

**ELECTION ISSUE
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LETTERS

Randi's Lecture and Forum Awards

I enjoyed reading both the Szilard award and Forum award lectures (October 1989), especially the lecture by James Randi. This lecture ought to be more widely disseminated to the public, and especially to physics teachers, perhaps by publication in *The Physics Teacher*.

I would like to suggest that in the future the Forum present its awards and schedule its major lectures at the Joint APS/AAPT meeting, which attracts a rather general audience of physicists plus many physics teachers, rather than at the March or April meetings, which emphasize a few specialized areas of physics. After all, promotion of public understanding of physics is one of our main goals. Right?

Thomas D. Rossing
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Response:

It's a good idea, but APS's January general meeting, usually held jointly with AAPS, is soon to be abolished. A new rumor is that AAPT will join APS in April, which is very good, and that they will keep a small January meeting and their usual summer meeting. The APS hopes to broaden the April "Washington" meeting.

David Hafemeister
Representative to the APS Council from the Forum

The Meaning of Quantum Theory, Cont.

Thanks for running my letter (October 1989).

When relativity was new, many physicists who had little background in philosophy wrote carelessly about how relativity theory introduced fresh insights in metaphysical questions — how it supported determinism, abandoned the correspondence theory of truth, led to all sorts of relativisms, etc., but it soon turned out that relativity raised no fresh metaphysical problems. The same thing is happening all over again with QM, perhaps starting with the claim (Eddington, Compton, etc.) that QM supports free will. My own view, which I am prepared to defend, is that the nature of science and metaphysics (as Carnap said, there is no bridge between these two continents) is such that science cannot solve any metaphysical problem, let alone raise new ones.

When I say that QM has not raised a single fresh metaphysical problem, we must have a common understanding of two key words: "fresh" and "metaphysical."

By fresh I mean new. By metaphysics I mean problems that by definition are beyond the reach of empirical physics. This is how the word is used by all modern philosophers of science: Russell, Carnap,

Popper, Reichenbach, Hempel, to mention a few. In Carnap's often-used phrase, metaphysics has no "cognitive content."

"Philosophy of Science" is a different matter altogether. Carnap rejected all metaphysics as meaningless, but he wrote a book (on which I collaborated) called *Introduction to the Philosophy of Science*. Now obviously relativity and QM have made significant contributions to the philosophy of science. As I stressed in my *Relativity Explosion*, it was relativity theory that made clear that determining the structure of spacetime was an *empirical* question (in contrast to Kant's views). And QM did indeed make clear that physical laws can rest on a basic indeterminacy.

None of this raises a fresh metaphysical problem. For example, the question of whether the future is completely determined by the present, or whether elements of pure chance underlie "being" is one of the oldest questions in philosophy. It was constantly debated by the ancients and the medievals. The Greek atomists injected randomness into the basic structure of the universe by introducing a random "swerving" of particles on a level too small to be seen. Lucretius has a beautiful metaphor on this. He speaks of a flock of sheep moving about at random on a hill. But to a distant viewer, they appear as a white spot that is motionless. Jumping to recent times, Charles Peirce, America's greatest philosopher, firmly believed (before QM) that pure chance was an element in the evolution of the cosmos. He called his view "tychism." It had a major influence on William James. Note also that this old metaphysical question is far from settled today. Many QM experts, Bohm for example, believe (with Einstein) that QM is incomplete and that when a deeper level is discovered, determinism will be restored. And if one accepts (I don't) the many-worlds interpretation of QM, strict determinism is restored. Thus, the indeterminism of QM is certainly not a "fresh metaphysical question."

Consider another ancient metaphysical debate. Did the universe have an infinite past, or was it created by a transcendent deity, or did it pop into existence, all by itself, from nothing? Again, this was endlessly debated by the ancients and medievals. QM has shed no light on this question. There is speculation that the universe started with a random quantum fluctuation in the false vacuum, but this vacuum has nothing to do with metaphysical "nothing." The fluctuation presupposes quantum fields and laws, and laws of probability. So the question is simply pushed down to a deeper level, but the problem of why there is something rather than nothing is as opaque as ever.

