such as having an ongoing herpes virus or other infection, the amount of virus to which a worker is exposed, and the severity of the injury or exposure.

In May, Burroughs Wellcome announced a new study to test AZT in health care workers exposed to HIV in accidents on the job. The program is unusual because it tests AZT in people recently exposed to the virus who show no signs of infection. The company will monitor levels of viral proteins and antibodies in the workers for a year. The trial is a controlled, double-blind study, in which half the people who participate will receive drug and the other half will receive a placebo.

"Right away we knew that there would be some logistical problems with the company's study," says Julie Gerberding of the University of San Francisco and San Francisco General Hospital. First it will take at least several thousand participants to be able to determine whether AZT prevents infection because the actual infection rate is so low—estimated at an average of 0.4 to 0.5% among health workers who stick themselves with contaminated needles. Second, AZT kills bone marrow cells in many AIDS patients, a risk of toxicity that is unknown in healthy people exposed to HIV, but that could be greater than the risk of becoming infected. Third, it may become increasingly difficult to justify why only health care workers, and not people who fear exposure to HIV because of sexual contact or other means, should be allowed to participate in the study. Fourth, workers who suspect they are getting placebo instead of AZT may not comply with the terms of the study and obtain the drug by some other means.

As an adjunct to the Burroughs Wellcome study, the National Institute of Allergy and Infectious Diseases (NIAID) has just applied to the Food and Drug Administration for permission to give AZT to all health care or laboratory workers who have had massive exposure to HIV. Current thinking is that people exposed to large quantities of virus may be more likely to become infected and for that reason should receive AZT as a matter of course. Other workers exposed to smaller amounts of HIV are regarded as more appropriate for the Burroughs Wellcome study. "The question we will have to study is what constitutes a massive exposure versus a small one," says Deborah Katz of NIAID.

Gerberding tells workers who have been exposed to HIV what she would do in a similar situation. "Personally, if I had a needlestick and not a very severe injury [with HIV-infected material], I would enroll in the study and risk the toxicity," she says. ■ DEBORAH M. BARNES

Space Science Looks to the Future—Cautiously

The next decade could be exciting—if everything goes as planned; meanwhile, a new report looks to the 21st century

AFTER YEARS OF NEARLY unrelieved bitterness and frustration, American space scientists are beginning to speak in tones of (very) cautious optimism. At a recent symposium* celebrating the 30th anniversary of the National Academy of Science's Space Science Board, in fact, the speakers could point to a number of positive signs.

For one thing, the long hiatus in flight opportunities seems to be coming to an end. Thirty-one months after the catastrophic flight of the space shuttle Challenger on 28 January 1986, its sister ship Discovery is scheduled to fly on 4 September.

Furthermore, if that flight goes well—and *if* the revived shuttle program can attain its planned flight rate of 12 flights per year in the 1990s, and *if* the National Aeronautics and Space Administration's (NASA's) $9-billion budget continues its multiyear rise toward the $13-billion to $14-billion level promised by President Reagan, and *if* the agency's science and application programs continue to receive their traditional 20% share of the budget—then the coming decade should see space science missions being launched at a rate not seen since the 1960s, when Mariners, Pioneers, and Explorers went aloft at an average frequency of seven or eight per year. The list presented at the symposium by NASA's space science and applications head Lennard Fisk was a long one, ranging from the Hubble Space Telescope to the Galileo mission to Jupiter. All of these near-term missions are well along in planning and development, he said, and two-thirds of them are already funded. Indeed, he said, given the assumptions listed above, "all this is completely doable."

Of course, no one looking at that long chain of *if*'s can be very confident that Fisk's schedule will hold for long. Nonetheless, now that NASA has quit chasing after commercial payloads for the shuttle, and now that the Pentagon is planning to transfer most of its shuttle payloads to expendable rockets, the scientists can be reasonably hopeful that their own backlog of missions will eventually fly. And when that happens, they will even have a blueprint for what to do next: the 30th anniversary celebration also marked the official release of the Space Science Board's report on *Space Science in the Twenty-First Century*,† which has been in preparation for 4 years.

Outgoing board chairman Thomas Donahue of the University of Michigan emphasized two caveats for readers of the report. First, he said, the schedule implied by its subtitle, "Imperatives for the Decades 1995 to 2015," really means "the two decades or so *after* the currently planned missions are finally flown."

Second, the recommendations are not a list of priorities; without the data from the upcoming missions, said Donahue, the board members could see no rational way of setting such priorities. Nor could the board do much to estimate cost; the recommended missions are so far off and so broadly defined that the estimates would be little more than guesses.

That said, however, the report offers a cornucopia of possibilities in each of six disciplines:

■ **Earth sciences.** The board recommended a continued emphasis on studying our planet as a global system—a theme dramatized by the recent international agreement on chlorofluorocarbons, the ozone hole, the midwestern drought, and the renewed concern over the carbon dioxide greenhouse effect. In the 21st century the board would like to see missions that include a set of five global monitoring satellites in geostationary orbit (two provided by the United States); a set of two to six lower altitude instrument platforms providing high-resolution, global coverage from polar orbit (two or three provided by the United States); a global network of ground-based sensors, perhaps using NASA satellite technology for autonomous operation in remote locations; and advanced computer systems for archiving and analyzing the torrents of sensor data, and for building better theoretical models of Earth processes.

