PHYSICS & SOCIETY
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EDITOR'S COMMENTS

The issue which precipitated the intense interest of many physicists (and their organizations) in the problems at the interface between science and society during the last half of the twentieth century was the initial construction and use of nuclear weapons. It still holds our attention today – in the form of the planning for contemporary use of nuclear weapons and as the recurrent attempts to understand and assess responsibility for its initial developments. Tightly linked to the problem of nuclear weapons is the issue of nuclear reactors as mobile and stationary power sources.

In this issue of *Physics and Society*, J. Altman illustrates the contemporary interest of German physicists in the problem of nuclear weapons and international security. With the comments of A. DeVolpe, we return to the question: should we be planning to use nuclear weapons in the course of "ordinary events"? And L.Wolfenstein reminds us that there are still unresolved questions in the U.S. system for procuring and maintaining nuclear weapons.

The issue of responsibility for creating and maintaining nuclear weapons, though contemporary, seems to be most popularly examined via the lens of the past. The play *Copenhagen* and the reactions of its audiences continue to fascinate me and many of my colleagues. (Even though I, and perhaps many of these colleagues, first started pondering the issues of responsibility raised by the play many years ago with the appearance of Sam Goudsmidt's *Alsos* and Robert Ruark's *Brighter than a Thousand Suns*.) An immediate question is why the very different reactions to the play by American and European audiences? W. Liebert gives some German insight into this question while J.Salomon looks at it from a French perspective. H.Lipkin asks us to look beyond the WWII competition between Allied and German physicists over the creation of nuclear weapons to the apparent lack of competition with respect to non- nuclear weapons. And I, together with my old colleague B.Pugel, again puzzle over the apparent ability of W. Heisenberg to forget his past weapons activities. Observing one's past self is apparently still an observation, subject to the distortions of the present observing "instrument".

The contemporary issue of nuclear power – vital in a day of increasing pollution due to fossil fuels and threatened access to, and continued availability of, these fuels – requires continued examination of those notorious events which demonstrated the non-benign aspects of the "civil atom". Then most notorious is Chernobyl, which is examined here again by two French authors, J.Frot and A. Aurengo, and engineer and a physician.

A major manifestation of the physicist's interest in "science and society" is our recently renewed interest in the science education of the general public as well as that of our successor generations. J. Marque has some interesting – if disturbing – comments about the education of future scientists. L. Lerner and A. Melott add to our unease about the 'science education' received by many of our fellow citizens, though they do suggest some ameliorative approaches. A. Hobson reminds us that we cannot separate the fundamental science education of future scientists from that of the general public. Finally, though not included in this journal, our readers should be aware of recent efforts by our colleagues in the *Division of Particles and Fields* to introduce the lay public to the future of particle physics as well as to illustrate how forefront physics can lead to important practical applications in medicine and technology. They have produced a full-color- illustrated brochure called "Quarks Unbound" which will be distributed to all high-school physics teachers. It will also be available on the web at (http://www.aps.org/dpf/quarks_unbound.html).

It should be clear that issues of Physics and Society have important implications to present and future societal actions, both here and abroad, as well as providing clues for understanding past actions. I hope that our readers will share their thoughts on these subjects with their colleagues via submissions to this journal.

A.M.S.

ARTICLES

Germany: Disarmament Research in Physics

Jürgen Altmann

To some extent motivated by the US role model, in the last two decades new research groups for disarmament and international security have been started in science in Germany. This article is to provide a short overview of their history, status, and outlook.

It all started when in 1984 a fellowship program of the Volkswagen Foundation met a few physicists who had been active in the scientists' peace movement and had cared about their science's connections to war and peace. After a few years of fellowships and one-person projects, the Volkswagen Foundation supported, from 1988 on, the foundation of three groups:

(1) IANUS (Interdisciplinary Research Group in Science, Technology, and Security) at Darmstadt University of Technology. Among its members were/are physicists, mathematicians, biologists, economists, ethicists. They do studies on nuclear-material verification and disposal, models of strategic stability, detection of bio-warfare agents, etc.[11]

(2) BVP (Bochum Verification Project) at Ruhr-Universität Bochum, later also Dortmund University, comprised mainly of physicists. Their focus is on the potential of acoustic, seismic, and magnetic sensors for the cooperative verification of limits on military land and air vehicles. Another strand deals with military technology assessment.[2]

(3) CENSIS (Center for Science and International Security) at Hamburg University. Here, physicists, computer scientists, and mathematicians work on automatic processing of overhead images, stability models, and military-technology assessment.[3]

In addition, a few individual scientists are at work at research institutes.

Whereas this work is recognized by the respective department and university, only IANUS has been successful in getting continuous - though limited - university/state funding. Also here, there is a high dependency on external projects funds. Due to the underdeveloped field, these flow fairly irregularly. Nevertheless, at all institutions an impressive number of projects has been funded and carried out.

Informal cooperation between the three groups grew into FONAS (Research Association Science, Disarmament, and International Security), founded 1996 at Bad Honnef near Bonn, in the Physics Center of the German Physical Society DPG.[4] The DPG has some tradition concerning disarmament - in 1957 eighteen leading German nuclear physicists signed a letter opposing a nuclear-armed Federal Republic of Germany. Much later, the DPG spoke out in favor of the comprehensive nuclear test ban and founded a corresponding commission. From 1995 on, physicists from the FONAS community organized topical sessions on Disarmament and Verification at the annual DPG Spring Meetings. In 1998, DPG founded its Committee Physics and Disarmament (AKA, Arbeitskreis Physik und Abrüstung) that from then on co-organized the sessions together with FONAS.[5] Among the main topics are: test ban, verification technology, nuclear disarmament, missile defense, mine detection, military-technology assessment. The goals

1 http://www.ianus.tu-darmstadt.de

2 http://www.ep3.ruhr-uni-bochum.de/bvp

3 http://www.kogs.informatik.uni-hamburg.de/censis

4 http://www.fonas.org

5 http://www.dpg-fachgremien.de/aka/index_e.html. The AKA speaker is Jürgen Altmann, deputy speakers are Götz Neuneck and Christoph Pistner. Note that AKA is solely for disarmament. There is a separate Committee on Energy, AKE.

are to provide information on actual problems of physics and disarmament, to present the results of recent research, and to provide a forum for the presentation of industry/government work that is normally not published. Often, main lectures are given by invited speakers from the USA.[6, 7] Our audience varies between 20 and 200 physicists, i.e., we reach 5 to 10 % of the attendees at the Spring Meetings.

After the elections of 1998 the new Federal Minister of Education and Research wanted to resume Federal funding for peace and conflict research (which had been reduced to zero by the former government). Projects involving the natural sciences were among the first to be funded. Five of these formed joint projects on preventive arms control, three dealt with verification technologies, and one with mathematical modeling.[8] These projects lasted only little more than a year. From 2002 on, funding takes place via the new German Foundation Peace Research (DSF), which unfortunately, due to its limited capital, has a lower budget for projects. Still, natural-science groups have successfully applied for funds and will be able to continue significant work.

There is now a small community in Germany of professionals doing research of disarmament and international security using methods from the natural sciences. More than a dozen doctoral dissertations and diploma theses have been written.[9] Colleagues take part in the Pugwash Conferences on Science and International Affairs and the Summer Symposia on Science and Global Affairs.[10] Repeatedly, we have been called upon to do studies for the German Federal Parliament (the Bundestag has an Office of Technology Assessment TAB that - different from its U.S. precedent - still is alive and well). Twice per year, FONAS is organizing a briefing in the German capital (first Bonn, now Berlin), attended by politicians and staff from Parliament and Ministries, as well as journalists. Within DPG, the Committee Physics and Disarmament is respected. Important discussions have been initiated, e.g., about the use of highly enriched uranium in the new German research reactor FRM II.[11]

The central institutional task for the next few years is to provide more continuity - in personnel and funding. Most important would be a few professorships for this area of research and teaching. This could be done if physics departments decide to open up a job description for a new professor to include problems of disarmament and international security.

Jurgen Altman
Experimentelle Physik III
Universitat Dortmund
D-44221, Dortmund, Germany
FAX: +49-231-755-755-3516
altmann@e3.physik.uni-dortmund.de

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6 U.S. invitees 2000-2002 were: Richard Garwin, Ted Postol, Allison MacFarlane, George Lewis, David Mosher, and Geoffrey Forden. Abstracts of all talks at the AKA sessions are accessible via http://www.dpg-tagungen.de/archive, year, Physikertagung, Arbeitskreis Physik und Abrüstung.

7 With U.S. speakers present in Germany, we often ask them to speak at AKA/FONAS briefings in the capital, see below.

8 Preventive arms control: http://www.fonas.org/prk

9 Some exemplary topics: stability models with missile defense, tritium controls, magnetic vehicle detection, change detection in multispectral overhead images.

10 http://www.summersymposium.org

11 Phys. Blätter 55 (1999) 16 ff.

ARTICLES

The Causes of The Chernobyl Event

*Jacques Frot**

The number 4 Chernobyl reactor suffered a power excursion on April 26, 1986 during a low power test. The power increased to about 100 times its nominal value: the reactor was destroyed by a steam explosion and 12 exabequerels of radioactive isotopes were injected into the atmosphere contaminating an area of about 60 000 sq miles inhabited by 6 millions people and causing a measurable increase in the level of ionizing radiation in most of Europe.

This event had two components: the **explosion** and **the effects** on public health. We will examine them separately and discover that both were mostly avoidable.

The two major civilian nuclear accidents before Chernobyl -WINDSCALE (195)7 in the UK and TMI (197)9 in the United States- caused no deaths.

The 1000 Megawatt-electric RBMK reactor is graphite-moderated and light water cooled. In addition to electrical power, it produces weapons-grade plutonium-239. The Chernobyl power station was a major source of energy for the Ukrainian SSR

THE CAUSES OF THE EXPLOSION were of three types: (1) **design** weaknesses, (2) management **faults** and operating staff **errors** and (3) **political** causes.

Regarding **design, the RBMK** reactor suffers 5 major weaknesses: core instability at low power which means that the reactor is then difficult to control and any tendency toward a runaway chain reaction is automatically and rapidly amplified; insertion of control rods is very slow and when the control rod is inserted its graphite tip first increases the reactivity before reducing it; these reactors are not protected by a system to filter exhaust gases nor by a containment structure; and finally hot graphite bursts into flames when it comes into contact with the atmosphere and vaporizes radio-isotopes dispersing them in the air. Russian nuclear engineers knew of this instability as did French and British experts. The Soviet authorities were warned well before the Chernobyl accident, but the warning fell on deaf ears. None of these 5 design weaknesses exist in western light water reactors (PWRs and BWRs) nor in Soviet VVER (PWRs).

Management faults were mostly a criminal lack of adequate training of the operators, inadequate permanent operating procedures, lack of enforcement of the rules and incomplete and imprecise instructions for this delicate low power test.

These management weaknesses led to at least **six human errors** committed by the operators. Two permanent operating rules were violated: not to run the reactor for any length of time at reduced power level, and never to have fewer than thirty control rods fully inserted into the core. One error consisted in not following the test procedure, and three safety mechanisms were deliberately bypassed - one for emergency water injection, and two others for emergency shut-down. It is clear that operators were not able to appreciate the implications of their acts

Turning to **political causes:** in the Cold War the plutonium production aspect of the RBMK imposed a sense of urgency on their design, construction and operation; no time and no funds were to be "wasted" on improvements however essential to a safe operation. The scientists and engineers worked under one and only one guideline: to produce weapons-grade plutonium as much as possible and as quickly as possible.

It was under these circumstances that the Minister of Electrification declared at a Politburo meeting on May 2, 1986, six days after the explosion: "In spite of the accident, the construction team will meet its socialist obligations and soon begin to build reactor number 5."

The culture of secrecy, universal in the USSR until 1989, imposed compartmentalization of knowledge: no single person was allowed to see the big picture and to integrate all aspects of the safety of the operation.

Some Soviet scientists were strictly honest. Others, just as competent, were motivated first by their personal interests and lacked the courage to be scientifically rigorous. Without scientific debate they accepted certain questionable decisions made by the political authorities.

The design weaknesses arise from Bureaucratic dictatorship, not from engineering incompetence.

It is clear that the explosion of the Chernobyl reactor was made possible by the many shortcomings of the Soviet system. One may well say that the Chernobyl explosion was more a Soviet event than a nuclear event.)

Before looking at **THE CAUSES OF HARMFUL EFFECTS TO HEALTH** let us stress that, apart from the death of two persons present atop the reactor when it exploded, these effects were not inevitable. But circumstances were such that, due to **immediate** and **deeper causes,** there were harmful effects to public health which we first summarize below.

Much controversy surrounds the magnitude of these effect, too often with a lack of scientific rigour. In the interest of objectivity we refer to the **UNSCEAR** (United Nations Scientific Committee for Effects of Atomic Radiations) report of June 6, 2000. Paragraph 136 reads as follows: "Apart from the increase in thyroid cancer after childhood exposure, there is no evidence of a major public health impact 14 years after the Chernobyl accident. No increases in overall cancer incidence or mortality have been observed that could be attributed to ionising radiation. The risk of leukaemia, one of the main concerns (leukaemia is the first cancer to appear after radiation exposure owing to its short latency time), is not elevated, even among the recovery workers. Neither is there any scientific proof of other non-malignant disorders, somatic or mental, that are related to ionising radiation."

We note that **UNSCEAR**'s conclusions are consistent with observations made since 1945 on 86 500 survivors of the atomic bomb attacks on Hiroshima and Nagasaki.

We recall the following data which characterize the harmful effects to public health due to Chernobyl. They concern an area of 60 000 square miles around Chernobyl, in Belarus, Ukraine and the Russian Federation: 2 operators were killed by the explosion; among 134 persons acutely irradiated, 28 persons died in the 3 months following the accident; up to the beginning of the year 2000, about 1800 cases of thyroid cancer had been reported among persons who were under 18 in 1986 with a very low mortality of about 10 deaths. New cases are expected in the coming years. No excess of solid cancers nor of leukaemia nor of congenital anomalies have been reported. By far the greatest harm - but there are no available figures - is found as suicide and violent death among the firemen, policemen, other recovery workers (officially 313 000 recovery workers) on the site and among the evacuated population who suffered a considerable reduction in the quality of their life.

There is no evidence of any effects to public health outside USSR. One might say that the real victims were an estimated 100 000 foetuses unnecessarily aborted in panic in central and eastern Europe because the pregnant women and medical personnel - midwives and physicians - fell prey to an exaggeration of the effects of radioactive fallout. "

The **immediate cause** of harmful health effects was the absence of an emergency plan. The public was kept in the dark. Instructions to stay indoors with windows and doors closed were not issued for 36 hours. A ban on the consumption of fresh milk and locally produced fesh fruit and vegetables was not issued for seven days. There was no provision for the immediate distribution of stable iodine to prevent thyroid cancers, nor was protective clothing available for the firemen, operating personnel and recovery workers.