Finally, take the question of whether the tree exists when no one observes it. QM has indeed introduced a tinge of solipsism into the measurement problem, which is far from completely understood, but it certainly hasn't introduced a "fresh metaphysical question." One of Wigner's famous essays, in which he wonders about the persistence of a tree when no one sees it, never mentions Bishop Berkeley!

Martin Gardner
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Response:

OK, I can agree that quantum mechanics raises no metaphysical problems that have not been raised at some point in the history of human thought. But most of us tend to frame the question in the more limited context of the history of scientific thought (i.e. not Bishop Berkeley) since Copernicus (i.e. not Lucretius, either). Relative to post-Copernican scientific thought, quantum mechanics does indeed

raise fresh questions about determinism versus free will, the existence of a purely objective reality, and other matters. Quantum mechanics, or any other scientific theory, should not be expected to answer such metaphysical ("beyond physics") questions, but it does throw them into a fresh perspective, and I think this fresh perspective is important.

Art Hobson

ARTICLES

Tagging Technologies and Reduction of Conventional Forces in Europe

Ruth H. Howes

Introduction

As the United States and the Soviet Union rapidly approach an agreement to limit the non-nuclear forces deployed in Europe, the arms control community is concerned about verification of likely treaty provisions. If the proposed treaty is based on President Bush's arms control initiative announced earlier this summer, it will include ceilings on numbers of tanks, armored troop carriers, artillery pieces, land-based combat aircraft and helicopters based between the Atlantic and the Urals as well as on numbers of troops in the region. Thus verification of the treaty will require each side to monitor on the order of 100,000 individual weapons. Unlike existing strategic weapons systems, conventional forces are deployed and maintained at a large number of bases spread widely over the continent of Europe.

A favorite technique for monitoring on such a massive scale would be to tag each individual weapon in such a way that it could be uniquely identified and could not be upgraded or switched (1). After establishing a baseline inventory of all equipment and the associated tags, inspectors could verify that treaty provisions were being observed by on-site inspection of samples of the weapons limited by the treaty. Samples would be selected by the inspecting side and compared with an inventory prepared by the side being inspected to ensure the accuracy of the inventory. If the treaty required destruction of weapons, the tag of each weapon could be checked and removed from the inventory as that weapon was destroyed.

Details of the inspection procedures including numbers of inspections, types of equipment used by the inspectors and conditions of access to the weapons being monitored will depend on the technology used to tag weapons in the field. If a treaty limiting conventional weapons in Europe follows the precedent set by the INF Treaty, these details will be included as part of the text of the treaty. Therefore research on tagging technologies will be an essential preliminary to conclusion of an agreement limiting conventional forces in Europe.

Requirements for Tagging Technologies

Satisfactory tags will have to be very difficult to counterfeit. They must be resistant to removal from the original equipment on which they have been placed and reveal any attempt to move them or tamper with them. On-site inspectors must be able to read the tags quickly and simply in the field and compare them with a baseline inventory. The tags must not provide any signal that could be used for intelligence information or targeting.

Since thousands of tags will have to be provided, they must be inexpensive and easy to install. Ideally they could be installed in the field by troops manning the equipment and the installation checked by

samples collected by on-site inspectors. Installers would have relatively little training or manual dexterity, and tags would have to be designed to withstand rough handling and sloppy installation procedures. Because so many items must be tagged, the tags will have to be durable for at least a decade if the problem of placing tags and updating records is not to be insurmountable.

Although the political climate of Europe is hospitable to arms control efforts, the physical climate is less well-disposed toward many types of tags. Equipment will expand and contract under temperature changes in both summer and winter climates from the Mediterranean to the Baltic. Tanks and other treaty limited weapons routinely move through dust, mud, snow, ice and even corrosive salt water. Soldiers in the field are not noted for gentle handling of their equipment, and tanks and personnel carriers do not provide a boulevard ride. Thus any workable tag design will have to be extremely rugged.

Proposed tags divide themselves into two broad groups, attached tags and intrinsic tags.

