The BPX cancellation has also led to some rethinking of plans for ITER. A joint project of Europe, Japan, the United States, and the Russian Republic now in the first year of a $1 billion, 6-year engineering design phase, ITER was originally scheduled to make use of data produced by both BPX and what is now TPX. Physicists had hoped to use ITER "not to learn, but to confirm" data from these facilities, says Robert Conn, chairman of DOE's fusion advisory panel and a plasma physicist at the University of California at Los Angeles. Without data from BPX, however, fusion researchers say they will have to study ignition physics in ITER for much longer than originally planned—a minimum of 6 to 10 years, instead of 5 to 6. This delay "compromises" ITER's pace and scope and increases the technical risk of meeting the long-term DOE goals, Conn says.

In an effort to soften the blow on ITER, Conn's panel has recently proposed that DOE consider a "complementary" program that would lighten the burden on ITER by producing important data first. The top priority, Conn says, would be a 14 MeV neutron source for the design and testing of "low-activation" materials for lining confinement chambers. Such materials are less likely to become radioactive under the heavy neutron flux produced by fusion reactions. This facility is likely to be expensive, however, perhaps costing as much as $600 million. And although DOE has placed such a facility on its timetable, it has not proposed how it would pay for it.

Budgetary uncertainties, in fact, continue to cast a cloud over the fusion community's plans. Researchers have taken heart from DOE's official commitment to its fusion timetable (see chart), drawn up 2 years ago and since adopted as part of DOE's National Energy Strategy. And they are delighted by a promise from Happer to increase the fusion budget by 5% a year above inflation for the next 5 years. But outside critics are quick to point out that Congress has dashed similar promises in the past. William Kay, a Northeastern University specialist on the politics of technological development, writes in the Winter 1991 *Issues in Science and Technology* that a combination of long time horizons, enormous costs, and technological uncertainty will cause fusion's financial demands to outstrip the program's available funding in the years ahead. "The program is already dying a slow budgetary death," he writes. "Since we are not prepared to do the work and bear the burdens to make fusion energy a success, it is better that we not go on." Fusion researchers now must prove that their new-found cohesion can confound such gloomy prognostications. ■ DAVID P. HAMILTON

A Rocky Watch for Earthbound Asteroids

A NASA study is seeking ways to avert collisions—but participants argue about which asteroids to watch for

IT SOUNDS LIKE A SCENE IN A SCIENCE FICTION novel: Nuclear weapons experts meet with top astronomers behind closed doors to seek ways of protecting Earth from cosmic catastrophe. The cast of characters in this opus includes nuclear weapons designer Edward Teller and some 70 other scientists, and the plot devices are a global telescope network, Star Wars technology and another jarring reminder of the cold war, the neutron bomb (see box). Yet those were the elements of a January meeting at Los Alamos, convened by the National Aeronautics and Space Administration (NASA). It was the latest in a series of get-togethers that, beginning in 1990, have addressed the ultimate environmental hazard: the conceivable destruction of civilization by the impact of a comet or asteroid.

Evidence that this is not science fiction can be found in scores of impact craters around the world, in the explosion of a large meteor or small comet fragment over Siberia in 1908, and in the global catastrophe that may have wiped out the dinosaurs. Still, your memory of science fiction might lead you to think that scientists would quickly unite in the face of this newly recognized threat to the species. Not quite. The January meeting attempted to patch a schism that had become apparent soon after NASA, prompted by Congress, began the study. Two committees set up by NASA—one largely composed of astronomers concerned with detecting the threatening objects and the other of space technology experts concerned with intercepting them and averting disaster—were scheduled to report consensus recommendations to Congress by January. But a dispute arose between the chairmen of the two groups about the size of the objects on which the detection effort should focus and the technologies required. The result: The reports have been delayed at least until this month.

Both the detection committee's chairman, planetary scientist David Morrison of NASA's Ames Research Center in Mountain View, California, and his interception counterpart, NASA associate director for space technology John Rather, deny any disagreement. But interviews with committee members and correspondence seen by *Science* reveal a sharp divergence of views. At its heart is the initial conclusion of Morrison's committee, as stated in a preliminary draft obtained by *Science*: "The greatest risk from cosmic impacts is associated with asteroids a few kilometers in diameter." The draft goes on to recommend the construction of a $50 million global detection network called Spaceguard, consisting of six 100-inch telescopes fitted with charge-coupled devices. That technology would give 20 years' warning of asteroids bigger than about 1 kilometer across—time enough to divert them, perhaps with nuclear warheads (see box).

When Rather learned about the detection committee's recommendation last fall, he protested to Morrison that it amounts to turning a blind eye to "a whole class of [smaller] objects having destructive capa-

Slight blow. *Trees downed at Tunguska.*

bilities ranging from kilotons to gigatons." The detection effort, he argued, should extend to objects as small as 50 meters—something that would require the kinds of innovative and untested technologies originally conceived for the Strategic Defense Initiative. But Morrison has so far rejected Rather's arguments out of hand.

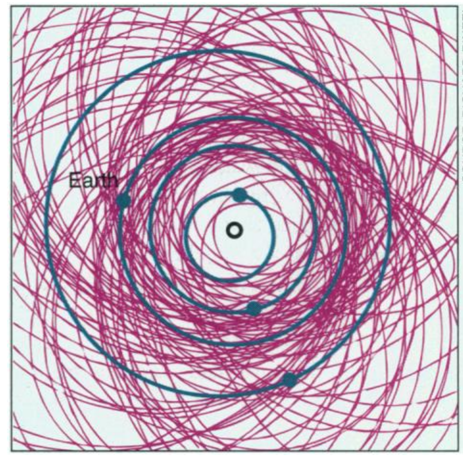
One reason the dispute has been so difficult to resolve is that it is fed by sharply differing assessments of the impact hazard. Based on the number of impact craters on Earth—some 130 have been identified so far—and the tangle of asteroid orbits known to cross the Earth's own path (see illustration), Morrison's committee has calculated that the average interval between impacts of kilometer-size objects is about 500,000 years. Smaller objects strike the earth much more often: In the size range of 50 to several hundred meters the Morrison group estimates that one impact takes place every 200 to 300 years. The most recent may have been the 1908 explosion of a meteor or comet fragment over the Tunguska River in Siberia. The object was probably no more than 50 meters across, but the energy release was the equivalent of a 15-megaton nuclear bomb.