The deeper causes of harmful health effects are political: the elementary precautions mentioned above were not taken because the authorities and the power station management did not know that they were needed. They had no emergency plan, no medical supplies, no protective clothing, not even instruments to measure radioactivity. Yet several murderous military nuclear accidents, which occurred as early as the 1950s (e.g. Mayak and others) causing 433 deaths by acute irradiation, had led Soviet scientists and physicians to develop suitable techniques for radio-protection and care. The useful recommendations they made early on to USSR authorities were ignored. For example the radio-protective substance "Preparation B" was ready by the mid-1970s but the program not implemented!! Similarly, Soviet biologists knew how radioactive iodine was fixed on the thyroid and knew the protective power of stable iodine. As far as back the 1970s they also knew how to protect against radio-caesium and radio-strontium. Due to the heavy administrative procedures, budgetary difficulties and political-scientific quarrels, none of these defensive measures, and in particular neither "Preparation B" nor potassium iodide, was available at Chernobyl in 1986!!

Let us finally remark that an efficient emergency plan providing for the simple and effective measures mentioned above was approved by the USSR Minister of Health in December 1970, but it remained a dead letter. A new plan, presented in 1985, was refused because an accident justifying such measures was "impossible in USSR".

The great breadth and depth of relevant knowledge developed by Soviet scientists was not made known to the medical and nuclear communities of the Soviet Union. Local civilian authorities either knew nothing of it or paid no attention to it. Ignorance and lack of preparation were so profound that in the wake of the explosion the vast majority of the actors in the drama: reactor operating crews, directors of the power station, local and higher authorities were so distraught that they were unable to appreciate the dimension of the disaster, unable to define priorities and unable to undertake even the most urgently required activities.

-**Thus it was** that the 28 deaths of rescue workers could have undoubtedly and easily been avoided.

- **Thus it was** that the population of Pripyat, 2 to 3 miles away from the power station, were not informed and evacuated until the afternoon of April 27, more than 36 hours after the explosion.

- **Thus it was** ,conversely, that the evacuation of 120 000 persons, decided later in spring 1986, was not proven justified for lack of measuring instruments while it led to numerous suicides and violent deaths.

- **Thus it was** that tablets of potassium iodide were not distributed to the exposed population, or were distributed too late to be effective. Those tablets would have protected their thyroid glands from irradiation by radio-iodine and thus prevented cancer: it is clear that the 1800 cases of cancer among young people could have been easily avoided. It is worth noting that stable iodine was indeed distributed in neighbouring Poland and, as a result, that country has not had any excess of juvenile thyroid cancers.

- **Thus it was** that the offer of the USA on May lst, five days after the explosion, to send a great quantity of stable iodine as sodium iodide tablets was declined.

- **Thus it was** that only on May 2, seven days after the explosion, the consumption of local agricultural products was forbidden.

- **Thus it was** that the uninformed, misinformed and disinformed population fell prey to fear, and soon realized that the public authorities had lost control of the situation.

- **Thus it was** that the people became the victims of tales and rumours which were, and still are today, the bread and butter of the "merchants of fear" who inhabit the local, regional, national and international press.

- **Thus it was** that many of the recovery workers and evacuees fell victim to psychological stress; in addition to many suicides, the psychological trauma led to respiratory, digestive and cardio-vascular disease. These cases are not the direct result of irradiation but they constitute by far the greatest harmful effects to public health inflicted by the Chernobyl explosion.

- **Thus it was** that the political context of the Chernobyl accident made it impossible to avoid a considerable amount of harm to public health; this despite the fact that medical knowledge and preventive and curative techniques had existed for years and years in the Soviet Union whose scientists, engineers and doctors were as competent as those in the Western world.

Here again, one may well say that the health aspects of the Chernobyl event were much more a Soviet event than a nuclear event.

As a ***CONCLUSION*** *let us say that the Chernobyl disaster was made possible by a* **political system** *which accepted a lack of a culture of safety at three levels: reactor design, reactor operation and plan of action in case of a serious accident.*

With Western assistance, the RBMK reactor design, operating procedures and training of operators have been progressively improved since 1986. **Another explosion like that which occurred at Chernobyl is now extremely unlikely to occur at any of the 12 other RBMK reactors**. However, compared to the very high level of safety which the Western countries have insisted upon, the present situation is not totally acceptable: more improvement is still needed .

At long last, emergency plans to protect the population have been put in place in the ex-USSR, while before 1986 they were considered an unnecessary luxury.

The design errors of the RBMK reactor and especially the absence of a containment structure are unique to that model. Every other reactor in the world, including the recent Soviet PWR reactors (VVER 1000 and VVER 440 of the second generation), has a containment structure. Should the core suffer a meltdown, an extremely unlikely event, the containment structure would prevent the escape of dangerous radioactive substances. Successful containment was demonstrated at Three Mile Island in 1979. We may thus conclude **that a Chernobyl type event, an explosion destroying the reactor and its containment together with very serious consequences for public health and the environment, cannot possibly occur outside the ex-USSR and its former satellites.**

Let us not forget, however, that the Chernobyl reactor even as it was in 1986 would not have exploded if the operating crew, while faithfully executing a poorly defined and dangerous test procedure, had not deliberately bypassed several safety systems.

Jacques Frot
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Translated from the French by Berol Robinson

Jacques FROT jfrotelsuz@aol.com is an engineer, ex-director of Mobil Oil France and a member of SFEN - Société Francaise d'Energie Nucléaire.
Berol Robinson berol.robinson@ecolo.org is an American physicist, member of APS and AAPT, and an environmentalist.
Until retiring he was a science officer at the Paris headquarters of UNESCO.
A more complete version of this paper is to be found at <www.ecolo.org> the Internet site of the Association of Environmentalists For Nuclear Energy : Click on the Union Jack, click on documents, click on documents in English and look for Causes/Chernobyl/JF

ARTICLES

Chernobyl : The Effects on Public Health ?*

André Aurengo ,

(Note: Figures I, II and III are inserted at the end of the document)

Because of its public health, ecological and industrial consequences, the Chernobyl accident has become a myth which serves as the focus of many fears, justified or not.

No one can question the seriousness of the event, but after fifteen years there is still no agreement about the effect it has had or will have on public health. For example, the total number of deaths attributed to Chernobyl varies from less than a hundred to several millions, and congenital malformations from negligible to cataclysmic. To exaggerate the numbers to absurd levels is just as dishonest as to minimise them.

Beyond disinformation, widely broadcast for one motive or another, and despite the fact that one cannot easily refute arguments set forth with the heat of passion, we believe it is important and even urgent not to let psychosis run wild. It is our purpose to show that there are scientific criteria which can be used to evaluate doses of ionizing radiation, the health effects of exposures and the risks. Even using data which are incomplete and perhaps not totally reliable, several group appraisals, especially the studies conducted by UNSCEAR and IPSN, based on the analysis of hundreds of valid publications and official records, lead us to draw some conclusions regarding the public health consequences of the accident and to set upper and lower numerical limits to them.

What do we know about the effects of ionizing radiation?

Some orders of magnitude

We are continuously irradiated by the radioactive isotopes present in our bodies (about 8000 Bq), by cosmic rays and by radioactive elements in the ground beneath our feet, in particular, radon, the gaseous radioactive daughter of uranium. In France, the resulting "natural ionizing (background) radiation" varies from 2,5 mSv/year in Paris to 5 mSv/year in Brittany and in the Massif Central (a mountainous region in the south-central part of France.) The annual dose exceeds 20 mSv in some parts of the world. To this we must add medical irradiation which is very unevenly distributed but estimated to average about 1mSv/year and industrial irradiation, about 10 Sv/year. The dose due to a chest X-ray is about 0.5 mSv, a week's vacation in the mountains at 1500 meters (5000 feet) adds 0.01 mSv and an airplane trip from Paris to New York adds 0.03 mSv. Rules of the European Community limit the irradiation of the public resulting from non-medical human activities to 1 mSv/year, and the irradiation of occupationally exposed workers to 100 mSv in 5 years.

Some effects are known but it is hard to attach numbers to them

Ionising radiation has both deterministic and stochastic effects.

Deterministic effects are observed for doses over 700 mSv ; for a given dose they always occur and their severity increases with the dose, up to lethal doses.

Stochastic effects occur at random, and the probability of radiation-induced cancers and congenital malformations increases with the dose.

Radiation-induced cancers occur only for doses over 100 mSv for adults and in the range of 50 to 100 mSv for young people.

Concerning the risk of radiation-induced cancer at low doses (below 200 mSv), there is ongoing controversy over the existence of a threshold below which there would be no effect and over the relation between dose and probability of radiation-induced cancer at low dose (is it linear or linear-quadratic?).

The risk of cancer

Our knowledge of the risk of cancer due to ionising radiation is mainly based on the long-term study of 120 321 survivors of Hiroshima and Nagasaki who received significant doses (from 5 mSv to 3 Sv with an average of 200 mSv) at a high dose rate (1 Sv/second). The follow-up study shows that the probability of developing cancer increases more or less linearly with dose for solid tumors (between 200 mSv and 3 Sv), and follows a linear-quadratic rule for leukaemia. Among the 120 000 survivors, in the half-century since Hiroshima and Nagasaki, one estimates that there have occurred 334 more cancers than in a matched non-irradiated population, and 87 more cases of leukaemia. ICPR used the Hiroshima-Nagasaki data to set radio-protection rules which, for prudence and simplicity, are based on a linear-no-threshold (LNT) law. This straightforward model is justified by its simplicity, but it cannot be applied to the calculation of cancer probabilities for low doses or for low dose rates. The improper use of the simple LNT law as if it had been scientifically proven has led to vast exaggerations of the danger of weak ionising radiation.

Thyroid Cancers

Radiation-induced thyroid cancers are caused by external irradiation or by the subject's ingestion of radioactive iodine isotopes. The radio-iodine is strongly concentrated in the thyroid gland so that the dose to the thyroid is 200 times greater than that delivered to other organs. For the same contamination, the dose to a young person's thyroid is higher than an adult's, and the foetus is sensitive starting with the third month of pregnancy.

For a young child and the fœtus, radio-induced thyroid cancers have been observed from 100 mSv upwards, received at high dose rate. The estimate of risk is based on data from the Hiroshima-Nagasaki study and from follow-up studies of children who had had radio-therapy.

These studies all deal with high doses and high dose rates and the data probably cannot be applied generally. For equal doses, the relative risk would be 2 to 10 times smaller for much lower iodine-131 dose rates. Short-lived radio-iodine isotopes, such as I-132, which, for the same dose, have a dose rate much higher than I-131, may have played an important part in causing thyroid cancer in the former Soviet Union. The relative risk of radiation-induced thyroid cancer decreases with age and becomes insignificant after the age of 20.

The adult thyroid is not very sensitive to radiation and we hardly ever see radiation-induced thyroid disease in an adult. Scintigraphic examinations of the thyroid have been performed on some 34 000 adults, using iodine-131 with an average dose to the thyroid of 1.1 Gy, and the procedure has been shown to be totally harmless.

Similarly for children we have seen no radio-induced thyroid disease after scintigraphic examination, but we have only 500 cases.

It is to be emphasised that the dose to the different organs (which is very poorly known in the case of the Chernobyl accident) is only one of the parameters needed to estimate the risk of radiation-induced cancer. Other important factors are the dose rate, the nature of the ionizing radiation and its homogeneity, as well as the age and sex of the subject and such things as genetic predisposition.

There are many difficulties in the analysis of Chernobyl

Effects on public health may be calculated from data on contamination, from the doses received and from the risk, all three of which are likely to be very roughly known; or they may be evaluated on the spot, either by epidemiological studies or by examining medical registers.

A very simple computation leads to very high estimates when risks are improperly modeled by the LNT relationship, because low risks are attributed to low doses but then multiplied by a very large population. This is like saying it is as dangerous to have one grain of lead fall on the head of one million people as one anvil on a few persons.

The contaminated area is not well mapped

The explosion and fire at the Chernobyl reactor N°4 injected into the atmosphere about 4×10^{18} Bq of rare gases, 8×10^{16} Bq of cesium-137 and 2×10^{18} Bq of short-lived radioactive iodine (iodine-131: T = 8 days, iodine-132: T = 2.4 hr and iodine-133: T = 20,8 hr). The areas heavily contaminated lie principally in north-western Ukraine, in the southern part of Belarus, and nearby areas of Russia. People there were exposed to external irradiation due to the proximity of radioactive material and to internal contamination from eating contaminated food and inhaling radioactive particles.

Because the pattern of rain and wind was irregular, the distribution of the contamination is complex. It was relatively accurately determined only for long-lived cesium-137; in view of its 30-year half-life, measurements could be made long after the accident.

Contamination maps for iodine-131 deduced from the cesium-137 data are only very approximate.

Epidemiological studies can be misleading

The ability of an epidemiological study to detect an increased cancer risk depends upon its **statistical power**, which depends on the size of the studied population and the duration of the study (i.e. the total person-years) as well as on the natural occurrence of the disease under study. If the result is negative, one can only conclude that the risk is below a certain threshold, but never that the risk is non-existent. For example, in statistical tests being done at a 5% confidence limit, it is likely that one test in 20 will show a positive result simply by chance. The results of epidemiological studies must, therefore, be considered cautiously, in the light of our general knowledge of radio-pathology and by comparing the results of several inquiries. These difficulties, common to all studies of risk, lead us to say that it is impossible to distinguish between a zero risk and a non-zero risk, and consequently we may speak only of a significant or an insignificant public health risk.

Medical registers are efficient tools

Public health registers for cancer are theoretically the best way to evaluate the consequences of this accident. In the countries of the former Soviet Union there are many registers of uncertain reliability, one for general medical follow-up which has followed 659 292 persons since 1986, specialized registers for malignant hemopathies and thyroid cancers, and registers devoted to military liquidators.

In France, we have 13 registers for "general" cancers and the specialized register of thyroid cancers in the Champagne-Ardennes region. These registers cover about 15% of the French population. For youngsters, a national register for leukaemia was created in 1995, and a national register of solid tumors has recently been opened.

In Ukraine, Belarus and Russia: one catastrophe may hide another.

For inhabitants of former Soviet Union, one has to distinguish three populations:

1. The 600 000 Chernobyl liquidators, who worked on the site of the accident and who mainly suffered from external irradiation, averaging 100 mSv with a maximum of 10 Sv);

2. The evacuated population (116 000 at first and another 220 000 later on) who suffered from external irradiation averaging 20 mSv with a maximum of 380 mSv as well as an internal contamination averaging 10 mSv, with thyroid irradiation of 500 mGy. The internal contamination of children by radioactive iodine was especially serious.

3. Seven million people still living in areas contaminated by cesium-137. They presently receive a highly variable external irradiation depending on soil contamination (from 1 to 40 mSv/year). Their internal contamination may be significant if they eat contaminated food.

The immediate consequences

Three persons died of trauma. During the emergency operations about 600 persons were irradiated; among them 134 exhibited acute irradiation syndrome; 28 of the most heavily exposed died. (Table I)

Table I

Doses and early deaths among most exposed liquidators

Dose mSv	Total number	Number of deaths
800 - 2 100	41	0
2 200 - 4 100	50	1
4 200 - 6 400	22	7

6 500 - 16 000	21	20
Total	134	28

Thyroid cancer in children and young persons

In view of the lack of reliable data on contamination, thyroid irradiation is much debated: 17 000 young people are supposed to have received a thyroid dose greater than 1Sv, 6000 greater than 2 Sv and 500 greater than 10 Sv.