Attached Tags

Attached tags are manufactured elsewhere and mounted on weapons being monitored. The most sophisticated tagging technology is the electronic identification device (EID) which is an electronic chip mounted on the weapon system. In one version, it is operated by a dual key system with each side holding one electronic key. During an inspection, both sides would agree to activate the tags on a sample of equipment and the tags could be interrogated by electronic equipment mounted on a truck in the field, in a helicopter above the deployment area or on a satellite. It seems unlikely that either side would agree to electronic tags that could be monitored by satellites since these tags might conceivably provide targeting data or enough information on deployments to be militarily useful.

In order to make EIDs tamper-proof, they would need to be equipped with a position-sensing feature or encased in a fibre-optic net. Each side would need to provide a considerable quantity of extra tags so that the other side could inspect a sizable sample before installing the tags on equipment in the field to be sure that the tags did not contain identification signatures which could be used to target the weapon in the event of war.

The major problem with EIDs is to make them rugged enough to survive in field conditions for times on the order of ten years. Not only

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must the electronic components be reliable and durable in extremes of temperature and humidity, but the mounting for the tag must be firm enough so that the tag will not detach itself from the weapon. The need to ensure that the EID mounting is sensitive to any attempt to remove or tamper with the tag may well mean that installation will require relatively skilled technicians provided by the inspecting country. Initial costs of EIDs are likely to be higher than those for other types of tags although reading them during an inspection will be simpler since it can be done with equipment mounted on a vehicle or aircraft.

In the simplest of the attached tag technologies, a transparent glue mixed with mica flakes is spread over an identification number painted on the weapon being monitored. The pattern of mica flakes in the paint is recorded by photographing the tag under lights mounted at several reproducible angles. For inspection, the photographs can be compared with a new set of photographs taken in the field (2). Unless the photographic procedure can be automated, it seems likely that initial photographs of the tags will have to be collected by trained inspectors rather than by field troops. Control of the lighting in the photographs may require that equipment be moved inside during inspection. In addition, the painted surface will probably need an outer coat to protect it from abrasion during maneuvers by the weapon. Although the actual glitter paint tags will be considerably cheaper than EIDs, they will require trained teams for their installation and will be more difficult to inspect than EIDs.

Intrinsic Tags

Intrinsic tags use a unique feature of the surface of a weapon as an identifiable tag. Because they require nothing more than the identification of the surface to be used as a tag, they are easier to install than attached tags. Although they may need to be protected from abrasion by paint or a metal plate, they will not protrude above the surface of the weapon and will therefore be less susceptible to accidental destruction in the field than attached tags. In most schemes for intrinsic tagging, the surface to be used as a tag will be marked and the weapon numbered near the surface tag by stamping or attaching a number and perhaps a barcode onto the metal.

Because the tagging procedure will not involve installation of a complex tamper proof system, it seems possible that intrinsic tags could be installed by the troops in the field who normally maintain the weapon. Each side would thus tag its own systems during the baseline inspection period. Inspectors from the other side could then spot-check equipment to ascertain that the baseline inventory was correct and that the tagging procedures had been correctly conducted. If the tens of thousands of weapons limited by a treaty can be tagged in this way, there will be substantial financial savings. Clearly this procedure will require a means for the tagging team to record unique data on the tag which can then be filed for comparison by either side during on-site inspections.

An initial argument against simple intrinsic tagging is that machined surfaces might be counterfeited using casting techniques, thereby permitting one side to deploy more weapons than are allowed by the treaty. Certainly a skilled counterfeit of a machined surface or a weld can fool a visual inspection. On the other hand, it should be feasible to design a portable scanning electron microscope (SEM) to examine surface tags at sufficiently high resolution to detect a counterfeit. Like the photographs necessary to identify glitter paint tags, a SEM would require skilled personnel for its operation so that

initial installation and cataloging of tags would be expensive.

