The explanation is quite similar to the explanation widely accepted for a common phenomenon in x-ray astronomy. In fact, the Illinois scientists say they were led to their theory by noting that a reasonable estimate of the total power emitted by the sources of gamma ray bursts coincides well with the total power of x-ray sources. The x-ray sources known in binary systems are thought to be relatively young, however, and are not plentiful enough to account for the number of gamma bursts observed. But older neutron stars in binary systems should be much more abundant.

Another theory for gamma ray bursts that originate within the galaxy, proposed by Floyd Stecker and Kenneth Frost at Goddard Space Flight Center, is that giant stellar flares in white dwarf stars produce the bursts. Noting that the energy and time structure of solar x-ray bursts are quite similar to those of the gamma ray bursts, Stecker and Frost see the x-ray bursts from the sun as a clue to what may be happening on a much larger scale. To be consistent with the observations, the giant flares would have to have 10^6 and perhaps 10^{10} times as much energy as a strong solar flare. Since energy is stored in the magnetic fields of a star, Stecker and Frost propose that white dwarfs, which have intense magnetic fields with values as high as 10^7 gauss, are the source.

In exchange for the requirement of very large energies, a theory by Ken Brecher and Phillip Morrison at the Massachusetts Institute of Technology, Cambridge, proposes that modest but directional stellar flares produce the gamma ray bursts. The price they pay for the lower total energy in each flare, however, is that the flares must be much more frequent than in the previous theory. Brecher and Morrison propose that directed beams of electrons stream out of the sun, hit optical photons, and convert them to gamma

Speaking of Science

Breeder Program: Bethe Panel Calls for Reorientation

The soundness of technical decisions made by the Atomic Energy Commission in its breeder reactor program have long been a subject of internal debate within the nuclear power community. Those who disagreed with Milton Shaw, director of the breeder project until his resignation in June 1973, frequently if privately complained of the lack of high level review of what is still the United States' largest energy research and development effort. A new report, the first independent assessment of the program commissioned by the AEC in many years, gives substance to those dissenting views and proposes a major reorientation of the program's goal and procedures while reaffirming the importance of the breeder as a future energy source.

The report recommends, among other things, redesign of the two major facilities in the breeder program—the Fast Flux Test Facility (FFTF) now under construction in Hanford, Washington, and the demonstration breeder reactor to be built in Oak Ridge, Tennessee. It calls for an accelerated research program on advanced nuclear fuels and for a change in the management policies affecting the conduct of the research. The report appears to have had sufficient impact on the AEC to cause some last minute changes in the agency's proposed budget for next year (fiscal year 1975), which is now in preparation.

The report is the work of a panel headed by Hans Bethe of Cornell, a well-respected nuclear physicist.* It originated in one of a series of workshops on major energy options which were financed by the AEC to assist AEC chairman Dixy Lee Ray in preparing an expanded energy research and development plan for President Nixon. The Bethe panel considered long-range energy sources and, on the basis of a possible shortage of uranium within 20 years, concluded that advanced nuclear power reactors of either the fission or the fusion type were urgently needed. They reendorsed the liquid metal–cooled fast breeder reactor (LMFBR) as the most logical first choice, but criticized the limited progress to date and the present directions of the program.

The planned demonstration reactor, for example, will be neither an economically competitive source of electricity nor an effective breeder with its present design and intended fuel. The major advantage of breeder reactors is that they produce more fuel than they consume, thus, in theory, freeing the nuclear power industry from its present dependence on high grade uranium reserves and breeding enough new fuel to supply additional reactors as needed. A measure of breeding effectiveness is the doubling time, the period required to double a reactor's initial inventory of fissionable material; doubling times of 10 years or less have generally been considered necessary to meet a demand for electricity that now doubles every 9 years. In contrast, the panel estimates a doubling time of between 30 and 60 years for the demonstration plant. A reactor of such low performance, they conclude, is not a useful breeder at all.

One source of trouble, according to the report, is that the goals of the breeder program have been somewhat confused. One objective, an economically competitive reactor, the panel thought could best be left to industry. A second and truly national objective is to develop a reactor with high breeding capability and low fuel requirements. It is this second goal, the panel suggests, which has been lost sight of in recent years and which they recommend as the focus of the AEC's redirected efforts.

The panel goes on to point out that the uranium oxide fuels currently being developed will probably not yield satisfactory doubling times even when pushed to their theoretical limit. Oxide fuels turn out to capture more low energy neutrons than originally expected, and the steel alloys used to clad all nuclear fuels swell under heavy neutron irradiation, thus requiring that unproductive space be

* Other members of the Bethe panel were Walter Zinn, one of the pioneer nuclear reactor designers (now retired); Chauncy Starr, head of the utility industry's Electric Power Research Institute; Milton Levenson, also of the institute; and Sol Buchsbaum, Bell Laboratories. The complete series of workshop reports—covering fossil fuels, short- and long-range nuclear options, and institutional problems—together with a lengthy overview article and other material is available as the *Report of the Cornell Workshops on the Major Issues of a National Energy Research and Development Program* and can be obtained from the Laboratory of Plasma Studies, Cornell University, Ithaca, New York 14850.

rays. Because the gamma rays would be oriented in only one direction, the energy needed to trigger a Vela satellite would be much less than if they were spreading out equally in all directions.