We know that the consequences of an accidental contamination by radioactive iodine can be avoided by keeping people indoors, by early administration (within 3 hours) of a dose of stable iodine which prevents radioactive iodine from being absorbed in the thyroid gland, by not drinking or eating contaminated water, milk and other food and by evacuation from contaminated areas. In fact, evacuation was late and no measures seem to have been taken to urge people to stay indoors. Stable iodine was distributed only after a fourteen-hour delay in Ukraine and after three to six days in Belarus; distribution was only partial, and some towns such as Gomel were never supplied.

As early as 1990 it had become clear that there would be a substantial increase in the number of thyroid cancers among young people who were less than 15 years old or in utero when the accident occurred (Figure 1).

To date, nearly 2000 thyroid cancers have appeared among these youngsters. They are papillary cancers, the least serious kind of thyroid cancer, although more severe than natural cancers. They are accompanied by cervical ganglionic metastases which are not serious in 90% of the cases, and with pulmonary metastases which are much more serious in 30% of the cases. Particular mutations of the RET gene, involved in thyroid carcinogenesis, are found much more frequently in these radiation-induced cancers than in spontaneous cancers.

An early and appropriate treatment leads in all cases to a normal survival for several decades and, in the absence of pulmonary metastases, a recovery rate of about 95%. After a difficult start, when international help was essential, these cancers are now quite well taken care of. The main shortcomings were inadequate screening and, in some cases, the poor quality of surgery. Ten youngsters are said to have died from thyroid cancer (unofficial figures which can hardly be verified); this can only be attributed to inadequate care. For comparison purposes, among 39 young persons (from 6 months to 33 years) treated for spontaneous papillary cancer at the La Pitié Hospital in Paris and followed for an average of 13 years, no fatality has occurred which could be attributed to cancer.

Among youngsters subjected to radiotherapy, one observes some radiation-induced thyroid cancers, which peak 25 to 30 years after irradiation. The evolution of post-Chernobyl thyroid cancers seems to be different, and a plateau is already evident. It is impossible to forecast the number of cases still to come, but they may be very numerous. To identify and treat new cases in time, it would be necessary to institute an early and systematic screening by annual ultrasound examination of the exposed youngsters (about 200 000 in Belarus and 70 000 in Ukraine), but this is far from being realized. The economic situation in Ukraine and Belarus is such that adequate care for these cancers cannot be provided without help from the West.

Frequency of thyroid cancer among youngsters born after 1987 is back to pre-Chernobyl levels.

Leukaemia

According to the Hiroshima-Nagasaki data, one should have observed an excess of cases of leukaemia among the liquidators within six to eight years after accident. As a matter of fact an increase in the number of cases of leukaemia is observed in Ukraine, Russia and Belarus, but also for forms of leukaemia which are never radiation-induced and in non-contaminated areas as well. The follow-up of Russian liquidators between 1986 and 1997, shows six times as many cases of chronic myeloid leukaemia (possibly radiation-induced) as before 1986, but also three times as many cases of chronic lymphoid leukaemia (never radiation-induced). Among 65 cases of leukaemia detected among liquidators in eleven years for 1 011 833 person-years, ten or so are possibly due to irradiation.

During the period from 1986 to 1991 in the most contaminated zones in Ukraine a possible excess of about ten leukaemia cases was reported among youngsters who were up to 14 years old at the time of accident. Later rates are back to normal. This excess was not observed in Belarus.

Except for these observations, no excess of leukaemia has become evident, not even among adults evacuated from or living in contaminated areas.

Other cancers

Overall there is no significant increase in the number of other cancers, but some peculiar instances were reported: an overall excess of cancer among Russian liquidators not working in nuclear industry (898 cancers observed versus 847 forecasted in 8 years for 704 375 person-years); an excess of breast cancer among female liquidators (38 cancers observed in 1991-1999 versus 31 forecast for 5332 women) and, possibly, an excess of breast cancer among evacuated women and among women living in contaminated areas. All these data must be taken with caution because the excesses are barely above random fluctuations and because the frequency of breast cancer is clearly increasing in all countries due to improved screening.

Any increase in adult thyroid cancer is difficult to detect because of the bias introduced by better screening. For liquidators, evacuated people and residents of contaminated areas, an increase in thyroid cancers is clear (see Table II), but it is not obvious that it is due to contamination. First of all, the number of cancers normally expected is very small, because adult thyroid cancer is a relatively rare disease. On the other hand, a study of the dose-effect relationship in liquidators paradoxically shows that the risk of thyroid cancer decreases when the dose to the thyroid increases. Lastly, for residents, the increase is identical in the most contaminated region (Gomel) and in the least contaminated (Vitebsk). These elements suggest that improved screening plays a dominant role in this apparent increase of thyroid cancer.

Table II

Adult differentiated thyroid cancers in former Soviet Union

	Period	Persons - years	Expected Cancers	Observed cancers
Liquidators	1990-1993 1994-1997	263 084 314 452	3 5	13 24
Evacuees	1990-1993 1994-1997	208 805 200 077	6 7	23 43
Contaminated areas	1990-1993 1994-1997	654 501 556 631	22 19	24 48

Non malignant diseases

A very large number of non-specific pathologies (asthenia, anaemia, sensitivity to infection, cardiovascular disorders) have been described and sometimes attributed to ionizing radiation. Taking into account the doses received, these pathologies cannot be the result of irradiation. Like psychic disorders and suicide, they arise from the major psychological trauma suffered by the liquidators and evacuated people as well as from anxiety and the badly deteriorated socio-economic conditions in the contaminated areas.

Heart disorders attributed to the chemical toxicity of cesium-137 were reported in unrefereed confidential communications. The work was done without even a minimum of methodological precautions and they are just not credible. We mention them only to express our solidarity with their author, Professor Bandazhevsky, who has the right to make a mistake without incurring the serious legal proceedings he is facing in Belarus.

An increased incidence of thyroid nodules and of thyroiditis, a thyroid pathology which may lead to hypothyroidism, has been reported and seems to be confirmed in areas where thyroid contamination was the strongest.

Digestive pathologies (acute diarrhoea, fibrosis) and a decrease of spermatozoid mobility and of fertility index were also reported among employees of the power station and liquidators.

Congenital malformation

The birth rate has greatly decreased in Ukraine and in Belarus; it is only about half of what it was fifteen years ago. Any possible increase of congenital malformations cannot be determined either by simple counting because they occur naturally in 2 to 5% of pregnancies;

or by comparing their incidence before and after 1986, because the quality of data taking may have changed in unknown ways. The register of malformations in Belarus shows an overall increase which began before 1986, with no difference between the contaminated and non-contaminated areas. Conversely, a 1997 study shows an increase of congenital malformations of the foetus after abortion. Three studies, covering more than 20 000 pregnancies in three regions of Russia, looked for a variation of the rate of abnormality (malformations, prematurity, newborn infant mortality) related to local contamination. They give contradictory results and only the decreased birth rate is systematically found.

Radiation-induced congenital malformations are well known and the procedure to be followed in case of accidental irradiation of a pregnant woman is well established: irradiation during first week leads to spontaneous abortion; later, most authors agree that no particular measure is indicated for doses to the embryo or to the foetus smaller than 50 mSv, and that therapeutic abortion is recommended if dose exceeds 200 mSv. Between these two limits, practice depends on the context. In the most contaminated areas of northern Ukraine, 99,9% of women received less than 100 mSv accumulated dose from 1986 to 1997, that is, less than 7 mSv for the duration of a pregnancy. These figures show that the massive epidemic of malformations, which some alarmist media would like to have us believe, is simply impossible.

Indirect consequences

In terms of public health, it is the indirect consequences of the Chernobyl incident which have had the most serious impact. Because of the vast area contaminated (150 000 km^2 - 60 000 square miles - contaminated with more than 37 kBq/m^2), because of the enormous amount of money which had to be spent and because of its major political impact, the accident greatly disturbed an already precarious health organisation in three countries which were already in total political, economic and financial disarray.

Taking into account our knowledge, it is impossible to answer the question: What is the total number of deaths caused by this accident? However, if one compares the total number of observed cancers to the number of cancers naturally expected among Belarussian and Ukrainian liquidators, one notices that the excess of cancers is small. One even observes fewer cancers in Belarus than otherwise expected! We are far from the slaughter sometimes proclaimed. (Table III).

Even if the number of excess cancers could have been predicted, the survival of the patients would depend on early diagnosis and on the therapeutic methods available, which in turn depend on the economic level of the country. Only massive and well-supervised international help will be able to mitigate the consequences of this catastrophe.

Table III

Total number of naturally expected and observed cancers among the liquidators

	Person-years	Expected cancers	Observed cancers
Belarus	314 204	1 352	1 195

Ukraine	1 155 072	2 708	2 992

Controversy in France over the effects of Chernobyl

The radioactive cloud crossed France from east to west, from 30 April to 5 May 1986, producing a contamination mostly due to iodine-131 which disappeared in a few weeks' time, and by cesium-137 which is still present in significant quantities in some areas. One can evaluate two doses:

- an overall effective whole-body dose. The highest effective doses received in France were in the range of 0.4 mSv for the year 1986 and, if integrated over the sixty years from 1986 to 2046, 1.5 mSv. These doses are small compared to natural irradiation which is about 2.5 mSv/year in Paris and 5.5 mSv/year in Clermont-Ferrand.

- a dose to the thyroid coming mainly from food contaminated with iodine-131 consumed in May and June 1986. According to an evaluation by IPSN, this dose is in the range of 0,5 to 2 mGy for an adult and 6,5 to 16 mGy for a 5-year-old child. These figures are very sensitive to the consumption of fresh cow or goat milk, and the IPSN assessment gives an average value 100 to 1000 times lower than for children in the Chernobyl area. But these evaluations probably underestimate the dose received by a few youngsters who may have a very unusual diet, while overestimating the average for the country as a whole.

For both these doses, one observes a geographic distribution which decreases significantly from east to west (see Figure. II).

Thyroid cancers

The incidence of thyroid cancer in France has increased significantly since 1975 (Figure III). There were 2600 new cases in 1995, i.e. 1% of cancers. This increase, which is observed among adults as well as young people, is the origin of the polemical hypothesis (and related complaints lodged with the government) that the Chernobyl accident might be responsible for the increase, and the suggestion that the public health authorities failed to take precautionary measures in 1986.

It is worth recalling here that thyroid nodules are extremely frequent (occurring in 40% of women 40 years old and in 50% in persons older than 60), and so are micro-cancers less than 1 centimeter in diameter. Most of them are undiscovered and do not progress. Systematic analyses of the thyroid gland among adults who died without any peculiar thyroid pathology shows small seats of thyroid cancer in 6 to 28% of cases. So the incidence of thyroid cancer is only apparent and essentially linked to screening and especially to the spread of ultrasound examinations in the 1980s. The spatial resolution of this technique, a few millimeters, enables practitioners to identify nodules which in 90% of the cases would not appear through palpation or scintigraphic studies. Many micro-cancers of multi-nodule goitres are also discovered in the anatomo-pathological studies of excised tissue, for they are now more frequently operated on than 20 years ago. In the Champagne-Ardennes records, the rate of micro-cancer increases from 4.3% in he period 1966-1976 to 37% in the period 1996-1999, while the proportion of tumours greater than 4 cm (1.6 inch) goes down from 42% to 22%.

Many facts are at variance with the belief, widespread even in the non-specialist medical community, that the Chernobyl accident is the origin of this increase:

1. the increase began around 1975, at a rate of about 7%/year for papillary cancers, with no break after 1986 (thyroid cancers identified before 1989 cannot be linked to Chernobyl);
2. a similar increase is observed in developed countries, even those not affected by the Chernobyl fallout (USA);
3. the increase concerns adults of all ages but not youngsters, as shown by the Champagne-Ardennes records (Table IV). This is consistent with the fact that there are no hidden micro-cancers among youngsters;
4. no study has ever shown an increase of adult thyroid cancer due to iodine-131, even for much higher doses;
5. the increase between the five-year periods 1982-1986 and 1992-1996 is greater in some less contaminated areas (Calvados x 4.3) than in other much more contaminated areas (Haut-Rhin x 2);
6. among analysed subjects, the RET gene mutations, frequently observed among irradiated youngsters in former Soviet Union, are not more frequent than for natural cancers;
7. changes in diagnosis and therapeutic practices, which are the subject of a current study, are probably sufficient to explain the observed increase.

Table IV

Differentiated thyroid cancers among young people (less than 15 years old)

Year	**1986**	**1987**	**1988**	**1999**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
Belarus	3	4	6	5	31	62	62	87	77	82	67	73	48	
Ukraine	8	7	8	11	26	22	49	44	44	47	56	36	44	
Russia	0	1	0	0	1	1	3	1	6	7	2	5	-	-
Champagne-Ardennes	0	1	1	0	0	0	1	1	0	0	1	0	0	0

IPSN has evaluated the number of excess thyroid cancers in France due to the accident. They estimate that the excess may be in the range of 0.5 to 22 cases for the decade 1991-2000 (to be compared with an expected 97 +/- 20 spontaneous cases) and in the range of 6.8 to 54.9 for the quarter-century 1991-2015 (to be compared with an expected 899 +/- 60 spontaneous cases). This estimate must be viewed with great caution. In particular, it is based on the LNT relationship which, as we explained earlier, is inadequate.

Moreover, the greatest excess of cancers given above were calculated on the basis of studies of young people who were externally irradiated, thus irradiated in a manner very different from the irradiation of the thyroid by iodine-131. For the external irradiation, the doses were 10 to 60 times greater, the dose rates were 10^3 à 10^5 times greater and the external irradiation was much more homogeneous than the iodine-131 irradiation.

Conscious of the limitations of their study, the authors themselves conclude: "Taking into account the methodological limits mentioned above and the question of whether there is any risk at low doses, it is also possible that the risk of an excess of thyroid cancer, at dose levels considered here, is nil"

Other thyroid diseases

In view of the doses to the thyroid in France, it is inconceivable that hyperthyroidism, hypothyroidism, nodules or chronic thyroiditis might be attributed to the Chernobyl accident. Hyperthyroidism is never radiation-induced, hypothyroidism occurs only in subjects who have received a dose largely exceeding 1000 mSv, while nodules and chronic thyroiditis are difficult enough to discern in the former Soviet Union, even assuming that they exist

Other cancers

Similarly, cesium-137 contamination, which can produce only a negligible irradiation compared to the background, cannot be the cause of radiation-induced pathologies, especially cancers or leukaemia.

It has been calculated that 15 days camping on the most contaminated area would lead to a 0.015 mSv dose and picnic of a youngster eating food spattered with mud a 0.001 mSv dose. A gastronomic hunter-gatherer, eating contaminated boar and mushrooms every day, would receive a yearly excess dose of 1mSv, the excess dose a Parisian would get if he were to spend six months in Clermont-Ferrand.

To restore confidence

The French health authorities of 1986, and in particular SCPRI, have been reviled ever since for not taking the necessary preventive measures, as other European countries had, and even for having deliberately hidden the truth from the French public in order to protect the interests of the "nuclear lobby".