It is possible to monitor intrinsic surface tags using plastic castings of the surface that can be prepared by personnel with a minimum of training. The casts can then be shipped back to the laboratory for storage and analysis with a SEM. During the baseline inventory, all tags would have several casts prepared during initial tagging by the troops actually doing the tagging. These replicas could be stored by each side or in a central cataloging center. To verify the baseline inventory, an inspecting team would reexamine a sample of the tags in place on the weapons and prepare casts of them. The casts made by the inspecting team would then be shipped back to the central laboratory for comparison with the baseline cast for the weapon with the same number and/or barcode using a SEM. In subsequent on-site inspections and during destruction of equipment, similar casts could be prepared, compared with the baseline casts and left on file for future reference.

Using this technology, tags could be installed by troops in the field. Inspecting equipment would consist only of the relatively simple kits needed to prepare the casts. Complex and sensitive systems like the SEM could be kept in laboratories where they would be easier to calibrate and maintain. Finally this sort of intrinsic tagging would not require that data storage capacity be brought to the field. Since identification of a single surface tag might easily involve 10^6 - 10^8 pieces of information, tags to be compared during a single inspection would involve data storage on the order of 10^{12} - 10^{14} bytes. The information could be handled in analog form in the field and digital comparison could be done with advanced computer systems in the lab.

Conclusion

The variety of proposed tagging technologies and the research efforts on them in the national labs and the universities are encouraging signs that a treaty limiting nuclear weapons in Europe will be backed by a workable verification scheme. Development of tagging technologies has reached a stage when the research community must ask the larger scientific, military and political communities to examine proposed tagging schemes for fatal flaws. By "red teaming" tagging technologies, arms control verification can avoid over-reliance on sophisticated technologies which are expensive and do not work well in the field, as well as spotting bugs in simpler, cheaper tagging scenarios. The time for public debate on tagging technologies is now!

Acknowledgements

The author wishes to thank Dr. Alex Devolpi of Argonne National Laboratory for helpful discussions of this paper including several unpublished communications.

References

1. A good overview of verification of a CFE Treaty is found in Russell Maxfield and Arend J. Meerborg, "Two Ways to Verify a CFE Accord," *Arms Control Today* 19, 18-21 (August 1989).
2. Glitter paint tags are described in Christopher Joyce, "The Telltale Tags That Help to Trust and Verify...Or Not," *New Scientist*, 48 (July 29, 1989).

Symposium: Plasma Physics, Public Policy, and the Future of Fusion

The following four papers form another of our sets of papers based on invited sessions at APS meetings. This set is based on a session held on 13 November 1989 at the annual meeting of the division of plasma physics in Anaheim, California. A manuscript was not available for the fifth paper in the session, by Mark Crawford of *Science Magazine*. The session was chaired by Stephen O. Dean, President of Fusion Power Associates.

Editor

Introduction

Stephen O. Dean

A fusion power plant can be operational early in the next century. However, a firm national commitment is necessary to accomplish that goal.

Extraordinary progress in fusion has been made during the past twenty years. The plasma conditions (temperature, density, confinement) necessary for the substantial release of fusion energy have been systematically approached (Figure 1). That progress was achieved in facilities committed in the 1970s. During the 1980s, the fusion budget has declined to about one-half of its 1980 level. No major new facility has been constructed since the TFTR in 1976. It is time to commit to a policy that will lead to practical fusion power.

The goal of the fusion program should be to demonstrate early in the 21st century that fusion is a safe, reliable, environmentally-attractive and economically-competitive energy source. Strong national management will be required to accomplish this goal.

The strategy that should be followed to achieve this goal has four essential elements:

- continue to improve the science and technology basis for practical fusion applications;

- construct a U.S. magnetic fusion burning plasma experiment;
- participate in the design, construction and operation of an international fusion engineering test reactor; and
- construct a U.S. fusion power demonstration facility that produces net electrical power and provides the basis for commercial power plants.

The proposed strategy is shown in Figure 2.

The budgets required depend on the schedule desired. If the U.S. magnetic fusion budget does not increase beyond its current level of \$300-350 million, then the schedules would surely slip. The amount of annual funding required for technology development depends critically on the planned schedules for the test facilities and the fusion power demonstration facility.