■ **Planetary and lunar exploration.** Here the board emphasized the importance of understanding the origin and evolution of

* "Space Science in the United States: A Celebration of the Past—A Vision of the Future," held 27 and 28 June 1988 at the National Academy of Sciences, Washington, D.C.

† *Space Science in the Twenty-First Century: Imperatives for the Decades 1995 to 2015* (National Academy Press, Washington, DC, 1988).

the solar system as a whole, as well as the insights that other planets can provide into understanding *our* planet. Its recommendations include surface landers and sensor networks on all the rocky planets of the inner solar system—Mercury, Venus, the moon, and Mars—together with samples returned from all but Mercury; orbiters and atmospheric probes for all the gas giant planets of the outer solar system—Jupiter, Saturn, Uranus, and Neptune—as well as an orbiter for icy Pluto; landers for Jupiter's moon Io and Saturn's moon Titan; and rendezvous/sample-return missions to a variety of comets and asteroids. The board also recommended that Mars, as the most Earth-like of the planets, should be the subject of more extensive investigation and perhaps even human exploration—but only as a supplement to the baseline program, not as a substitute.

■ **Solar system space physics.** The board emphasized a better understanding of the physics of the sun, and of the processes that link solar variability to phenomena on the earth. Among its recommendations are high-resolution x-ray and ultraviolet telescopes to study the small-scale phenomena on the surface of the sun that are thought to play a critical role in generating solar flares and the solar wind; a solar probe mission to carry instruments to within 2 million kilometers of the sun's surface; a high-speed interstellar probe that would reach the edge of the sun's magnetosphere within 10 years; and new instrumentation for large-scale monitoring of the earth's magnetosphere.

■ **Astronomy and astrophysics.** The board pointed out that space offers unique opportunities for large imaging interferometers, in which orbiting arrays of optical, infrared, or radio telescopes would combine their beams to form images of distant galaxies and quasars that are hundreds of times sharper than those of the Hubble Space Telescope; and for individual telescopes with very large collecting areas—say a 16-meter optical telescope, or an imaging gamma-ray telescope—that could gather in scarce photons by the bucketful. The board also called for a new high-resolution cosmic-ray spectrometer using superconducting magnets.

■ **Fundamental physics and chemistry.** The board saw many opportunities for high-sensitivity tests of general relativity and gravity, using techniques such as laser ranging to reveal the effects of low-frequency gravity waves on the position of spacecraft. Also addressed was the possibility of studying the small-scale behavior of matter under conditions of weightlessness—the "materials processing" research that NASA has advanced as a major rationale for its multi-billion dollar space station. The board agreed that there is interesting work to be done in this area. However, the report pointedly noted that very little is really known about the basic scientific questions, "[and] until these are answered, there does not seem to be any way to structure a rational program of materials processing in space."

■ **Life sciences.** Among the most urgent areas in this field, assuming that the nation eventually decides to attempt a manned lunar base or a manned expedition to Mars, is space medicine. Top priorities are a better understanding of how weightlessness degrades bone and muscle, what kind of shielding astronauts would need in the interplanetary radiation environment, and what it would take to build a reliable "ecosystem" for recycling wastes on missions of long duration.

The latter recommendations notwithstanding, one very clear undercurrent at the symposium, and in the report itself, is the community's abiding bitterness at NASA's manned space program. As pointed out by NASA's Fisk, himself a space plasma physicist, the agency's science programs have always gotten plenty of money, "but we weren't allowed to spend it wisely." Researchers were required to use the shuttle whether they needed the manned capability or not—and then to watch their missions multiply in costs because of the endless and finally catastrophic delays in the shuttle. Not surprisingly, they now tend to be deeply suspicious that the same thing will happen again as NASA keeps pushing for its space station.

Thus, the report's strongest recommendation: a call to make science "an objective no less central to the space program of the United States than any other." It was left to the reader to decide whether this meant that space science should somehow be separated from NASA. But for his part, said Donahue, "I think the possibility should be discussed."

■ **M. Mitchell Waldrop**

Turning Down the Heat on Thin Films

Superconducting thin films will be essential to any practical application of superconductivity to microelectronics. Scientists have now succeeded in putting these thin films onto silicon, which is the base element in most integrated circuits.

Recent announcements and publications indicate that superconductivity researchers have made an important breakthrough in processing high-temperature superconductors. Teams at several labs across the country have found ways to make thin films of superconducting yttrium-barium-copper-oxygen at significantly lower temperatures. Although the breakthrough may not have the drama or media appeal of discovering yet another record-setting superconductor, it could have just as much practical importance in the long run.

Thin films are the key to what many experts see as one of the most valuable applications of high-temperature superconductors: use in integrated circuits and computers. Since integrated circuits are made by laying down thin layers of different materials and etching those materials in different patterns to form electronic circuits and components, researchers have been working on molding the high-temperature superconductors into thin films for over a year.

There has been some success in this work. Researchers have made very high quality thin films out of not only the Y-Ba-Cu-O compound but also the recently discovered thallium-based superconductors. The problem is that these films had been made under conditions that would not transfer well to semiconductor manufacturing.

To integrate superconducting thin films into existing semiconductor technology, the films need to be placed on silicon, which is the basic material on which almost the entire semiconductor industry is based. But the techniques for making superconducting films, while successful with specialized base layers, or substrates, broke down in the presence of silicon. The problem was that the temperatures used in the processing were too high.

The processing techniques for making a superconducting thin film vary, but they have certain steps in common. The substrate