Still, that's trivial compared with the Morrison committee's calculations for a kilometer-wide impactor: an energy release equivalent to a million megatons or more of TNT, sufficient to wipe out a quarter of the world's population. And according to the committee's calculations, a few big bangs outweigh many smaller ones. The group puts an individual's annual risk of death from a global impact catastrophe at about 1 in 2 million, compared to 1 in 30 million for the risk of dying in a limited, Tunguska-type disaster. If the assumptions underlying the calculations are correct, the prudent thing might be to concentrate on the larger objects.

But some space scientists question those basic assumptions. Astrophysicist Victor Clube of Oxford University and his colleagues think small impactors tend to come from disintegrating comet nuclei, which might gradually shed many pieces 50 to 500 meters across over the course of a century or two. In that case these smaller objects might be more abundant than is usually assumed, and impacts like Tunguska might come in swarms. Last year, Clube made his worries clear in an open letter to Morrison. As he explained to *Science*, "I'm very concerned that insisting that Tunguska events come singly could be a grave mistake. The effects of a swarm impact could be anything but local."

Morrison calls Clube's ideas a "minority view," but they have their supporters in both Rather's and Morrison's own committees. A differing assessment of the risk, however, isn't the only thing leading Rather and his supporters to stress the danger from smaller objects. Even if Tunguska-sized events are a lesser danger than the massive impacts Morrison and his colleagues are focusing on, they would still be a sizable menace—and Rather (who would not be interviewed for this article) is said to think that if spotting them early is at all feasible, the detection committee should recommend ways of doing so.

Early detection of Tunguska-sized bodies is no easy trick. As astronomers have already learned, such objects can sneak up quickly. In January of last year, for example, a 10-meter asteroid came within 170,000 kilometers of Earth—half the distance to the moon—just 12 hours after astronomers at the University of Arizona spotted it with the 35-inch telescope at Kitt Peak.



Dodge city. *Orbits of 107 near-Earth asteroids—perhaps 5% of the total.*

Doing very much better would take some innovative technology, as Rather made clear in a letter to Morrison late last year. He urged that the detection report mention a "passive infrared detection system in space using DOD/DOE derived technologies" and a "super-power radar using new free electron laser technologies." Such ideas, according to committee members, were originally developed for Star Wars, and their details are classified—a fact that seems to account for some of the irritation in Morrison's response. "I am personally confused by your style of pulling secret or ill-defined ideas out of a hat and expecting anyone to take them seriously," he wrote.

But the key issue may turn out to be practicality. As committee member Richard Binzel, a planetary scientist at MIT, points out, "We can have a system that could detect the larger objects—the globally threatening ones—for a modest cost of tens of millions of dollars. If we go down to smaller objects, it becomes orders of magnitude more expensive." As a result, Binzel, along with other insiders, thinks Morrison's more modest scheme is likely to come out on top.

Whatever NASA's final recommendations, the United Sates may not have to foot the bill alone. The International Astronomical Union is studying the problem of asteroid hazards, and the former Soviet Union held an all-Union conference on the subject last October. Cosmic impacts, it seems, are everybody's problem. ■ ROBERT MATTHEWS

Robert Matthews is an Oxford-based journalist who covers science for The Sunday Telegraph *in London.*

Giving a Nudge to an Asteroid

While some of the scientists deputized by NASA to examine the risk of rogue asteroids wrangle about the best way to detect threatening objects (see main text), others have been studying ways of deflecting such objects once they had been identified. As the presence of Lawrence Livermore Laboratory founder Edward Teller at the January Los Alamos meeting devoted to the asteroid hazard suggested, this group's thoughts are turning to nuclear weapons. And an oddball scion of the weapons labs has emerged as a potential instrument of salvation: the neutron bomb.

Astronomers and engineers present at the Los Alamos meeting say the committee, led by NASA associate director for space technology John Rather, is leaning away from simply blowing up a threatening asteroid or comet: The resulting fragmentation would yield a hardly-less-deadly swarm of city-killer objects, still on a collision course. Instead, the experts who convened at Los Alamos favor a kinder and gentler strategy: nudging the threatening object off course. And if you want to give an asteroid a good push without shattering it, the experts concluded, the neutron bomb looks like a promising candidate.

Neutron bombs, properly called enhanced radiation weapons, won notoriety in the late 1970s for their ability to kill people without knocking down a lot of buildings. Their blast effect is typically limited to a few hundred yards, but they emit lots of lethal neutrons and gamma radiation. Exploded off to the side of an asteroid, a neutron warhead would leave the object intact while the radiation would heat up the asteroid surface enough to vaporize it. The resulting jet of vapor would act as a small rocket, providing enough thrust—so the researchers calculate—to deflect the object from a collision course.

Sources say the interception committee won't be putting a firm price tag on a scheme for dealing with an impending impact. And it's not likely to recommend that neutron bombs be readied for launch on a moment's notice. Even so, not all the civilian academics present at the Los Alamos meeting are happy with this surprising new use for nuclear weapons. "I'm a little frightened by all this," says asteroid expert Tom Gehrels of the University of Arizona. "We could end up putting more danger in space than we started with." ■ R.M.