How far ahead is the U.S.S.R. in developing strategic ABM defense?

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One of America's leading defense scientists, Dr. Lowell Wood of Lawrence Livermore National Laboratory, noted in an interview in the January issue of *Defense Science and Electronics* that the Soviet Union is spending an "order of magnitude" more on beam weapons research and development than the United States. Other leading U.S. weapons scientists, whose work is focused on advanced X-ray and nuclear lasers, have privately revealed that this disparity in funding levels is even larger in specific, crucial basic plasma and atomic physics research areas that are key to realizing the most advanced forms of beam weapons.

In terms of applied military beam weapons research, the following Soviet developments have been reported from publicly available sources, primarily *Aviation Week:*

- The U.S.S.R. is currently operating a large, multi-megawatt, prototype laser beam weapon experiment.
- The Soviets have been perfecting for a number of years a large, multi-terawatt particle beam weapon system.
- A large variety of systems has been tested by the U.S.S.R. in a full range of beam weapon military applications which include: a) laser imaging and radar, b) laser anti-satellite systems, c) laser anti-ballistic missile (ABM) systems, d) laser anti-tactical missile systems, e) particle-beam terminal ABM weapons, f) plasma beam weapons, g) microwave beam weapons, h) macroparticle beam weapons, including electromagnetic rail guns and plasma accelerated macroparticles, i) laser underwater detection of submarines, and j) laser dispersal of fog and cloud cover.
- Reported successful Soviet tests include: a) a laser beam interception of a ballistic missile, and b) deployment of operational laser weapon systems on Kirov-class battle cruisers for tactical missile interception, remote sensing, and weather modification.

Fusion Energy Foundation scientists have determined that besides the outstanding quantitative disparity between the United States and the U.S.S.R. beam weapon programs that there exists a more significant qualitative disparity in favor of the Soviet Union. The three causes of this qualitative U.S. deficit are:

1) A stronger Soviet commitment to traditional concepts of war-fighting, one which recognizes the necessity of developing effective ballistic missile and civil defense capabilities. This has resulted in a higher Soviet priority for directing scarce scientific resources into these areas.

2) A larger, more diverse base of fundamental scientific research relating to beam generation, beam propagation, and theoretical plasma physics. A key element in this broad-based program is the Soviet controlled thermonuclear fusion (CTR) research and development program.

3) A methodological approach to mathematical physics which emphasizes the Riemannian continuum mechanics and analytical methods as opposed to the numerical, kinetic, statistical approach which dominates in the West.

Soviet plasma physics program

As early as 1960, U.S. observers remarked on the astounding emphasis accorded plasma physics and controlled fusion research in the Soviet Union. Don Kerr, one of the most respected American plasma physicists, summarized his assessment of the future of the Soviet effort (and implicitly replied to some American skeptics):

> We find that the recent rate of progress [in the Soviet plasma physics program] has been little short of amazing. This rapid growth suggests that if they considered it important enough, in the next few years the Soviets could outstrip the West in a field such as controlled thermonuclear fusion.
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> From the beginning of the renascence of Soviet intellectual effort in the early 1930's, the problems of plasma physics have challenged some of the best Soviet physicists, particularly theorists. As a consequence, a number of the very best Soviet physi-

cists now have considerable experience with plasma problems, are in positions of importance, and are highly respected in the scientific community. The position of plasma physics in the West is not as favorable, but is improving rapidly as more people enter the field.

There are many top-grade Soviet scientists working in plasma physics who are also contributing actively to other frontier fields such as field theory, high-energy physics, solid-state physics, nonlinear theory, and the many-body problem. The West has no more, if even as many, top-flight people of such versatility actively working in plasma physics; but this situation is also improving, as indicated above. . . .

There is exceptional Soviet strength in the fields of mathematical statistics and nonlinear differential equations, and their application to physics and technology. The strength rests upon Soviet leadership in these fields of mathematics, extending back over a period of many years.