Without joining in a debate which is not strictly medical, let us note that newspapers reported as early as May 2nd: "*The director of SCPRI announced yesterday that an increase in radioactivity had been recorded all over the country."* This did not keep the press from writing ten days later, on May 12th : "*A radioactive lie: French scientific authorities have hidden from the public the passage of a radioactive cloud over our territory between April 30th and May 4th."* The main concern of French authorities seem to have been to avoid a panic which, for example, led to a considerable number of unjustified abortions in certain countries.

Today we ask whether an epidemiological inquiry on thyroid cancers in France would be of any relevance. Only such an inquiry will permit us to put people’s mind at ease by showing that in all likelihood the Chernobyl accident had no perceptible consequences on French territory. But an epidemiological study will be meaningful only if it can separate out the effect of improved screening for cancer. The latter is likely to be much greater than the effect it seeks to discover.

In conclusion, we would say that the consequences of the Chernobyl accident in France are probably negligible. Obviously it would be better to prove it, but the epidemiological studies launched by the Government may not be able to supply an absolute proof, due to statistical uncertainties. On the other hand, in Ukraine, Belarus and Russia the consequences, mainly indirect, are nevertheless very serious and justify an effort of international solidarity which remains very parsimonious compared to needs. This duty of international solidarity goes hand-in-hand with the right to know what happened at Chernobyl.

Glossary

Becquerel - Bq : the unit of radioactivity - 1 Bq = one disintegration per second.

Gray - Gy Unit of absorbed dose - 1 Gy = energy transfer of 1 joule per kilogram

Sievert : Unit of effective dose. The Sievert was created for radioprotection purposes; it is a measure of the risk due to ionising radiation. It is a weighted average of mean doses absorbed by the various organs or tissues, using coefficients characteristic of each type of radiation (alpha, beta and gamma) and coefficients depending on each organ or tissue.

ICRP : International Commission on Radiation Protection (a private self-perpetuating body)

IPSN : (French) Institute for Nuclear Protection and Safety

SCPRI : (French) Central Service for Protection against Ionizing Radiation (which has become OPRI : Office for Protection against Ionizing Radiation)

UNSCEAR : United Nations Scientific Committee on the Effects of Atomic Radiation

About the Author

Born on April 4th 1949, a graduate of the Ecole Polytechnique in 1967, Interne des Hôpitaux de Paris (member of the medical staff of the municipal hospital system), Doctor of Medicine, Doctor of Science and University Professor, André Aurengo is Chief of the Nuclear Medicine Department at the La Pitié-Salpêtrière Hospital in Paris. This Department specializes in thyroid pathology and its doctors have have treated, cured and followed up over 4000 thyroid cancer patients, one of the largest cohorts in the world.

André Aurengo and his team have visited Ukraine on several occasions. In the La Pitié Hospital they have treated 33 Ukrainian youngsters who suffered from thyroid cancer after the Chernobyl accident. André Aurengo is vice-chairman of the Radioprotection Department of the Conseil supérieur d'hygiène publique de France (Higher Council for Public Health), member of the French delegation to UNSCEAR and a corresponding member of the French Académie Nationale de Médecine.

*Original in French, English translation by Jacques Frot and Berol Robinson

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Figure I

Thyroid cancers among youngsters less than 17 when the accident occured

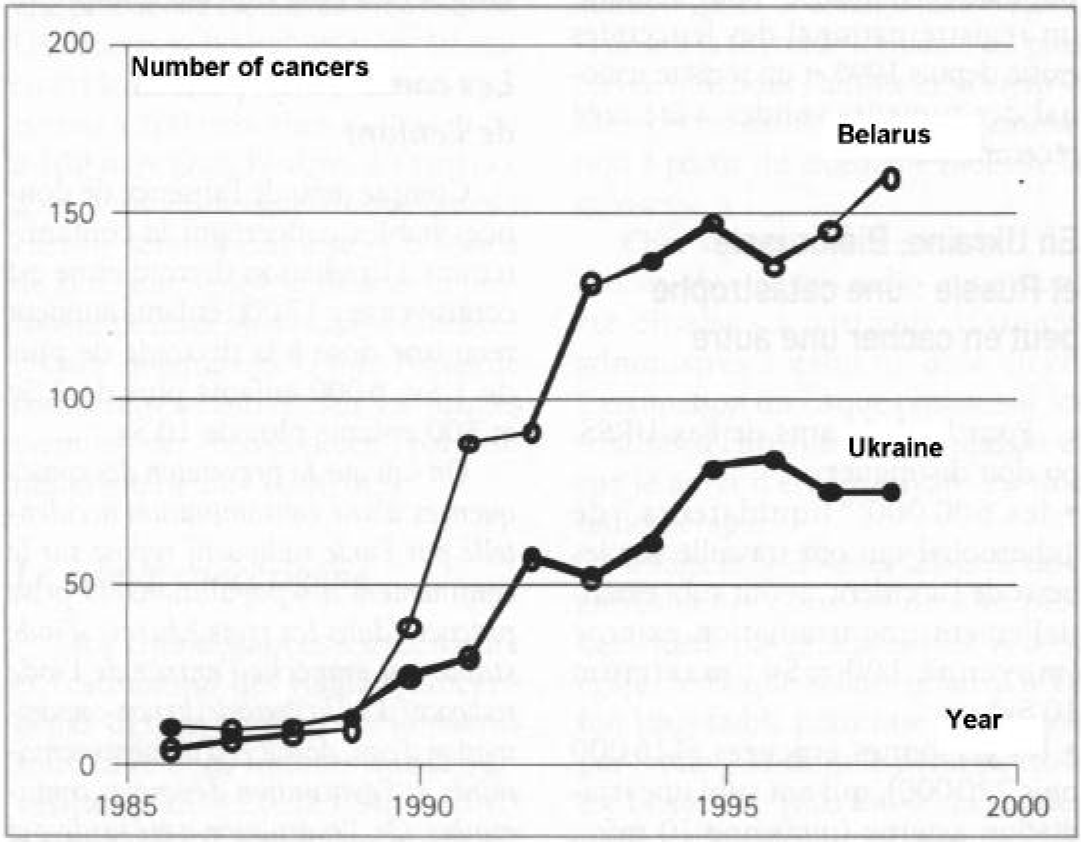


Figure II

Maximum efficient dose secondary from accident, cumulated over 1986-2046

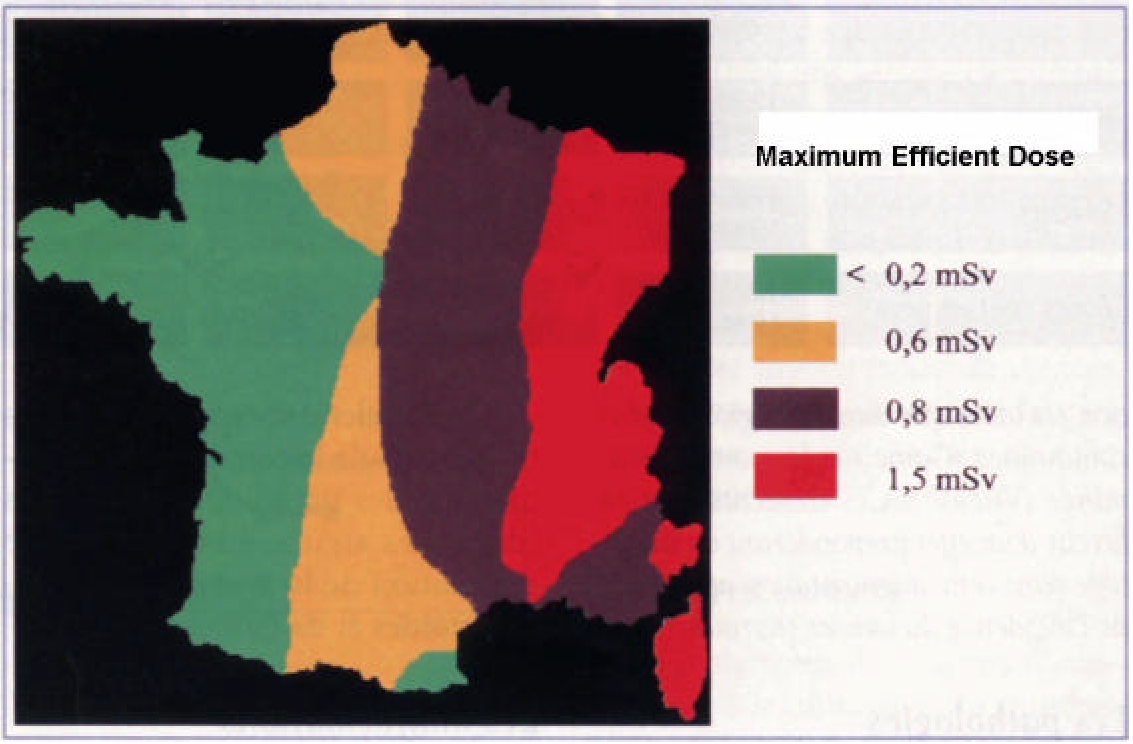
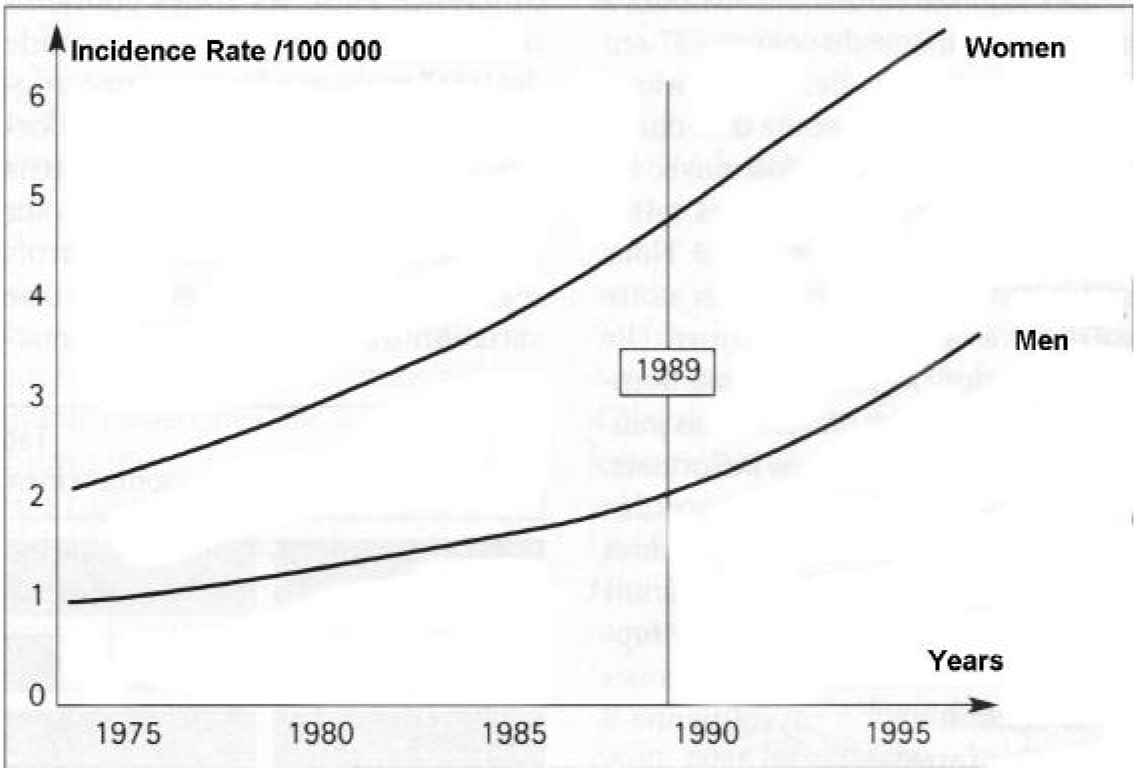


Figure III

Change in thyroid cancer incidence rate in France



COMMENTARY

Nuclear Earth-Penetrators: a Dangerous Fantasy

A. DeVolpi

As made clear by Frank von Hippel's insightful analysis in the July issue of *Physics and Society* ("Does the U.S. Need New Nuclear Weapons?"), the recently disclosed U.S. strategic posture review reveals an unyielding dependency on a nuclear fantasy: the ill-advised notion that atomic weapons can do useful things that conventional weapons can't. It is worrisome that, according to foreign intelligence reports, nuclear weapons of various types were moved close to Afghanistan after the 9/11 atrocity.

To reinforce Von Hippel's point, I would like to add some specifics about earth-penetrating nuclear weapons (EPNWs), especially with regard to local "collateral" damage and distant fallout, both of which are likely to create far more unfavorable consequences than acknowledged by EPNW advocates.

The earth-penetrating nuclear bomb (B61-Mod11) now in the U.S. arsenal could spray radiation over an area comparable to that at Hiroshima or Nagasaki. The B61-11 reportedly has a yield that can be "dialed" from 0.3 kilotons to 340 kilotons. At the upper end of that range, the explosion is about 20 times as energetic as the one at Hiroshima. Von Hippel quotes Los Alamos's Stephen M. Younger as saying that "some very hard targets require high yield to destroy them." In other words, there is at least one EPNW proponent who envisages the use of yields well above the kiloton range.

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Because of their subterranean objective, EPNWs must enter the ground before detonating. In contrast to air bursts (such as the ones over Japan), atom bombs that are exploded at or under the surface cause much more local and distant radioactive contamination. They vaporize earth and whatever else is there -- all drawn up in the mushroom-shaped cloud mixed with fission products. Much of this condenses and descends from the drifting cloud to become intense local fallout. As a result, the residual radiation effects can be serious.

With a surface (or subsurface) burst, the local and distant fallout have major public significance. When a nuclear fireball touches the ground, some 50 percent of the total residual radioactivity will be ejected into the air and stay suspended for a long time while it decays and disperses.

No EPNW burrows so deep that its explosion will be contained, as shown in a calculation by Robert W. Nelson, one of Von Hippel's students[1]. From Glasstone's *The Effects of Nuclear Weapons*, one can estimate that even a 0.1 kiloton EPNW burrowing 50 feet into dry soil would make a crater with a diameter of over 100 feet [2].

The "local" fallout would be deposited in a cigar-shaped "footprint" extending a distance that depends on the yield of the bomb and prevailing weather. With a 100-kiloton (fission) explosion and a 15 mile-per-hour wind, the radiation-deposit contours for 300 roentgens/hour, one hour after the burst, could extend about 20 miles [3] (an accumulated dose of 600 roentgens kills about half of those exposed).

Many of the people within a mile or two of such a large blast would receive a lethal or near-lethal dose from the prompt radiation. Fires would be widespread within three or four miles of the explosion, where they would probably constitute a greater immediate hazard than the radiation.

According to Nelson, the B61-11 is able to penetrate only about 20 feet in dry earth. He reckons a mushroom cloud radius of over a mile from a 5-kiloton explosion.

Near the low end of the dialable yield, at 1 kiloton, the 300 roentgen/hour contour is somewhat more than a mile, covering an area of one or two square miles [3]. Civilians in this zone who did not quickly evacuate or seek shelter would probably develop radiation sickness, with perhaps some deaths among those within a half-mile or so of ground zero.