Clearly the most novel theory of gamma bursts has come from Jonathan Grindlay, at the Center for Astrophysics, Cambridge, Massachusetts, who proposes that a rain of small iron pellets generated by pulsars falls on the solar system, and that the pellets are broken up by sunlight to produce gamma rays. If little iron grains about 1 mm in diameter were traveling toward the solar system at relativistic speeds, they would perhaps break into several blobs or melt into droplets at a distance 30 times the orbit of Pluto. As sunlight grew more intense, the material would break up further into individual atoms, and as they ionized, cascades of x-rays would be produced. At about the mean orbital diameter of Pluto most atoms would radiate, and because of their relativistic speeds the radiation would be shifted by the Doppler effect into gamma rays emitted in a small cone. If the cone, which Grindlay expects to have a diameter comparable to three times the moon's orbit, were pointed at the earth, the Vela satellites would be triggered. Grindlay points out that a simple test of this theory would be to see if any distant satellite, such as the Pioneer satellites to Jupiter, also detected a gamma burst.

Other possible explanations for the unique gamma ray bursts have also been discussed. Reuven Ramaty, at Goddard, has proposed that the source may be an extragalactic neutron star, and one jocular individual has even proposed the "catastrophe theory," namely that the bursts do indeed come from nuclear weapons, perhaps as other civilizations detonate themselves. The puzzle is not yet solved, and the data are coming in so slowly that astronomers may be vexed for a good while to come.—WILLIAM D. METZ

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left within the breeder core to accommodate the swelling. Both effects raise the doubling times that can be achieved. Fuel in the form of uranium carbide or perhaps uranium nitride, although these forms have not been well studied, has a higher potential, and the panel recommends a major new effort to develop them and to find improved cladding alloys. So urgent is the need for irradiation experiments with these advanced fuels, the panel believes, that they suggest the AEC attempt to borrow space in French and British breeder reactors until the FFTF is complete. (The AEC says it has contacted the British and the French, but with a comfortable lead on the U.S. program they showed no interest in helping us catch up.)

To facilitate the research program, the panel recommends dedicating the FFTF to testing advanced fuels and suggests design changes to make it a more flexible test reactor. The demonstration reactor, on the other hand, should be frankly oriented toward commercial feasibility by giving industrial contractors a relatively free hand in its design, even at the risk of delaying its construction a year or two. By uncoupling the FFTF and the demonstration plant the panel hopes to more closely approach both the commercial goal and the national goal.

The panel report implicitly criticizes past management policies within the breeder program and calls for the AEC to tell its laboratories and contractors what to do, but not how to do it. The new director of the breeder program, T. A. Nemzek, told *Science* that he is in full agreement with such a policy and that he favors encouraging initiative in and delegating more authority to the field. "We are making decisions here that should be made elsewhere." The intended changes may thus presage an end to the long and often bitter conflict within the nuclear community over the management of the reactor program and a new measure of independence for the AEC's national laboratories.

Nemzek also agrees with the need to put more emphasis on the development of advanced fuels, although he is more optimistic about the potential for oxide fuels than is the Bethe panel. In any case, he intends to rapidly expand ongoing work on improved cladding and has inserted new money for work on carbide fuels into next year's budget. Nemzek does not believe that the breeder program needs to be greatly reoriented, however, and he defends the present approach of starting with a conservatively designed demonstration plant and gradually upgrading its fuel. Nonetheless, a review (which Nemzek describes as thorough) of the demonstration plant design is under way with industrial participation.

The urgency of the breeder program depends strongly on how much uranium is available, and the remarkable fact is that neither the AEC nor anyone else has more than questionable estimates of available reserves. The Bethe panel raises a number of questions about the uranium supply situation, including: How much intermediate grade ore (extractable at $10 to $30 a pound) is there? Is it feasible to mine low-grade ores, considering the large environmental impact this would have? Should import of uranium be permitted? In view of the priority of the breeder program, the Bethe panel believes it important to get better answers to these questions than are available now.

As far as fusion is concerned, the panel cautioned against overoptimism and recommended a deliberate approach. A decision to build a large-scale test reactor of the magnetic confinement type should only be made, the panel suggests, after considerable experience with smaller machines, and not as early as next year. In laser fusion, the panel recommended more basic work with small lasers on the interactions of laser beams with plasmas. They also suggested exploring the possibilities of electron beam fusion, since efficient, high energy electron beams already exist.

The sweeping nature of the Bethe panel's recommendations and their sharp enumeration of technical oversights within the breeder project suggest the need for more frequent independent assessments of the AEC's major programs. In the early years of the agency's existence, prominent university and industrial scientists regularly undertook such reviews. In the 1960's, however, the agency tended to seek its own counsel and became more defensive in its role as a promoter of nuclear power. The Bethe panel's report and the agency's reaction to it may indicate that a return to earlier practices has begun. Bethe himself believes "the academic community should return to an active advisory role." And Nemzek told *Science* he thinks it is a healthy trend and is looking for means to assure more overseeing of all facets of his program.

—ALLEN L. HAMMOND