The Soviet work, of which the beginnings were studied by Kerr, grew into the world's largest research effort in plasma physics over the next decade. Almost without exception, every significant advance in plasma physics and engineering has originated as a result of that research. The tremendous success in engineering terms of the U.S. plasma physics work, especially in controlled thermonuclear fusion, should not be confused with the origins of most of the ideas that were only successfully developed here: They almost all bear a "Made in U.S.S.R." trademark.

The most outstanding of these ideas are:

1) **The tokamak:** The mainline plasma confinement device for research in CTR is the donut-shaped magnetic configuration invented by the Soviets in the late 1960s. This device is the primary line of fusion research in every country of the world pursuing that research today.

2) **The tandem mirror machine:** The backup device for nuclear fusion research—an open, linear machine called the tandem mirror—was also the product of a Soviet laboratory. This machine is being actively researched in the United States, the Soviet Union, and Japan.

3) **The radiofrequency quadrupole accelerator:** The most successful device for the generation of high-energy, large-current particle beams is based on a series of Soviet experiments conducted in the early 1970s.

4) **Pulsed power MHD generators:** The concept of using explosive energy for the compression of magnetic fields to produce inductive electricity (one of the few known ways of producing the intense pulses of electricity needed for beam weapons) was arrived at independently in both the Soviet Union and the United States. However, in the 25 years since then, the vastly larger Soviet program has produced almost all the scientific and technological developments required for both civilian and military applications.

5) **Theory of strong plasma turbulence:** Almost all the problems of beam generation, stability, propagation, and kill-effectiveness fall into the area of plasma physics called strong plasma turbulence. The Soviets have pioneered almost all the important ideas and techniques in this field, under such scientists as B. Kadomtsev, Yu. Klimontovich, N. Tsytovich, and S. Zacharov.

Of course, the Soviet co-invention of the laser (by N. Basov), their leadership in ionospheric physics, their work in advanced accelerator techniques (proton cooling by G. Budker, for example), their massive program of experimental work in the propagation of beams through non-ionized gases, their innovative work in plasmoid physics (plasmoids are self-confined blobs of plasma) are all evidence of a very large, broadly based effort in plasma physics research. There is simply no corresponding comparable body of work in the United States.

Soviet methodology in plasma physics

Contrary to accepted opinion, a host of fundamental scientific problems is raised by physical phenomena occurring in the energy-dense regimes necessary for beam weapons. To solve these problems demands more than the engineering and industrial skills for which the United States is justly famous; it requires a group of scientists and an educational establishment capable of generating new knowledge.

For more than 100 years, it has been the case that all important scientific discoveries have come from a relatively small base of work in the classical German school of mathematical physics. Science has been working from the ideas of the German classical school of mathematical physics—Leibniz, Gauss, Weber, Riemann, and their successors. The major discoveries of the past period all derive from the results and method of these scientists. While this method remains the dominant school of research and education in the Soviet Union, this method has been attacked in the West with increasing success over this period by the British or Newtonian school, with the result that the most essential tools of continuum mechanics and Riemannian global geometry are used in the West in only the only the most rudimentary way.

Newtonian versus Riemannian method

The divergences between these two approaches are central to the question of the science of the beam weapon:

1) The question of energy. Conventional Newtonian or Maxwellian physics defines energy as an internally measurable, conserved, scalar quantity. The role of energy in the evolutionary properties of various beam weapons systems makes this assumption of scalar energy measure untenable. Newton's original opponent on the question of the

nature of energy, Gottfried Leibniz, defines a dynamic, directed concept of energy much more adequate to deal with the nature of energy than the Newtonian atomic one, but the mainstream of Western science has rejected the Leibnizian formulation. The experimental evidence already gathered from high energy plasma physics poses a fundamental challege to this Newtonian idea.