A nuclear attack on deep bunkers could devastate an area considerably greater that the damage zone at Hiroshima. Many potential targets are unavoidably or deliberately set in populated areas; so nearby collateral damage (to civilians and the environment) could be extensive, depending on the yield of the EPNW.

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In addition, "distant" radiation fallout is intensified. Subsurface detonation of the EPNW in the U.S. arsenal could send fission products well beyond the borders of the target.

The atomic bombs used in Japan were detonated high in the air; so practically none of those casualties have been attributed to fallout. But the inevitable mushroom cloud from EPNWs would disperse wind-borne fallout not only on the surrounding population but also extending over adjacent nations and into the worldwide atmosphere. Although the distant fallout is unlikely to pose an immediate medical trauma, it tends to be an unacceptable hazard in the public's perception.

While local fallout normally fans out to some tens of miles, the very fine particles (from a surface burst that creates an atomic cloud in the troposphere) remain suspended in air for days to years. In contrast to megaton explosions, which push the particles up into the stratosphere, nearly all the fine particles from atomic-bomb debris in the kiloton range will generally not rise above the troposphere; so they will remain there until eventually deposited around the world (by which time the fallout is no longer a significant health threat, though it would exceed regulatory and societal thresholds).

The distant fallout would largely consist of radioisotopes that tend to concentrate in bones and tissue: strontium-90 (which is chemically similar to calcium), cesium-137(similar to potassium), and iodine-131 (thyroid-prone).

One nuclear weapons test ("Simon," 43 kilotons), detonated on 25 April 1953 from a tower at the remote Nevada test site, spread radioactive debris over half of the continental United States[4].

Regional aftermaths from exploded EPNWs could be calamitous. Refugees from the impact zone would be unwelcome because potential hosts would suspect (realistically or not) that their bodies, clothing, or possessions were dangerously contaminated. An agricultural embargo would probably ensue, even if the radiation levels were below reasonable health tolerances. Certainly nation re-building would be severely hampered by the presence of radioactive territories.

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New warheads with a lower explosive yield ("mini-nukes") could be devised, but that would require revision of a 1994 U.S. law that prohibits their development. Also standing in the way are the Comprehensive Test Ban Treaty, the current moratorium on nuclear testing, and the Non-Proliferation Treaty (for which the U.S. pledged not to target non-nuclear weapons states with nuclear weapons). Although also a party to the African Nuclear-Weapons-Free Zone agreement, the U.S. in 1996 reportedly contemplated using nuclear weapons to destroy an underground facility in Libya [5].

In fact, one wonders if these legal constraints are part of the real reason that the Clinton and Bush administrations balked at signing on to the International Court of Justice. If nuclear weapons were to be used in violation of treaties and agreements, then the Court might hold U.S. administration officials personally responsible for crimes against humanity.

With all these drawbacks, using EPNWs to knock out hardened or deeply buried targets -- such as leadership bunkers, command centers, buried mobile-missile shelters, and weapon stockpiles -- would be not be practical either militarily or politically.

Nuclear earth-penetrators have no deterrent value -- they are designed expressly for war-fighting. In acquiring and deploying such weapons, the U.S. would be abandoning all pretense that its nuclear forces exist solely to prevent war.

Nor are they needed. Non-nuclear, high-explosive weapons can be effective. The Pentagon has some that can destroy hardened targets at depths of 50 feet and cause extensive structural damage at greater depths. Collateral damage from conventional warheads would be much less, since there is no radiation or fallout. Conventional weapons have been effective against Taliban/Al Qaeda sanctuaries in Afghanistan.

Collateral damage, distant fallout, and nuclear-weapon use potentially add up to counterproductive consequences of EPNWs. The message the Pentagon is transmitting to the world is that the United States is determined to pursue global dominance by threatening its opponents with nuclear retaliation, regardless of the outcome. The symbolic importance of a policy under which nuclear weapons are legitimated for warfighting cannot be overstated; and , if actually used, the concomitant local devastation and the emotion-rousing increment to global background radiation would surely trigger severe, world-wide political reaction.

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The author is a nuclear scientist with extensive arms-control and non-proliferation experience -- collaborating on a book about Cold-War nuclear weapons policies, tentatively titled Nuclear Shadowboxing: Myths, Realities, and Lessons of Cold-War Weaponry. Dr. DeVolpi can be reached at 815/293-0049, 21302 W. Monterrey Dr., Plainfield, IL, 60544, or <waterfox@westerncom.net>.

Heisenberg, Bohr and the atom bomb

Wolfgang Liebert

What happened in the autumn of 1941 in Copenhagen during talks between the two giants of science Niels Bohr and Werner Heisenberg? Did Heisenberg at that time want to convince Bohr to work with him towards the creation of a German atom bomb? Or did Heisenberg intend just the opposite, as he later claimed, namely convey the signal that the “Uranverein” was not striving to construct a German atom bomb?

A definite and clear interpretation of the matter does not seem to come into sight. It is no wonder then, that there exists no transcript of the talks, instead, only assumptions, myths, attempts to understand the problem and testimonies formulated later on by the erstwhile participants remain. But even if every spoken word was to have been transmitted to us, only the context of the war times, their past history and future perspectives could provide us with the necessary clues leading to our eventual perception of the subject.

The cause of the present debate is “Copenhagen”, the brilliant play by Michael Frayn, in which he brings to life the meeting that took place between Bohr and Heisenberg. His vivid analysis focuses on the contents, context and the purpose of the meeting. At its German premiere in June 1999 in Essen the play was denied a large public response, but engendered rave reviews in London and on New York´s Broadway. Historians pounced on it and used it to fuel their continuing debate about the history of science, a debate that had its roots more within America than across the Atlantic. In February 2002, the Danish Bohr-archive published a number of unsent letters written by Bohr to Heisenberg from 1958-62. For the first time, thanks to these documents, we are offered a private glimpse of Bohr´s own interpretation of the situation. Because of this, the flames of the argument have been rekindled, not only in the American but also in the German press.

The spectrum of reactions Bohr´s letters have provoked is wide. It sways from one extreme of opinion to the other; on the one hand, it has been claimed that the letters have brought “nothing new historically” (Dürr) and on the other “that Heisenberg, during his visit, acted like a 'Herrenmensch' in the eyes of Bohr” (Hagner). The physicist and philosopher Carl Friedrich von Weizsäcker, who was also involved in the German nuclear program, is now repeating what he always reassuringly maintained, that: “We gave up building the bomb in 1941 and only wanted to built the reactor.” This message was supposed to have reached the Allied scientists through Bohr. Helmut Rechenberg from the Munich Max Planck Institute of Physics backs up this theory: “All the listed works prove that the scientists involved were only working on an energy producing reactor.” The scientific journalist Rubner counter-argues that “Heisenberg´s case is representative of the failure of the German elite during the 3rd Reich.”

However, there remain a few facts that are hard to doubt and therefore should not be ignored. Nuclear scientists worldwide realised very soon after the discovery of nuclear fission in 1938 what many of them had suspected for a long time, that within their research lay an incredible potential for exploitation in different fields of technology. This concerned in particular the military sector, a fact that can be proved by numerous statements and newspaper articles published in 1939. With the outbreak of World War II, nuclear scientists around the world began to seriously consider the possible development of a new type of weapon with enormous destructive powers. Directly after the invasion of Poland the German arms office (`Heereswaffenamt´) grouped together the remaining renowned German nuclear scientists who were not Jewish and therefore were not forced to emigrate. They were to form a top secret project of high strategic value, in which Heisenberg soon emerged as the intellectual head of the so-called "Uranverein" and later on became its official leader.

So, it cannot be denied that there was indeed a nuclear weapons program in Nazi Germany. Compared to the US efforts of the last three years of World War II it was quite small, but in 1942 it comprised research groups at nearly 20 scientific institutions and for the first few years of its existence it was ahead of the US program.

By autumn 1941 first results made clear that the creation of the bomb was feasible. The project of uranium enrichment had had a certain amount of success and the first small experiments striving for the construction of an(a) reactor were showing definite signs of progress. Thousands of elite soldiers secured the acquisition of uranium ore and the exploitation of the Norwegian Deuterium production plant. Weizsäcker´s claim, that the scientists involved in the project already knew before the talks between Bohr and Heisenberg in German occupied Denmark, that no atom bomb could possibly be created, therefore seems highly implausible. It was even Weizsäcker himself who, in a report of summer 1940 expounded that a fictive "Uranmaschine" would produce a transuranic element outstandingly useful for weapon building - later on known as plutonium. It would be comparatively easy to separate and only 10 - 100 kg of it would be enough to built a bomb. In this way, Weizsäcker very early on provided the knowledge that the way to the bomb can be paved by a plutonium producing reactor.

It was not until 1942, after an extensive report from the German Heereswaffenamt and two conferences in February and June of that year, in which a number of most prominent government and military figures took part, alongside the scientists concerned, that the preliminary decisions for the reduction of German interest into the project were taken. On the 4th of July General Field Marshall Gerhard Milch openly asked Heisenberg, who had reported with the cold rationality of a scientist: "How big does a bomb have to be in order to obliterate a city the size of London?" Heisenberg responded quite competently, referring to the active nuclear part of the bomb: "About the size of a pineapple." Further questions posed by the military concerned the parallel development of the program in the US and the time it would take to bring a weapons program to completion. Heisenberg correctly answered that a timespan of at least two years would be needed for the production of material within a reactor, due to the scale of scientific and technological enterprise it required.

The Minister of Arms, Albert Speer, offered the scientists financial support, to which they responded with the modest demand of a raise in their budget by several ten thousand Reichsmark. The decision-makers came to the logical conclusion that this project was not going to be one which would decide the outcome of the war . The raise was however accorded, but with the result of a "first class state funeral", as Erich Bagge, another nuclear physicist involved in the project, put it. At the same time, the Allied parallel project overtook its German opponent and from 1942 on the USA built up an official research and industrial program, larger than anything that had ever taken place before, with the single goal of developing a nuclear weapon.

Open ended questions still remain. For example, why was the development of a bomb through uranium enrichment (as it was done in the US, leading to the Hiroshima bomb) not enforced? Was the true cause of this the rivalry between the different groups of German scientists and the tactical moves propounded by them? In this way, was the seemingly more 'elegant' path, namely the use of plutonium (which led in the US to the Nagasaki bomb) pushed to the fore? Or was this decision based on wrong calculations, which predicted the critical mass of the uranium at too high a level? This mistake would have led the scientists to believe that there existed a number of insurmountable technical obstacles. Or was the decision caused by the setbacks due to the bombing by the Allies of the early test areas? Was it just a question of incompetence on the part of the political decision-makers (or of the physicists) themselves? Did Heisenberg's group of scientists want to avoid being quartered in barracks for the rest of their research time like the colleagues in the V2 rocket program? Or, as some people still hope, was there more to their actions than meets the eye, and were they in fact hatching a clever plan to foil the whole nuclear weapon program? In any case, the German project was put on the back burner and carried on quietly. The whole situation was hanging in the balance and the German scientists were teetering on the brink of tipping it and building a bomb for Hitler. Thank God they did not.

Many further aspects are still to be considered. Among these, the ongoing general feeling of the Germans in Autumn 1941, that victory was almost certain, or the role of the hard-liners (like Bagge, Diebner or Harteck) within the German program who were staunchly in favour of the bomb. The need for justification weighed heavily upon the shoulders of Heisenberg and his theoreticians, who, on the one hand, tried to reinstate their so-called 'jewish' and therefore intolerable quantum physics against the fierce accusations of the supporters of the "Deutsche Physik", on the other hand, however, they wanted to use the importance of their science with regard to the war as an argument. Heisenberg´s role in the "Kulturpropaganda" of the 3^{rd} Reich in the occupied countries also needs to be put into question.

In the end it seems that the nuclear scientists of the war do not set a good example with regard to dealing responsibly with the process of discovery and way it can be shaped by technical and political means. This represents the actual core of the debate, of which the meeting between the former friends and colleagues Heisenberg and Bohr could be seen as its culmination point. The key question, the one which reveals itself to be relevant to us today, lies hidden beneath the surface of what actually happened: How far should research with potentially dangerous consequences be allowed to go before it gets out of hand? How much do we have to take national power relations and the outside influence of international politics into account? To what extent must the perception of foreseeable consequences influence the way a research project is conducted? From this point of view, this type of critical question must also be asked of the participants of the British-American nuclear weapons project. Why did only one of the members of the Manhattan project (Joseph Rotblat, winner of the Nobel Peace Prize in 1995) leave the program in 1944 after the Allied secret services were able to give the all-clear that the German nuclear weapons program had not come to significant results? The study of the history of science can and should help us to answer these complex and underlying questions , leading to a better understanding of today's science.

The parable of “The resistance of German nuclear scientists”, which is told with good intentions by Robert Jungk in his book “Brighter Than a Thousand Suns” has now, in any case, been obliterated by the publication of Bohr's texts: “You related how in the preceding years you had devoted yourself almost exclusively to this question [that of nuclear weapons] and were quite certain that it could be done, but you gave no hint about efforts on the part of German scientists to prevent such a development.” Doubts about the true resistance of the German scientists had begun to grow already in 1993 after the publication of the transcripts of the bugging in England of interned German scientists in 1946.

But inconsistencies still remain, just like they do with the question of nuclear weapon plans in the young Federal Republic of Germany. In this situation however, Heisenberg, Weizsäcker and a number of other nuclear scientists knew exactly where they stood. With the “Göttinger Erklärung” of 1957 they refused publicly and explicitly Chancellor Konrad Adenauer and his Minister of Defence Franz Joseph Strauss their possible participation in a nuclear weapons program. However, their willingness for the further and unconditional development of “civil” nuclear technologies did everything but hinder the fact that at least all material-technological prerequisites for the possible production of an atomic bomb were also prepared in Germany. Once again, the acquisition of plutonium was the main focal point.

The dilemma must however have been clear for a long time for all people involved: Civil-military ambivalence is inherent to nuclear science and technology. It is exactly this matter that deserves true analysis and interpretation. Where is it impossible to draw a clear line between civil and military aspects and where an how can this be made possible? Which intentions are the driving force of those scientists, politicians and economists who take part in the projects? Which consequences are we faced with? Which alternative pathways are seriously taken into consideration in order to avoid potentially dangerous developments? Which of these still exist today? In the meantime, these problems are not only those of the historical figures Bohr and Heisenberg, but now they have general importance in our everyday dealings with the world of science and technology.

Dr. Wolfgang Liebert
IANUS (Interdiszipl. Arbeitsgr. Naturwiss., Technik und Sicherheit/
Interdiscipl. Research Group in Science, Technology and Security)
Technical University Darmstadt,
Hochschulstrasse 4a D-64289 Darmstadt, Germany
phone: +49-6151-16-3016, -4368, fax: -6039 e-mail:
liebert@hrzpub.tu-darmstadt.de
IANUS-homepage: http://www.ianus.tu-darmstadt.de

Copenhagen in Europe: Why not the same debate as in the US ?

