The technique is to bounce a radar beam off another planet when the other planet is almost on the opposite side of the sun. The gravitational field of the sun should be strong enough to cause a perceptible slowing of the beam.

In fact, the slowing was calculated to be only about 200 microseconds in a total transmission time of about 22 minutes. Yet with equipment at MIT's Lincoln Laboratory—the 120-foot Haystack radio-radar telescope—the measurement could be made, and in 1967 it was accomplished by Dr. Shapiro and his colleagues: Drs. Gordon H. Pettengill, Michael E. Ash, Melvin L. Stone, William B. Smith, Richard P. Ingalls and Richard A. Brockelman. They used Mercury as the reflector. The result came out within 20 percent of the prediction, which is, coincidentally, the same accuracy as is usually claimed for the other tests of the theory.

All this evidence goes far to bolster Einstein's contentions, but it has not quieted the critics. They point out that 20 percent accuracy is not very exclusive; any other theory that could predict the same effects and gave amounts within 20 percent of Einstein's figures could fit the evidence. Furthermore, if a theory predicted part of any of these effects and its proponents at the same time brought forth some other plausible mechanism to account for the remainder, it too might stand on the available evidence.

But why throw stones at a good theory? Philosophical unease is one reason. Certain people have not been entirely happy with some of Einstein's basic assumptions, especially his interpretation of the statement that the strength of gravitation anywhere in the universe depends on all the matter in the universe (known as Mach's principle).

The mathematical intractability of the theory is another reason. Einstein's basic gravitational equation is virtually insoluble and many people have wished they could finagle the theory somehow to ease the mathematical difficulties.

A recent example of attempted modification is the theory put forward by Drs. Carl H. Brans and Robert H. Dicke (SN: 2/11/67, p. 144). Arguments from Mach's principle led them to question Einstein's way of representing gravitation mathematically. So they changed it. The result is a theory that, among other things, predicts only 92 percent of what Einstein predicted for the excess motion of Mercury's perihelion. (The total amount is only 1/21,600 of a full circle in a hundred years.)

How to explain the other eight percent? Dr. Dicke suggested that if the sun were oblate—slightly flattened at the poles—its gravitational field would be altered in such a way as to cause the extra motion of Mercury in a straightforward, pre-Einstein fashion. The theory of solar oblateness has run into serious objections, but if it should turn out to be true, then the Brans-Dicke gravitational theory could be said to fit the evidence as well as Einstein's.

Will the evidence ever allow a choice between Einstein and his critics? The radar experimenters hope to sharpen the accuracy of their measurement to within five percent. At this level it may be possible to begin making distinctions among rival theories. However, some of the theories include scale factors (sometimes called finagle constants by people who object to them) that allow a degree of stretching or squeezing to fit the evidence, thus increasing the difficulty of a decision. But for the present radar supports Einstein.

BIOSATELLITE 2

Radiation and weightlessness

A few days before Christmas in 1966, a crew of flies, wasps, beetles, bacteria, amoebas, spiderwort seedlings and other living things were carried into space aboard the first U.S. Biosatellite. On the ground, scientists sweated out the three days before the satellite's scheduled reentry, awaiting the mid-air snatch that would put capsule and crew back in their hands for study. At the last minute, the researchers were deprived of their triumph when a short-circuit kept a retrorocket from firing, thereby leaving the satellite stranded in orbit for days until gravity finally dumped it somewhere near Australia.

Last September a duplicate flight got back successfully (SN: 9/23/67 p. 299), and now, six months later, the delighted scientists are still poring over their data, many of which are in the form of direct descendants of the life forms on the flight.

The main thing offered by the flight, unobtainable on earth, was an extended period of weightlessness. To many of the investigators, however, even more important was the chance to subject their specimens to a combination of weightlessness and a controlled dose of radiation, provided by a measured, onboard source. They expected that radiation without gravity might have an effect different from the same radiation on earth.

In many cases they were right. But despite all sorts of laboratory tests, computer analyses and sleepless nights, they still do not know why.

The two factors are simply too different. What is the connection between gravity, a pure force, and radiation, the impingement of either solid particles or energy?

No one knows, but there are theories. One is that of Dr. Rudolf H. T. Mattoni of the NUS Corp. in Hawthorne, Calif., whose contributions to the satellite were two batches of bacteria, Salmonella and Escherichia coli. Identical batches, treated with matching doses of radiation, were kept in normal gravity on the ground. Both kinds of irradiated bacteria grew both faster and larger in space than on the ground; there were 48 percent more Salmonella in the spacecraft than in the ground control chambers, and 19 percent more E. coli.