2) The direction of evolution in physical systems. The most fundamental assumptions of modern physics insist that changes with time in a physical system are the result of the summation of microscopic dynamics; particle-by-particle interactions "add up" to the global behavior of a physical system. As a consequence, the quality of this global evolution is statistical and random in a systematic way. Even the most avant-garde of the proponents of a so-called nonreductionist formulation of physics, like Ilya Prigogine, begin with this Newtonian fact. The behavior of high energy plasmas (like those in a beam weapon) overthrows this premise in a rigorous way. Beam weapon experiments present striking evidence of an inherently global kind of causality that directs the microscopic evolution of a physical system but is not reducible to microscopic interactions. This invariant quality is a negentropic, developmental direction to physical evolution that appears in a dramatic form in high energy beam weapons.

On the one hand, failure to recognize the fundamental scientific challenge posed by the new physical phenomena characteristic of beam weapons leads supporters of beam weapon development to underestimate the long-term economic and technological impact of beam weapon development. They fail to see the qualitative changes implied by the perfection of a technology based on a physical theory as different from conventional physics as the quantum mechanical revolution (and its technological descendants like lasers and transistors) was from the Maxwellian physics before it (with its technologies of electric motors, resistance lighting, and so on).

On the other hand, failure to recognize this fundamental challenge by opponents of beam weapons leads them to try to assess the scientific and technological feasibility of beam weapons on the basis of totally inadequate physical considerations. The attempt by a physicist who does not understand the implications of these new experimental results in plasma physics to project the behavior of a beam weapon is ludicrous—and disproved as imperiously by the existence of these new phenomena as were the theories of the impossibility of ballistic missiles 30 years ago.

The debate implicit in an examination of the scientific basis adequate to describe beam weapons has been at the center of an intellectual and policy fight up through and immediately following World War I. This debate pitted the followers of the Newtonian atomistic tradition against the followers of the Leibnizian hydrodynamics school. The final round of that fight in the West was concluded when Bertrand Russell conducted a successful attack on the two most important modern representatives of the Leibnizian school, Georg Cantor and Bernhard Riemann. Russell identified the central nature of the Leibnizian school as its commitment to the "Platonic" idea of nested manifolds connected by a negentropic invariant, and against this he defended the radical Newtonian idea, later formulated in his *Principia Mathematica*, that all phenomena are reducible to fixed, atomistic (and logical) structure.

This debate, now largely unknown among Western physicists, is not an academic question.

On the one side, the information most subject to immediate classification are those results of Riemannian physics that threaten the intellectual hegemony of the Newtonian idea. In case after case, the methodological and mathematical tools of the Riemannian school have been kept hidden by the supporters of the Newtonian school (we review the most egregious case below). On the other side, the Soviet Union has based large parts of its physical research on beam weapons on an at least implicit understanding of the hydrodynamic method. The education given Soviet physicists, the design of experiments, and the originality of Soviet theoretical work in continuum mechanics are all evidence of a generally recognized methodological divergence between Western and Soviet science. What is not generally understood is that this methodological difference derives from the fact that the mainstream of Soviet science is in the Riemann-Leibniz tradition, while the mainstream of Western science is in the Newtonian one.

The defense of the Newtonian position in this fight reached absurd proportions in 1976, when British military intelligence classified the experimental work of a Soviet physicist! Leonid Rudakov, the director of the Soviet electron beam fusion research program (and a leading contributor to the Soviet military beam weapon program and inventor of several critical technologies in electron beam production), visited several U.S. weapons laboratories in summer 1976. His lectures at Los Alamos National Laboratory and Lawrence Livermore National Laboratory created great interest among American scientists, because he addressed one of the several central problems in the interaction of high energy beams with matter—the production of soft X-rays. This topic, although at a lower level of elaboration, was studied in the United States and the results were classified. Rudakov presented new results, not previously known to the American researchers. At the instigation of the British military intelligence, Rudakov's lectures were immediately classified in the United States by the Department of Energy, and they remain classified today.