Jean-Jacques Salomon

Why is it that the production of *Copenhagen* in New York did not lead to the same intense discussions in London or Paris? The reaction in Paris was, as in London, extremely positive to the play as much as to the actors, the three outstanding and superbly led by the same director as in London: a real theatrical success. For those who didn't know anything about the story of the building of the atomic bomb, it was the discovery of some of the ethical issues at stake in a piece of history which precipitated not only the end of World War II, but also opened up a New World (as qualified by the title of Hewlet and Anderson's account **please reference this**) doomed to live for ever under the threat of a nuclear warfare. And for those (scientists, political scientists, journalists, etc.) who were aware of this story and its strategic stakes, it was a theatrical show whose reconstruction of the dramatic dialogue between the two geniuses, the master and his disciple, could indeed be challenged in some parts, but did stand with great talent on its own legitimacy. By the way, at the performance I attended, the theater was full (most likely with reservations organized by scientific Unions) of members of the National Center for Scientific Research (CNRS, the public institution supporting basic science) who obviously discussed, at the end, the story they were confronted with. But, apart from the most favorable reviews in the press and the media, no debate took place as intensely as in the United States.

I personally, knowing the story, having read almost all the literature and being familiar with many of the actors who took part in The Manhattan Project and having written often about it (to start with, *Science and Politics,* MIT Press, 1973), I certainly had questions about the real motivations of Heisenberg's visit that Frayn's play did not really answer or clear in my mind, but I simply considered that the author of a play is absolutely free to write or rewrite history as he wishes or can — granted that it is a real good piece of literature (which is indeed the case, in my mind). Even if this story is still close to us, with some survivors still, there is no reason at all to reproach the author for presenting (or occulting) the various possible explanations of what the real purpose of Heisenberg's visit to Bohr was. The value of good playwriting is certainly not its historical accuracy. Moreover, how far the play gave a "real" historical account may appear in the future as derisory as to try to know, between Shakespearean specialists, whether the reasons expressed on the stage by Henry the IVth to call to the Crusade were exactly those of the "real" king, or whether he "really" died in "the room called Jerusalem".

All the more so since, when the play was produced in Paris and later on in New York, Bohr's famous letters were still supposed not to be released before 2012. The unsent letters were the mystery that justified Frayn to think of writing the play — one of its basic themes being the difficulty, if not the impossibility, to determine why Heisenberg made his visit, in spite of all that was said later on by Heisenberg himself, and, in particular, von Weizsäcker, or their disciples and the various and divergent historians who wrote about it. And now that the unsent letters are no longer a mystery, it is fair to acknowledge that — except for very small points not really new, but confirmed — Heisenberg's visit remains a mystery, so much that Frayn was well advised and gifted to organize his play around its "debateability".

What may appear as new doesn't help to understand what Heisenberg "really" tried to convey to Bohr: alert him, spy upon him, or even threaten him; but it underlines how deeply Bohr was shocked by Heisenberg's conviction (in September 1941) that Hitler would win the war, by learning "that everything was being done in Germany to develop atomic weapons", that Heisenberg "had spent the last two years working more or less exclusively on such preparations" and that "it was quite foolish to maintain the hope of a different outcome of the war". How could the patriot Bohr, already involved in the Danish Resistance, tolerate Heisenberg's appeal to "cooperate" (which had no other meaning but "collaborate") with a triumphant Germany ?

The number of drafts of these unsent letters show how precisely Bohr tried to memorize again and again what was said (or not said) during Heisenberg's visit, and how deeply he felt deceived by Heisenberg's and von Weizsäcker's explanation given to Robert Jungk (who later on said indeed that he had been manipulated by von Weizsäcker). At the same time Bohr admitted, with some fair indulgence for somebody he considered almost as his son, that he understood that "it may be difficult for you to keep track of your thoughts and express yourself at the various stages of war, the course of which changed as time passed so that the conviction of German victory gradually had to weaken and finally end with the certainty of defeat". Of course, one year and a half after the Copenhagen visit, Stalingrad had fallen, the United States had entered the war, the final fate of the Nazi regime was obvious and the German program for an atomic bomb was almost stopped for the sake of more urgent and feasible priorities such as von Braun's missiles. In the paradise or the hell where *Copenhagen* takes place, this "dialogue of the dead" is not and has not to be directly affected by "the various stages of war the course of which changed". It is revealing that it is Bohr's wife, Margrethe who, like the chorus in Greek tragedies, always calls the two men to go back over facts and dates.

But then the real question remains: why such a debate in the US — and almost as intense in Germany — but not in France or England? The answer may simply be that what was *then* at stake — a German victory as expected, if not wished for, by Heisenberg thanks, perhaps, to the availability of Nazis atomic weapons, as opposed to the final bombing of Hiroshima and Nagasaki, the result of an American program mainly meant to precede the German nuclear threat —*was out of European hands*. Some have thought (Goudsmit, for instance, who led the Alsos mission) that the Manhattan Project was a race for the bomb with Heisenberg himself. And when Goudsmit discovered that von Weizsäcker's laboratory in Strasbourg hadn't gone very far and that Heisenberg's reactor had never worked, the Alsos mission was like Don Quixote fighting the windmill — difficult to digest. Yet, from then on, the advice to control or decide on the launching of the bomb was no longer (if it ever was) in the realm of British or French scientists' influence. Remember that Joseph Rotblat, who later became Secretary General of the Pugwash conferences and won the Nobel prize for peace, left the Manhattan Project precisely after the German defeat. Launching the bombs on the Japanese cities was an exclusively American decision (although of course, many ex-Europeans in exile took part in their building and some tried desperately to affect the decision, such as Szilard and Franck).

The core of the American and German debate resides in what Frayn claims about the "epistemology of intentions" which is what the play is about ("Copenhagen Revisited", *The New*

York Review of Books, March 28, 2002, p. 23). His Heisenberg is saying that "Bohr will continue to inspire respect and love, in spite of his involvement in the building of the Hiroshima and Nagasaki bombs, and he himself will continue to be regarded with distrust in spite of his failure to kill anyone". By the way, if this doesn't change what the play is about and its value, it is one example of Frayn's distortion of history. Actually, Bohr didn't play any important role in the building of the bombs; on the contrary, suspected after his talk with Churchill to be communist and excluded from Los Alamos, if he inspires respect it is because of his very early and continuous fight for an international agreement against these weapons. And Heisenberg ? True, he didn't kill anyone — not more, not less than Bohr. He was not at all a Nazi and he was effectively threatened by death in a SS newspaper denouncing him as a "white Jew" who, following Einstein's theories, didn't trust the "pure aryan physics" of Stark and Leonard. But, true again, he was protected by Himmler himself against the SS, not necessarily because he was a great scientist, but perhaps because in a simpler fashion his father was a friend of Himmler's father, both having been teachers in the same elementary schools and their mothers were very close friends. And not only did he take part in the building of German weapons systems, he also considered that Hitler's offensive against Russia was justified and his nationalism was such that he didn't see, at least up to the end of 1941, any problem in Hitlers' victory against the Allies.

Whatever Heisenberg's motivations were, he didn't come to Copenhagen to warn Bohr on the ethical dimensions of the nuclear venture in such a way that it should or could refrain the Allies from going ahead. Between the two extreme interpretations — converting Bohr to the rightness of collaborating with Germany, trying to find out what Bohr may have known of the Allies' program — there are still many other possible interpretations that Frayn's play exposes very well without exhausting the mystery. Obviously Bohr has been much more angered in his unsent letters than in Frayn's play: time and "the dialogue of the dead" make great minds more indulgent to each other's intentions. But one could also consider their intentions in a very different manner: for instance, that the real hero was Bohr, patriot, already part of the Danish underground, definitively opposed to the Nazi domination on Europe, convinced already in September 1941 that Hitler could not win even if he was then close to occupying Moscow, and who helped the Danish Jewish community to escape to Sweden just before he himself left his country, whereas Heisenberg led — after all — the German nuclear program, believed that Hitler could win and that destroying communism was the most urgent target, and didn't show much concern as to the concentration camps and what they implied.

This is where, it seems to me, the "epistemology of intentions" has different meanings in the US and in Germany, but it presents no reason to mobilize the other Europeans towards the same *committed* discussions. There were of course French scientists who took part in the Manhattan Project, notably the group of F. Joliot-Curie's disciples who worked in Montreal on the heavy water reactor. The last survivor, Bertrand Goldschmidt, died this year; he could have explained, as he did in many books, how this part of the Project was considered as less important and not well supported by the Americans. All were even more excluded than their British counterparts from the decision-making process which led to the atomic bombing of Japan. This is already one factor which may explain that the controversy raised by *Copenhagen* was not part of their personal involvement as it was for the other European scientists (German, Hungarian, Dutch, etc.) who were directly associated to the building of the bombs and who had a say, although it was not taken into account by General Groves and President Truman, on the decision to launch the bombs on Japan.

From the American standpoint (including, of course, the European scientific émigrés), Heisenberg was *anyway* guilty of two sins. First, invited to stay when he visited the US in 1939, he decided to come back to Germany and thus, as in Albert Hisrchman's enlightening analysis in *Exit and Voice*, he couldn't appear as disapproving the regime and became it's "objective" accomplice — which he was, no doubt, at least up to 1942. And thus his visit to Bohr has for ever raised in some American's eyes the suspicion that he could have won the race with them — *if* so many factors beyond his will or good faith had not interrupted, after two years, the German effort in this field in which he was then, without contest, the most competent, and the main, leader.

Secondly, and more important, thanks to von Weizsäcker's self-aggrandizing propaganda transmitted by Robert Jungk, the claim that Heisenberg has been spared ethical dilemma is even much stronger than in Frayn's play. Here, we are very far indeed from Oppenheimer's sense of guiltiness when he told Truman, following Dean Acheson's interview, that he "had blood on his hands" — and was immediately considered by the President as a "damn fool" (*New York Times*, 0ctober 11, 1969). In von Weizsäcker's version, which he never ceased to defend, the German nuclear scientists kept their hands as clean as possible, as for instance when he wrote in his *Bewussteinwandel* that "History will record that the peaceful development of the uranium engine was made by the German under the Hitler regime, whereas the Americans and the English developed this ghastly weapon of war." It was, no doubt a ghastly weapon and the hydrogen developments which did flow under the Cold War have become even more evil (as Rabi said). Yet, speaking of the "peaceful" nuclear activities of the German physicists under Hitler may appear to their American counterpart as a provocation, as if such "peacefulness" could occult what was the cost in terms of horrors and victims of the Nazi regime in Germany as well as in the occupied European territories. And, by the same token, what was the cost of the Japanese horrors and victims in Asia.

Such an interpretation tends of course to obliterate what Bohr underlined in his unsent letters, namely that he and Heisenberg "had to be regarded as representatives of two sides engaged in a mortal combat". In "the dialogue of the dead", in paradise or hell, this mortal combat appears as belonging to another world and time. Certainly not for the Americans (survivors or successors of the nuclear complex) concerned by "the decision to launch the bombs": if, as Oppenheimer said, "physics has known sin", von Weizsäcker's version tends to imply that such sinfulness is exclusively on the American side — and if not at all on the German one, at least in such a way that one could forget or forgive what were Hitler's crimes and intentions.

Let me underline that few Europeans, French or British, would not consider that such a interpretation is unbearable, and if they would be consulted, as I was by *Physics and Society*, I am ready to bet that all would conclude that any version presenting Heisenberg's motivations as "innocent" or "neutral" in September 1941 is ludicrous. But the debate is not *theirs, if what is basically at stake* is not the building of an atomic bomb, but the moral decision to drop it. It remains that von Weizsäcker's argument seems to exclude by definition that, if Hitler or Himmler or Speer would have taken more seriously the program led by Heisenberg — and if they would have had available the material and technical resources to build the bomb, the fate of Europe might have been quite different. In such circumstances, could Heisenberg have been in position to resist such a pressing national mandate, or even to resist (as Oppenheimer said of the building of the H bomb) the "pleasure" to find such "technologically sweet" solutions? Nobody knows the answer, and if *voicing* in a totalitarian regime to the point that one challenges its orientations implies that one is ready to martyrdom, it hardly could be said that Heisenberg was of such stature. Bohr says in his unsent letters that "there was no hint on your part that efforts were made by German physicists to prevent such an application of atomic science." And there is no proof that Heisenberg and his colleagues did, or even attempte to, torpedo the nuclear project: their discussions when they were prisoners in Farm Hall don't lead at all to such a conclusion.

The very fact, it seems to me, that nobody can demonstrate that Heisenberg made any effort to prevent work on weapons is enough for the American side to balance their possible sense of guilt against the good conscience of the German scientists who claimed after the war that they avoided — thanks to Providence —sharing the same ethical burden. I may add that this American passionate sensitiveness is best illustrated by the reproach made to the play that it did not put a greater stress on the persecution of the Jews. In particular, Lawrence Rose, "the most outspoken critic of Heisenberg and (the) play" as Frayn himself noted in *Copenhagen' Revisited*, who "managed to detect in it a subtle revisionism": since the calculation of the critical mass (which persuaded the Americans of the possibility of building a nuclear bomb) was made by Frisch and Pierls, German and Austrian Jewish émigrés in Britain, the Heisenberg comment in the play on this "historical irony" implies to him that Frayn attempted to blame "the Jews" for the bomb's invention. Really, this looks to me as stupid as the fact that any criticism to day of Israel's policy, even coming from a Jew, is immediately considered as an act of anti-Semitism!

Moreover, it tends to ignore (as usual in most American literature on the subject) the following historical facts: already in May 1939, before the beginning of the war and thus much before the Maud Committee's conclusions were transmitted to the US, F. Joliot-Curie's team had deposited within the CNRS three patents - one on nuclear energy production, two for the building of an atomic bomb; already in the early months of the war, a program was launched for a reactor based on heavy water; that Francis Perrin correctly calculated the necessary critical mass; and that they had already thought of preparing a site for an experimental explosion in the Sahara. It was indeed the French team which alerted their British colleagues to create the Maud Committee (see for instance, in addition to Bertrand Goldschmidt's personal accounts and Margaret Gowing's history of "the atomic relations between the Allies", Spencer R. Weart, *Scientists and Power*, Harvard University Press, 1979, translated into French as *The Great Adventure of the French Atomic Scientists* : *Scientists in Power*, Fayard, Paris,1980).

But then who today is in a position to judge Heisenberg? As Bohr was a Danish patriot, Heisenberg was a firm nationalist. That may be enough to explain that if he chose not to exit, it was in order to save the cause of German science against the pseudo aryan physics and, after 1942, to prepare himself to help rebuilding Germany after the Nazi collapse. We simply don't know, in spite of the release of his unsent letters, whether Bohr, shocked and angered by Heisenberg speaking of collaboration, misunderstood his intentions or understood them too well. How and who can judge today those who have chosen to stay in a totalitarian regime rather than to emigrate, even those who have — more or less reluctantly, as was Heisenberg's case — worked for it?

Again Albert Hirschman's *Exit and Voice* has definitive conclusions on what it costs to try to change *from the inside* a regime that one contests or even claims to fight. Here "the epistemology of intentions" is inevitably confronted with *objective roles* which open the door to endless interpretations. Who can decide, following Shakespeare, that Caesar was or wasn't an honorable man? Beyond this debate, clearly restricted between Americans and Germans scientists — if one takes for granted that they raced at a certain stage of the war for the same objective — there cannot be a definitive answer. A close friend of mine, a brilliant French physicist, has concluded, after having much enjoyed Frayn's play, that the mystery of Heisenberg's visit remains and will remain in a quasi- Heisenberg fashion an "undecidable affair" that nobody can either clear nor judge. Which means that there is still room for another excellent play.