The author is President of Fusion Power Associates, Professional Drive, Suite 248, Gaithersburg, Maryland 20879. He presented this statement to a subcommittee of the U.S. House Committee on Science, Space and Technology, on 4 October 1989.

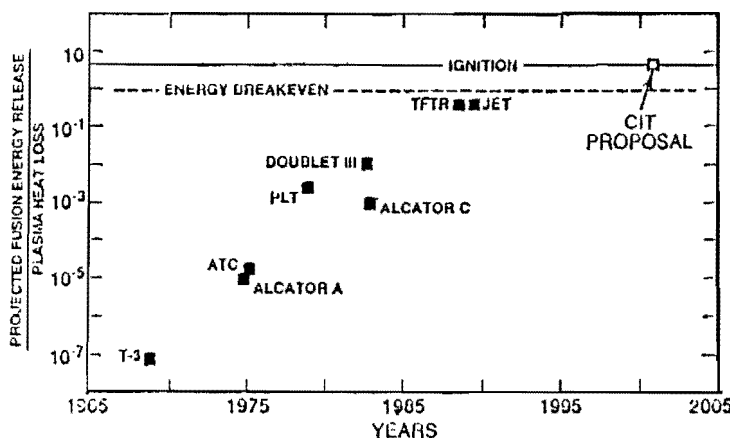


Figure 1. Progress in Achieving the Condition Required for Fusion Power.

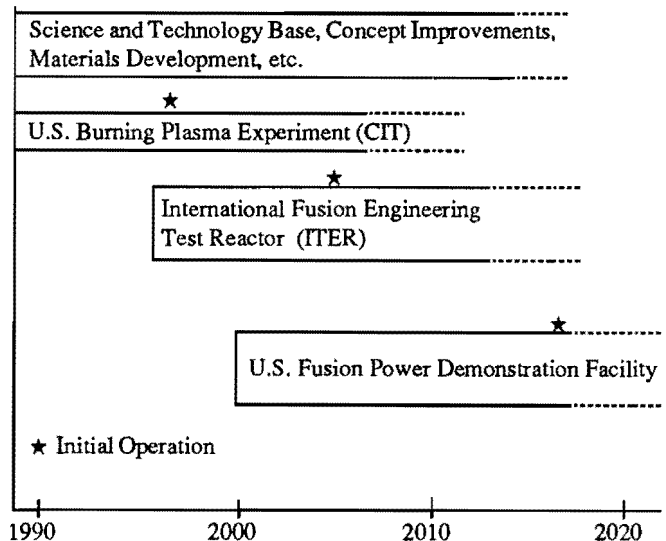


Figure 2. Schematic of U.S. Fusion Energy Strategy

The Impact of Environmental Issues on Public Support for Fusion Research

Jan Beyea

Support for fusion power research is very weak in the environmental community. Before I offend fusion supporters though, let me say that I do support fusion research, although not necessarily at the level of 350 million dollars per year, at which the program is now funded. As a physicist, I think the possibility of reaching ignition is terribly exciting intellectually. But as an environmental professional, I have to question a funding level that is ten times higher than federal research expenditures on photovoltaics and four times higher than federal expenditures on all solar power (see USDOE Budget Highlights, Fiscal Year 1990, Office of the Controller, Washington D.C., 1989). Concerns about the size of the fusion budget seem to be rather common with others too.

There are two indications of a narrowing support base:

(1) Fusion power is supposed to have environmental benefits. Yet, the recommendations of the environmental community to President Bush when he took office was to zero the fusion budget. True, none of the larger environmental groups paid much attention to this part of "Project Blueprint," prepared for the incoming president, and the process wasn't very open (I heard about this recommendation too late to influence it). Nevertheless, this action is an indication that the environmental community sees better places to put federal dollars and has, as I shall discuss below, real questions about the current fusion power proposals.

(2) For the last few months, as part of a National Academy panel that is reviewing the federal energy R&D program, I have had the opportunity to meet with dozens of engineers and scientists working in the energy field outside of fusion. When the subject of fusion comes up, there is often laughter. It may be possible to convince Congressional staff that investments in fusion make a lot of sense, but if the fusion community can't convince professionals outside the field, it won't be long before these negative views spread to Congress.

