D. C. 20510
ACDA, January 31, 1987, Personnel, Room 5722, ACDA, Washington, D. C. 20451
AAAS-Congressional, 1333 H St. NW, Washington, D. C. 20005

FORUM FELLOWSHIP CERTIFICATES

Marcel Bardon
"For unstinting attention to the health of physics as a discipline while promoting and guiding physics research programs at the National Science Foundation" ·
Spurgeon M. Keeny
"For applying physics to the formulation of national security policy during a career of service to the United States"
Bernard G. Silbernagel
"For developing links among physicists working in industries, universities, public education and state and national government to affect public policy in areas of concern to all physicists"
Thomas H. Moss
"For the application of physics to formulating policies to protect the environment, promote research, and link industries and state and federal governments"

REPORT ON APS COUNCIL MEETING (2 November 1986, Baltimore), Kenneth W. Ford, Forum Councilor

1. DEW STUDY. As of the meeting date, the report of the APS Directed Energy Weapons (DEW) study was under classification review at the SDI Office. Its release (expected early in 1987) will be organized to try for maximum impact on the public and the community of physicists. In addition to a news conference, a teleconference is planned, with downlink sites around the country. A summary of the report will reach every APS member, either by mail or as an insert in Physics Today. Speaker's packets will also be prepared for members who might wish to make presentations about the report.

2. FUTURE STUDIES. Among topics under consideration are Inherently Safe Reactors and Energy Efficiency Revisited. (A dozen years ago, reactor safety and energy efficiency were subjects of the first APS studies.) Members with other ideas should transmit them to Peter Wolff (MIT National Magnet Laboratory), the 1987 Chair of the Panel on Public Affairs (POPA). To be considered, any topic needs a champion.

3. PHYSICS WORKFORCE. A POPA subcommittee on the physics workforce, headed by Bernard Silbernagel and Peter Wolff, surveyed department chairs at PhD-granting departments (with the help of AIP), and came up with some interesting results. There are about 250 faculty vacancies in these departments, about one for every 16 faculty positions. The percentage of openings is about the same in large and small departments. The perceptions of shortanges and abundance of candidates are also about the same in large and small departments. Condensed-matter experimenters are in shortest supply, followed by experimenters in atomic, molecular, and optical physics. (Whether these specialists are really in short supply or are choosing industrial over academic opportunities is open to question. There is some evidence that industrial labs are also having difficulty filling positions in these fields.) The supply of high-energy theorists is perceived as "abundant."

4. STATEMENT ON US/USSR COOPERATION. A statement prepared by the Subcommittee on International Scientific Affairs (SISA) on US/USSR Cooperation was approved by Council. The critical issue in the debate on this topic was the linkage between scientific cooperation and human rights. The majority sentiment was that APS should continue to press vigorously in every possible way for the human rights of scientists in the Soviet Union, and should do this in addition to, not instead of, actively pursuing opportunities for cooperation and collaboration with Soviet scientists.

5. SZILARD AND FORUM AWARDS. These Forum-sponsored awards will henceforth be Awards of the Society. The APS Bulletin will include a call for nominations each year and an announcement of winners. Selection of winners will be by a committee named by the Forum Executive Committee and approved by the APS President. Criteria for the Awards are unchanged. (Stated simply, the Szilard Award is for applying physics to help solve problems of societal concern, and the Forum Award is for informing the public on science-and-society issues.)

6. EDUCATIONAL ACTIVITIES. Council approved a set of education-related expenditures for 1987, including (a) co-sponsorship of the International Physics Olympiad team, (b) co-sponsorship of a third bienniel Conference of Chairs (with AAPT), (c) support of the College High School Interaction Committee and its Newsletter (a joint APS/AAPT activity), (d) preparation of a physics career brochure, (e) participation in the New York City Science Fairs, (f) inauguration of an education newsletter directed especially to department chairs.

COMING FORUM SESSIONS
San Francisco Meeting, January 28-31, 1987

1. CHERNOBYL AND THE FUTURE OF NUCLEAR POWER, A. V. Nero presiding.
    Edwin Zebroski (EPRI), "Physics and Other Lessons of the Chernobyl Accident"
    Lynn Anspaugh (LLL), "Environmental Impacts of the Chernobyl Accident"
    Bertram Wolfe (GE & ANS), "Is theire a Nuclear Future?"
    Jim Harding (MHB), "Myths, Fallacies and Lessons from Chernobyl"

2. SCIENCE, TECHNOLOGY AND THE COMPREHENSIVE TEST BAN TREATY, Warren Heckrotte presiding.
    John Holdren (Berkeley), "The Case for a CTB: Cornerstone for a New Arms Control"
    Paul Brown (LLL), "Nuclear Weapons R & D and the Role of Nuclear Testing"
    Charles Archambeau (Colorado), "Underground Nuclear Testing Monitoring Using High Frequency Seismic Data: Verification of a Test Ban Treaty"
    Thomas Bache (SAIC), "Seismic Verification of a Comprehensive Test Ban Treaty - A Difficult Problem"

3. PHYSICS AND SOCIETY TEACHING--NOW, Lester Paldy presiding.
    John Rigdon (Missouri-StL), "The Culture of Science and Human Culture"
    Albert Bartlett (Colorado), "Physics and Society; Not Subjects Apart"
    B. G. Dick (Utah), "An Interdisciplinary Science-Humanities Course"
    Art Hobson (Arkansas), Getting Serious About the Social Contest of Physics"

At the New York Meeting (March 16-20, 1987) there will be a session on Chernobyl chaired by Brian Schwartz. At the Washington Meeting (April 20-24, 1987) there will be 4 invited sessions: Some Peripherals to the SDI (Caroline Herzenberg), Born Secret (Alex DeVolpi), Big and Little Science (Aviva Brecher), Awards (Paul Craig). The abstracts for the Forum's Contributed Paper Session at the D.C. meeting are due at NY-APS by January 30, 1987; please send a copy of the abstract to Dietrich Schroeer, Physics, University of North Carolina, Chapel Hill, NC 27514.