Jean-Jacques Salomon
Honorary Professor, Chair Technology and Society,
Conservatoire National des Arts et Métiers,
Groupe Futuribles
55 rue de Varenne
75007 Paris, France
salomon@cnam.fr
(33) 1 53 63 37 70

The Role of German Physicists in WWII Science

Harry Lipkin

I keep being amazed at the stuff written about the role of Heisenberg and German scientists during World War II. The emphasis on the bomb, which played no role during the European war, obscures the enormous efforts of American physicists on the military R&D during the war which had an enormous impact, and the fact that there was no counterpart in the German war effort. The German government did not appreciate the fact that scientists could contribute usefully to the war effort; the Americans and British did. Nikolaus Riehl, who directed the German uranium production plant and was grabbed by the Russians immediately after they entered Berlin to do the job for them, states in his memoirs that "Hitler and all the men around him were intellectually incapable of understanding how so much energy could come from anything as small as an atom. Rockets they understood because they made noise."

I was at the Radiation Lab at MIT working on microwave radar where many hundreds of physicists, perhaps nearly a thousand, were working fulltime on the war effort, including top physicists like Rabi, Alvarez, Purcell, Bloch, Dicke, Schwinger, Uhlenbeck, Goudsmit and more. Even Hans Bethe spent several years at the Rad Lab working on radar before moving to Los Alamos. Their counterparts in Germany evidently did no war work at all. While our microwave radar annihilated the German submarines in the Atlantic, the Germans never knew what hit them; they did not realize that radar was feasible at microwave frequencies and never thought of recruiting their top scientists to try to help them figure out why they were losing submarines. And Luis Alvarez developed the GCA which enabled planes to land in bad weather and incidentally invented the air controller which is now the crucial feature of our ability to schedule commercia flights in all kinds of weather.

Heisenberg was free to work on a nuclear reactor, when the authorities knew that it would not produce any useful weapon during the European war, and devote a large part of his time to cosmic ray resarch and other activities. In the U.S. anyone with his ability would have found a niche in the war effort.

Has the Forum on Physics and Society ever looked into the real activities of science during World War II and this basic asymmetry between the German and Allied approaches?

Harry Lipkin
Dept. of Physics, Weizaann Institute of Science
Rehovot 76100 Israel
Ph. 548 256 9
ftlipkin@weizmann.ac.il

Creating a New Past: Heisenberg and Radioactive Decay

Alvin M. Saperstein and Betsy Pugel

One of the lessons quantum mechanics draws from the familiar phenomenon of radioactive decay is the nuclei's lack of memory. Each nucleus is "unaware" of whether it has just arrived in an excited state or whether it has been in that state for a very long time. In short, a lack of a physical memory means that *individual nuclei have no past*. Eyewitness accounts of events are often clouded by the associative nature of human memory, which biases the account, calling into question what we call "the past." How similar is the biased nature of eyewitness accounts to the nuclei's lack of memory? Without delving into issues of the quantum nature of consciousness, which often leads to misrepresentations of physics, this commentary attempts to raise the following questions: Can an analogy of the memory of nuclei be applied to the manner in which we remember events? Can *people have no past*? Can deliberate absence of past explain the actions of those German physicists, who having tried but failed to make “the bomb”, senselessly groped in attempts to grasp the moral high ground over those individuals and nations who had created and used nuclear weapons in WWII, namely, the United Kingdom and the United States?

The play, *Copenhagen* recently reminded many of us of such analogies between physics and human behavior. *Copenhagen* explores the *post-mortem* attempts by Danish Niels Bohr, his wife Margarethe, and German Werner Heisenberg to reconstruct what happened to them at their infamous September 1941 meeting in the Nazi-occupied Danish capital. The author, Michael Frayn, built upon the “Complementarity Principle” of Bohr and Heisenberg’s “Uncertainty Principle” to reveal his characters’ inability to understand or communicate with each other and to attain perspective on their place in the world. This is best shown by Margarethe, who, at one point, comments to Heisenberg that he sees everything in the world but himself.

The play emphasizes the inability of the two physicists to communicate with each other. Also evident, though not emphasized by Frayn, is Heisenberg’s inability to communicate with his own past, his lack of memory. This is best exemplified in discussions between Heisenberg, Weisacker and a group of other Nazi and "non-Nazi" German “bomb physicists”, discussions secretly recorded by British intelligence while the German physicists were confined at Farm Hall, an English manor house, at the end of the war in Europe. This inability to assess their past actions allows Heisenberg and his colleagues to create a new past whenever needed. Unlike some religious converts who, although "born again", are well aware of their own past "sinful" life as they awaken to a new life of grace, these fine physicists seemed oblivious to their "real past" (as observed by others) as they went about deliberately creating a "new past."

The lack of memory is also apparent in the attitudes of the many German scientists, who, if kindness is afforded to their actions, could be described as "turning a blind eye" to the horrors which took place in Nazi Germany, continuing to work on weapons research for the sake of its intrinsic physics interest and their intense nationalism. They apparently could not understand the post-war repugnance with which they were greeted by their former scientific colleagues of pre-war days. Their actions illustrate the associative nature of the human mind, the ability to disregard the "excited state" that one is in and function at a normal level of operation.

This disappearance of "real past" has been demonstrated by several historians and physicists including: Paul Lawrence Rose in *Heisenberg and the Nazi Bomb Project: A Study in German Culture*; Jeremy Bernstein in *Hitler's Uranium Club*, which contains his commentary alongside the recorded Farm Hall diaries. Not only are the members of this distinguished group of German physicists unaware of their moral past, they create for themselves a new history of physics and a new understanding of physics with no apparent memory of their previous activities or accomplishments in the same field of research. In spite of a great deal of evidence to the contrary, this group created, post-war, a past in which they understood, from the beginning, the physics of "the bomb". They could have built a bomb if they so desired, but they did not so desire! The contrary evidence of bungled and misdirected research includes their own writings in German physics journals and Army Weapons Bureau reports as well as recorded statements to scientific and political meetings.

In a world of resurgent tribalism, it is appropriate that the play forces us to contemplate the tribal loyalties of some, otherwise very rational, German physicists. They remained in their German "motherland" to "protect" the next generation of German physicists. Despite the evident Nazi destruction of their beloved science, Heisenberg and his colleagues refused to emigrate, considering themselves "non-ideological" and "non-political", as they worked on weapons research for the German military establishment. This should be contrasted with those many German physicists who left Germany to struggle against such tribalism and support more humane goals.

Much of literature has been devoted to pondering about the difficulties of human communication: one facet is the difficulty of eyewitnesses achieving mutual agreement on observed events. In addition to, Frayn's Copenhagen, the Japanese movie Rashomon comes immediately to mind. Here, we are raising concern with the failure of single individuals to communicate with their own pasts. It would be very interesting to have a Frayn develop a play about people of formidable intellect, but with no past - a human analogy to our understanding of radioactive decay. The resultant physics play might be called "Berlin" rather than "Copenhagen". (Perhaps such plays, without a physicist "hero", have already been written?). Hopefully, it would attract the attention of the physics world as well as of the non-scientist world, all of whom would recognize that the human failures and strengths dramatized in such a play would be characteristics not only of the physicist, but of the human being.

Alvin M. Saperstein
Dept. of Physics and Astronomy
Wayne State University, Detroit, MI 48207
ams@physics.wayne.edu
313-577-2733; fax 577-3932

D. Elizabeth Pugel
APS member and graduate student "in transition"
b_pugel@hotmail.com

LETTERS

A New Challenge from the Creationists

I am writing as the results of the Kansas primary election are in. There was a light voter turnout, and as feared two of the pro-science incumbents lost. We are clearly headed back toward significant power in the hands of those with a religious agenda against science. Just as when the earlier batch were elected, the electorate was asleep in the absence of an overt emergency, and woke up after the damage was done.

There is a contested race in one district: L. D. Anstine of Hutchinson, Kansas has taken a pro-science position. Persons with an interest in this issue should watch the outcome of this race in the November elections.

Adrian L. Melott
Department of Physics and Astronomy
1251 Wescoe Hall Dr. #1082
University of Kansas, Lawrence, Kansas 66045-7582
phone: 785-864-3037; fax: 785-864-5262
melott@kusmos.phsx.ukans.edu
http://kusmos.phsx.ukans.edu/~melott/Melott.html

A Reaction to a Reading of Jeff Schmidt's "Disciplined Minds"

The politics of professional work, which is the subject of Jeff Schmidt's book entitled "Disciplined Minds" belongs squarely in the agenda of the *Forum on Physics and Society.* In addition, much of Schmidt's discussion, and especially his pain, gives an eerie sense of *deja vu* to anybody who has read women's complaints about the professional world of physics.

Schmidt's basic thesis is that professionals work in the context of political agendas (...no debate from me on that...) and that professionals' training is designed to weed out those who do not possess the requisite compliance, obedience, submissiveness, etc, that will be demanded of them in their professional lives (...I have serious doubts about the validity of such an extrapolation...). He even makes the argument that political, as opposed to technical, criteria are primarily what determine the form of the certification barriers variously called qualifying exams, prelims, orals, etc.

I must admit that much of the anger and agony that saturates Schmidt's pages reminds me of the horrible feelings I sometimes had as a graduate student and post-doc. It is natural for people who are established in their professions to forget about what it was lke to be in a very vulnerable and insecure position. To me, Schmidt's book read like it was from someone who never found a niche [although it might be more proper to say that Schmidt rejects the moral validity of most such available niches] and who feels the need to tell the world what hell goes on at the bottom of the food chain.

I have very little argument with Schmidt's viewpoint that professionals'activities are, in probably most cases, dictated by political forces. However, my interpretation of the significance of this is quite different from his. In particular, I don't think that professionals are, or even should be, somehow excused from or exempt from the omnipresent political nature of the life of *homo sapiens*. I believe that it is a naive, and ultimately false, assumption or hope that the work of science is supposed to be carried out primarily within a context of "Love of Truth and Beauty". Put bluntly: Why should any scientist think that he or she, by virtue of merely loving science, should be consequently insulated from the nastier characteristics of existence of all other human beings, including competition, manipulation, domination, lying, betrayal, theft, intimidation, degradation...(I guess that's enough of a list for now...you get the idea...)?

Of course, one can reasonably ask, "Might it be possible to create a culture within science that is relatively free of such nastiness?" I think that the answer is probably "No" because science is just another tool of our species for survival. Insofar as tools resulting from scientific work lead to the accumulation of power, wealth, and other forms of "biological free energy", science is not exempt from, but rather is very much a part of, the processes of natural selection. Therefore, all the competition, manipulation, domination, struggle, etc, that is found in the world of science, whether it be in the life of a graduate student struggling to pass quals, or an assistant professor struggling to gain tenure, or an industrial scientist trying to avoid layoff, is a natural part of existence within the biosphere. Put simply: Scientists, too, are subject to the brutal forces of natural selection because scientists are living things. Schmidt's apparent belief that scientific activity should be motivated primarily by the love of ideas and/or a burning curiosity does not take this biological fact of scientists' existence into account.

One immediately practical aspect of these discussions concerns many women's complaints about males' behaviors in the professional physics world. Almost every time I read a narrative from a woman scientist about bad or insensitive treatment at the hands of a male scientist, I am reminded that I, too, was so mistreated (or at least felt uncomfortable) at some point in my working life as a scientist, or else I know of another man who was so (or much worse) mistreated. This is a *very* important consideration because probably no policy changes anywhere can eliminate the political nature of humans' relations with each other. As far as women's professional lives are concerned, although we might try to distinguish between brutalities and injustices that happen to anybody vs. those that happen to women specifically, I seriously doubt that making such distinctions is easy, or even possible in many cases. The sad truth is that sexual discrimination in science will be *passe* when women scientists, too, can compete, brutalize, manipulate, and dominate scientists with the same frequency and gusto as their male counterparts. (It will be like the Virginia Slims commercial used to say, "You've come a long way, baby...").

I realize that the viewpoint that I take above is not pretty, and even perhaps less pretty than that taken by Jeff Schmidt. However, I think it more accurately describes the possibilities (and realities) of professional life, and it hopefully is useful in the ongoing struggle to improve science by making participation in the professions of science more inclusive.

Jeffrey Marque
San Mateo, California
jjmarque@beckman.com

Women in Physics and Scientific Literacy

Meg Urry presents a fine account of the recent International Conference on Women in Physics (*P&S* July 2002, pp. 11-13). That conference covered many important topics bearing on the deplorable dearth of women in physics, but it left out one crucial item. That item is scientific literacy for all citizens around the world. Despite the importance of this topic for women in physics and for the scientific development of all nations, I have found that it is nearly ignored at international physics education meetings, and indeed at most meetings in the United States. Yet the American Association for the Advancement of Science has stated in no uncertain terms, in its study

Science for All Americans, that "The life-enhancing potential of science and technology cannot be realized unless the public in general comes to understand science, mathematics, and technology and to acquire scientific habits of mind; without a scientifically literate population, the outlook for a better world is not promising."

Urry's article does, in fact, mention this topic when she states in her introductory paragraph that "a more scientifically literate public, one that includes girls and women educated in physics, will lead to more public support of science." But her subsequent report on the meeting itself ignores this topic, presumably because the meeting ignored this topic.

Well-taught high school and college physics courses aimed at scientific literacy for non-scientists would help increase the interest and participation of women in physics. Such courses can attract women by showing non-scientists that physics is comprehensible and relevant to their lives. Humanely taught courses for non-scientists can gradually replace today's image of an inherently masculine physics that has often worked to dominate or conquer nature.

Physics courses that are relevant to the needs of our times--as all science literacy courses should be--will include physics-related societal topics such as global warming, the methods of science, pseudoscience, and technological risk. In my 25 years of experience in developing and teaching a large-lecture course of this type, I have found that women are particularly attuned to such human-centered topics. If more courses of this sort were taught around the world, women and men alike would discover that physics is an interesting, relevant and humane profession.

Unfortunately, many U.S. physics departments teach nothing for non-scientists, most non-scientists' courses are small, and such courses have a priority lagging far behind courses for majors and other scientists. The situation is even worse in other nations. Attendance at many international meetings has taught me that scientific literacy is even more ignored around the world than it is in the United States. Few nations teach physics courses directed at the non-scientific majority of their citizens, at either the secondary-school or university level. Instead, physics education is directed nearly uniformly at future scientists. This narrow focus of the international physics education community is an important contributor to the dearth of women in physics.

Art Hobson
Emeritus Professor of Physics
University of Arkansas
ahobson@uark.edu

REVIEWS

Energy: Science, Policy, and the Pursuit of Sustainability
Edited by Robert Bent, Lloyd Orr and Randall Baker
Island Press, May 2002, 257 Pages, $55.00
Cloth ISBN 1-55963-910-5, $27.50 Paper ISBN 1-55963-911-3

That our society is deeply dependent on energy should come as a surprise to no one. Consequently, the possibility that our energy sources could be running dry is quite troubling. This book is an impressively wide-ranging and multidisciplinary survey of the problem of supplying our society with the energy it wants in a sustainable way.