The loss of support can be attributed to the zealous overstatement of claims for fusion. People have heard claims of miracles before, for instance in regard to nuclear power, and have become skeptical.

The problems facing fusion power are twofold. The obvious acknowledged problem is how to dispose of the radioactive material produced by stray neutrons. The unacknowledged problems are more numerous.

The first concerns the production of nuclear weapons. Fusion power plants based on the deuterium-tritium (D-T) cycle will make great breeders of weapons-grade material. Fusion scientists swear they will never do such a thing, but they will be under great pressure to use this neutron-rich process to make weapons. D-T fusion has many of the same proliferation problems that are associated with fission reactors.

Secondly, there will be a temptation to use neutrons from fusion to make fuel for conventional fission reactors. Thus, fusion may not offer an escape from fission after all.

Cost is another problem. Supporters of new technologies have tended to underestimate cost, sometimes by as much as a factor of ten. There is the suspicion floating around that the same may be true for fusion power.

Finally, competition is a problem. Developments in other energy technologies are tending to eclipse fusion.

What developments are taking place in other energy fields that drain support from fusion power? Energy efficiency, most certainly, from superwindows to highly efficient jet engines. Idiot-proof fission reactors are another. Even the moribund nuclear community is

generating some excitement (outside of environmental circles, at least) with the possibility of these melt-down-free reactors, which rely on passive safety devices rather than pumps and diesel generators.

In photovoltaics the cost of PVs has dropped so much that even electric utilities are looking on them with favor as peakers for the late 1990s. It doesn't take too many calculations to recognize that peaking units can be turned into baseload suppliers with an economic penalty of about a factor of three (e.g., by generating hydrogen while the sun is shining and burning the hydrogen when it isn't). PVs will soon be able to produce base load power at a rate that is only five times higher than current costs, and the trend line for photovoltaic costs is dropping rapidly. It might take covering a land area the size of the interstate highway system, but the prospects for PVs over the time frame it will take to develop fusion look excellent. Certainly, it is hard to say that the prospects for fusion are any better.

CO₂-free coal has been promised by the coal intellectuals. Meyer Steinberg at Brookhaven has a working model of a plant that strips the hydrogen from coal to be used for energy purposes, leaving the carbon to be sequestered. Although a large energy potential is lost this way, the costs of coal are so cheap that the process may well compete with fusion for a very long time, even should fusion power prove practical.

Fusion power will have serious acceptability problems. Radioactive waste from neutron capture is the more serious one. Because of skepticism generated in the public mind by overstatements made by fission advocates, the public is unlikely to buy the argument that fusion radioactivity is okay. The issue of breeding fissionable plutonium or uranium for nuclear weapons and reactor fuel is also going to raise considerable public concern.

If the fusion community is to survive, it will be necessary to face up to those aspects of fusion that are perceived as problems. Rhetorical response may work in the short run, but improving the fusion program to respond to the concerns will be needed in the long run.

Facing the problems requires cleaning up the arguments and recognizing successes in other fields. The arguments against fusion programs must be heard. Advocates of fusion must talk to their enemies, not just their friends. They must not promise more than they can deliver to head off yearly budget cuts or to get increases. For instance, they must consider what would happen if the Compact Ignition Tokamak doesn't work? Won't that mean the final blow to fusion credibility?

Most importantly, the neutron problem with D-T fuel must be faced.

H.P. Furth in a statement before the Subcommittee on Investigations and Oversight, House Subcommittee on Science, Space and Technology, 3 Oct 1989, said, "The use of D-T fuel serves to increase fusion power production by a factor of about 300 relative to deuterium fuel. Correspondingly, there are significant incremental costs associated with neutron shielding, remote-handling equipment, and tritium-handling systems" Given the upswing in environmental concerns, I do not think the D-T cycle will ever be a politically practical energy source.

There do exist fusion cycles in which neutrons are scarce, for example cycles that make use of He³. Yet those cycles are never shown as part of the official vision of fusion. Clearly, delaying commercial fusion power to a second generation cycle will push back

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