The book tends to do a good bit of dwelling on the obvious. Few will be shocked to learn that energy resources are limited and their use environmentally damaging, nor that our demand for energy is rapidly growing. Our limited resources will soon be unable to meet this demand. Oil is cheap, and people are not as eager to save the environment as they are to cheaply heat their houses, and so we are likely to keep using exhaustible oil for energy until it is, well, exhausted. Many contributors to the book dwell on familiar points like these.

Randall Baker examines the energy problem from the less familiar political standpoint, concluding that political solutions are unlikely because of the short time-scale and the need for a crisis that characterize our political system. However, oil is cheaper and more readily available now than ever before. The science behind global warning seems to lack consensus and doesn't really suggest paths of action to be taken. The voter perceives no energy crisis; a political response is unlikely.

Luckily for us, as John Sheffield explains in the most thought-provoking chapter of the book, the ball isn't actually in the court of the developed western world anyway. Presuming that problems in sources like wind, solar, and nuclear power can be overcome and that efficiency of energy use improves, Sheffield determines that we can supply the energy needs of 12 billion people living at a reasonable standard of living for a very long time. This, according to groups like the UN, is the maximum population the earth can support, a level we will likely reach in the next century or two.

Sheffield's idea of a reasonable standard of living is not random. He explains that a society's population growth rate is related to the rate at which individuals in that society use energy. History indicates that populations stabilize only when their economies develop, raising per capita energy use. People in the future should use, Sheffield claims, enough energy to bring their populations under control. His conclusion is that we can find the energy resources to bring all 12 billion people to the point of energy use at which the population has no tendency to grow larger. However, if we reach the 12 billion point at which no more people can be supported and some people are not yet at this level of development, the undeveloped population's impossible tendency to grow in population will be checked by unpleasant factors, such as famine. At this point, the energy production of the world would be simply incapable of developing the majority of the world that needs developing. The problem would become unsolvable.

If a single nation is left undeveloped in the near future, this nation will quickly outgrow the developed parts of the world. Every day that goes by increases the population of undeveloped areas, thus increasing the energy needed to bring their population growth under control. The fact of the matter seems to be that the energy-greedy lifestyle of the developed world is actually more sustainable than that of the developing nations. However, even one nation that lags behind in development poses a problem for the rest of the world.

Sheffield's argument has the lovely property of shifting the blame for the energy problem away from the usual suspects, including America. Sure, we use absurd amounts of energy to fuel our SUVs and to keep our houses obscenely climate controlled, but at least our population is stable. If the rest of the world were more like us, there wouldn't be any problem.

However, Sheffield doesn't claim that we should be complacent and condemn the developing world. He realizes that we need to bring our lifestyles under control; the novelty of the argument is that this alone is not enough, and indeed may be the easy part. Not only must we drastically reduce the amount of energy used in the developed world, but we must also use the resources we save to move the rest of the world into a sustainable position. The energy we save today should not be used by tomorrow's America, but rather today's South-East Asia.

Lloyd Orr explains that economics will keep us from moving towards sustainability as long as oil is much cheaper than it would be if we could assess the damage its use will bring in the future. Orr suggests that the solution is to raise the price artificially by imposing a tax on the fuel. More expensive energy would cause use to become more reasonable and would give alternatives a greater chance of competing. Such a tax is the one concrete proposal to come from the book, but Orr realizes the difficulty of imposing a new tax on American voters; despite his efforts to make it feasible, the proposal seems like wishful thinking.

Energy: Science, Policy, and the Pursuit of Sustainability covers very little ground but from a wide range of perspectives. For the most part, the conclusions are not surprising, and where a point is unexpected, it tends to instill a sense of pessimism. The problems we are likely to face in the near future to satisfy our dependence on energy will be serious, and the only thing more apparent than our need to take action now is that we are unlikely to do so.

Matthew Sharp
Columbia University
mks42@columbia.edu

Science and Security in the 21st Century

by the Commission on Science and Security, John J.Hamre, Chairman

The CSIS Press(Center for Strategic and International Studies), 2002, 121 pages, ISBN 0-89206-410-2

This report comes from a commission set up by the Department of Energy to address the security procedures at the DOE laboratories with an emphasis on preventing these procedures from hindering the science goals. It was set up in the aftermath of the Wen Ho Lee fiasco which exacerbated the tensions that have always existed between the scientists and the security system. The report is supposed to cover 16 labs in all from Los Alamos to Fermilab, but it is mostly relevant to the weapons labs. Although the report is dated April 2002 it was essentially completed before 11 September 2001 and so does not deal directly with the issue of terrorist attacks. It contains a 10-page bibliography of related government reports and legislation.

A major theme of this report is the failure of the DOE security system to adjust to the post-Cold War era and to make use of modern security technology. It stresses the importance of international collaboration and the need for the labs, including the weapons labs, to employ foreign-born scientists. There is a particular emphasis on cyber security.

Recommendations include the ending of micromanagement by a large DOE staff, which is in part a relic of the past Watkins regime at DOE. The security responsibility should be in the hands of the laboratory director who should be fired if there are serious lapses. A major theme is that security procedures must be based on careful risk assessment so that resources can be directed effectively. A policy of "zero tolerance" for security infractions announced by the DOE in 1999 does not distinguish between serious and trivial. This can lead to low morale and may actually discourage the reporting of infractions. There is an interesting but inconclusive discussion of the somewhat open-ended category of "sensitive but unclassified information".

The report does not probe the fundamental question of what are the dangers from which this elaborate security system is protecting us. As far as I know the U.S. has not been significantly harmed from a security lapse at a DOE lab in the last 50 years. The most obvious danger is the spread of weapons of mass destruction to small dangerous states or terrorist groups. There is far more danger arising from the former Soviet Union with its security and financial problems than from U.S. sources. Thus logic would suggest that much of this security funding should be diverted to the Cooperative Threat Reduction Program and other efforts to safeguard Russian weapons. No such fundamental issues are addressed.

This report makes some useful general recommendations. In view of national attention focused on the aftermath of September 11 and the use of "homeland security" for political purposes, it is not clear how much attention the DOE will give to this report.

Lincoln Wolfenstein
Carnegie Mellon University, Pittsburgh Pa. 15213
lincoln@cmuhep2.phys.cmu.edu

Silent Spill, the Organization of an Industrial Crisis.
Thomas D. Beamish
MIT Press, 2000. 181 pp, $4.95, ISBN 0-262-52320-5

This book calls attention to a very large oil spill that occurred in the Guadalupe Dunes, 170 miles north of Los Angeles and 250 miles south of San Francisco. It was the largest recorded petroleum spill in U.S. history. The spill persisted over a period of 38 years with a total of 20,000,000 gallons, nearly twice the size of the more chronicled spill of the Exon Valdez in Prince William Sound of an estimated 10,900,000 gallons.

The author indicates early in his introduction a relatively clear motive in writing the book: that his home was located 65 miles from the spill site. Although the Guadalupe Dunes is only the largest discovered spill, as the author states, I could not buy his argument that it exemplified a "genre of environmental catastrophe that portends ecological collapse."

As I proceeded further through the book, I had no doubt that it had been well researched (as evidenced by the 17-page list of references). However, I could not fully grasp the significance of documenting this event which apparently did not emerge as an issue within its local environment until February of 1990. Granted, it is important to note that areas affected by the spill included an estuary and wetlands, and a preserve managed by the Nature Conservancy. But it would have been more helpful to know the exact effects of this spill on this fragile environment, rather than page after page of denials on the part of Unocal, the company allegedly responsible for the spill.

The only message I was able to walk away with after reading this book is a common one: how the environment can be adversely affected and destroyed by corporate irresponsibility and greed.

Daphne Burleson
Oregon Institute of Technology
2300 Radcliffe Street
Klamath Falls, OR 97601
yurigregarin@yahoo.com

***Reports of the National Center for Science Education*, ISSN 1064-2358**
Bimonthly, $30/year; NCSE, PO Box 9477, Berkeley, CA 94709-0477; ncse@ncseweb.org

When "the Russians beat us into space" in 1957, the event triggered the public furor that erupts every so often concerning the quality of American science education. This broad interest made possible the publication, within the next few years, of several excellent middle- and secondary-school science textbooks, notably the PSSC physics and BSCS biology texts. The latter, of course, were based on biological evolution, the central organizing principle of the life sciences, as naturally as the former were based on Newton's laws and their later extensions.

For the first time since the anti-evolution laws of the 1920s had banished the subject from most biology texts, at least some proportion of students nationwide were being exposed to biology as a modern science and not a mere cataloguing of disorganized information. In 1968, moreover, the U.S. Supreme Court, in *Epperson v. Arkansas*, struck down all such laws.

Responding to this changing environment, creationism evolved into a nod-nod, wink-wink "creation science" – an assertion that the mass of scientific evidence that supports and is made intelligible by evolutionary theory can equally well support the idea that the universe was created fewer than 10,000 years ago in six days, as is set forth in the first few chapters of Genesis. In 1979, the Institute for Creation Research began to peddle the idea that this "science" should be treated on an equal footing with evolution in public-school biology courses. By 1981, fifteen states had introduced "balanced treatment" bills, and political pressure for such legislation was being applied in at least 11 more.

In response to this serious threat to science teaching, a grassroots network of science teachers and scientists sprang up. Beginning in Iowa and expanding quickly to 42 states, these groups took the name Committees of Correspondence (CCs). With the aid of many national science and science-teaching organizations, these loosely knit groups were mainly successful in warding off It was clear, however, that creationist groups, well funded by the Religious Right, were not going to disappear. A coordinating organization for the CCs was needed, and in 1987 the National Center for Science Education (NCSE) opened its office. NCSE continues to act as a clearinghouse and assistance center for the quality teaching of science. In particular, NCSE responds to the needs of educators nationwide, who daily confront efforts to expunge evolution from all the sciences, but particularly the life sciences. As creationism evolves, these efforts take modified forms, some of them subtle.

A major endeavor of NCSE is its journal, *Reports of the National Center for Science Education* (RNCSE), now in its 22nd year. RNCSE provides a unique and vital service. It tracks the evolution of emerging species of creationists. Of these, the most ubiquitous at present are the intelligent-design creationists (IDCs). They have exhumed the view, abandoned by scientists more than a century ago, that at least some components of living things are too complex to have evolved and must therefore have been designed by a coyly unspecified intellect (read "God"). RNCSE keeps its readers up to date on efforts to introduce creationism and related pseudosciences into public-school science classes at every level from the classroom and school board to Congress. It furnishes a forum for criticisms of current creationist claims and even occasional rebuttals by the creationists themselves. In an ongoing science-religion dialogue, it opens its pages to religious scientists, ministers of religion, and theologians who, far from finding contradiction of their faith or heresy in evolution, find it more compatible with their religious positions than any other view of the natural world. It features summaries by experts of important emerging contributions to our understanding of evolution. And RNCSE is a rich source of book reviews, website references, and other relevant resources.

In a review of so diverse a journal, it is perhaps best to make brief mention of some typical content. Currently, IDC efforts to incorporate creationism into Ohio's K-12 science standards are the hottest issue. In its most recent number (Jan-Apr 2002) RNCSE extensively covered the history of this effort, whose high point to date has been a debate between two scientists (representing many thousands of their community) and two IDCs (representing their small but vocal group). The former two speakers were Lawrence M. Krauss, chairman of the Physics Department at Case Western Reserve University and Kenneth Miller, a distinguished biologist from Brown University who has written elegantly on evolution and his own deep commitment to Roman Catholicism. The IDCs were Steven Meyer, a philosopher from Whitworth College and the Discovery Institute (the principal IDC center) and Jonathan Wells, also of the Discovery Institute. Wells, like Miller, is deeply committed to religion; he states that he began his doctoral studies in biology at the behest of the Rev. Sun Myung Moon with the specific aim of opposing evolution. The debate was attended by an overflow audience; the Ohio Board of Education will vote this fall on the matter.

RNCSE Jan-Apr 2002 also featured an interview with Howard Van Till, emeritus professor of physics and astronomy at Calvin College and a traditional evangelical Protestant. In this interview, Van Till expands eloquently on the dynamic connection between the scientific and religious aspects of his cosmology.

Two of the most exciting recent developments in our understanding of the history of life on Earth are the confirmation, through fossil discoveries, of the prediction that whales are descended from land animals, and the deepening understanding of the ancestral roots of birds in dinosaurs. RNCSE Jan-Apr 2002 presents lucid discussions of these topics, by paleontologists Gregory S. Paul and Kevin Padian respectively.

A leading IDC, biochemist Michael Behe of Lehigh University, has set forth his irreducible-complexity argument in favor of intelligent design in a widely read book and numerous other publications. A critique of Behe's arguments by philosopher of science Niall Shanks and biologist Karl H. Joplin appeared in RNCSE Jan-Feb 2000. Behe's reply and the response by Shanks and Joplin, together with commentary by three other experts, followed in RNCSE May-Aug 2001. The three articles provided a lively interchange, though it is pretty clear that Shanks and Joplin inevitably had the better of the debate.

The fine PBS series, *Evolution,* was reviewed in RNCSE Sep-Dec 2001. Accompanying the review was an account of the strong creationist reaction.

RNCSE, for all its seriousness, occasionally publishes articles that cannot but amuse. I like to refer to Kurt Wise, a young-earth creationist, as the anti-Scopes. Remember that John T. Scopes, the defendant in the famous Monkey Trial of 1925, went from Dayton, Tennessee to the University of Chicago, where he earned his master's degree in geology. Wise, on the contrary, went from the University of Chicago, via Harvard, to Dayton, where he is an associate professor of science at Bryan College. In "Sermon Under the Mount," Matthew Chapman, a great-great-grandson of Charles Darwin, writes of accompanying one of Wise's classes on a geology field trip to a local cave. Though the students don't learn much science, Chapman learns quite a lot about the commitments of young fundamentalist students. ("I hear, like, intellectuals, a lot of them commit suicide? 'Cause they believe what they're taught, evolution an' all, so they got nothing to live for?") (RNCSE Sep-Oct 2000).

Such views are not restricted to fundamentalist Christians; similar attitudes can be found in ultra-orthodox Jews, among others. In "Creationism and Geocentrism Among Orthodox Jewish Scientists" (RNCSE Jan-Apr 2002), psychologist Alexander Nussbaum recounts his experiences in teaching at Touro College. There, all scientific questions are solved by reference to the Torah and the writings of revered commentators. Thus radioactive dating is false and the universe is about 6000 years old; thus Einstein, in his relativity theory, proved that the sun does indeed go around Earth.

Biologists are not the only scientists who need to devote effort to keeping such nonsense out of public schools. The physical sciences are affected not only directly, as in geocentrism and a 6000-year-old universe, but indirectly in common with all sciences when students are given a false idea of what science is about, how scientists do their work, and the results that emerge from that work. RNCSE performs a vital service in the cause of teaching good science.

Lawrence S. Lerner
Professor Emeritus
College of Natural Sciences & Mathematics
California State University, Long Beach
lslerner@csulb.edu