"The reason for the greater growth in space," says Dr. Mattoni, "appears to be that without gravity to hold them down, the bacteria are randomly distributed throughout the growth medium, and access to food requires less energy, as does elimination of waste products."

In the case of more sophisticated organisms, the mechanisms linking zero-gravity and radiation seem more complicated. Dr. R. C. Von Borstel of Oak Ridge National Laboratory in Tennessee and Dr. Daniel S. Grosch of North Carolina State University found that developing wasp eggs apparently can recover from radiation damage in weightlessness, and that they also show a lower level of genetic damage than eggs irradiated on the ground.

Again, gravity's influence is still a mystery. It is possible, the researchers think, that weightlessness allows a slowing-down of the rapid cell-division and metabolic processes which eventually produce eggs in the wasps' ovarian tubes. This slows production of mature eggs, perhaps giving more time for repair processes to eliminate some of the damage caused by the radiation. Since the flight, the scientists have also found that the weightlessness has seemed to reduce the proportion of deaths due to radiation-caused genetic damage among embryos resulting from the eggs, again because slowdown gave time for repair.

Weightlessness, however, is not the only characteristic of space flight that may affect the effects of radiation. Another, first pointed out years ago by researchers in the Soviet Union, is vibration.

The Soviet space biology program is older than that of the U.S.—the second satellite ever launched, Russia's Sputnik 2, carried a dog—and has sent more living things into space. U.S. scientists, however, make the same complaint about the Russian biospace program as they do about the rest of the Soviet space effort: it's big, they feel, but pretty unsophisticated.

Dr. Dale W. Jenkins, chief scientist in the National Aeronautics and Space Administration's bioscience office, calls the Russian attitude "a cavalier approach." Sure, he says, they have a lot of data—"they got there fustest with the mostest; but much of this data is uninterpretable or ambiguous."

Nevertheless, the Russians did point out the possible influence of vibration, and they did it with E. coli, the same bacteria as that of Drs. Grosch and Von Borstel. Several of the Biosatellite experimenters agree. "For example," Dr. Von Borstel says, "vibration could dislocate a cell component, and the gravity-free state could keep the component from settling back to an earth-bound position in the cell."

The possibility of such an effect due to weightlessness was encountered by Dr. Luolin Browning of Rice University, who sent almost 1,000 adult vinegar gnats up in the Biosatellite. Of some 20,000 offspring produced by the gnats since the flight, only 14 showed chromosome changes due to radiation, but this is more than four times the percentage that appeared in the control group on the ground. "In this case," Dr. Browning says, "where the chromosome had been fragmented by prior radiation, weightlessness may have interfered with recombination."

Other Biosatellite passengers also showed effects apparently due to radiation and weightlessness acting together, but as yet they have offered few if any clues toward an explanation. A miniature field of blue wildflowers, for example, showed twice as much damage ("cell death, abortion of pollen and loss of reproductive integrity") from radiation as did a similarly irradiated group on earth.

In general, the greatest effects of weightlessness were found in young and actively growing cells and tissues, and rapidly dividing cells with high metabolic activity, rather than in less active or more mature organisms. But the question persists: what is the connection with radiation? Theories range all the way up to the bizarre chance that gravity may be "some kind of radiation shield."

It is possible that the mystery may not be solved even by the four elaborate missions remaining in the Biosatellite program. Next year two flights will carry macaque monkeys into orbit for 30 days each, and 1970 and 1971 are each scheduled for a three-week mission carrying rats, plants and even human liver cells. Though some of the passengers will be instrumented for zero-gravity radiation studies, none of the flights will carry on-board radiation sources. Thus only the low cosmic radiation of space will be available in the quest for an answer.

RESEARCH AND BUREAUCRACY

A delayed birth for an independent NIH

The reorganization of the health part of the Department of Health, Education and Welfare has been 16 months in gestation. Now, on the eve of delivery, there appears to be a blockage. The reorganization plan will not emerge for some time; when it does it might find itself in unfavorable surroundings.

Reorganization generally has been the byword in HEW since former Secretary Abraham Ribicoff left in 1962. Critics of the department have said it is too loose-knit, composed of too many maverick agencies acting without regard to central control. Ribicoff's parting, frustrated proposal was that the giant bureaucracy be dismembered.

Few wanted to go that far, but the atmosphere of change grew. This atmosphere gave Dr. James A. Shannon, director of the National Institutes of Health, the opportunity to push for independence of the Public Health Service, an NIH goal of some long standing. The Institutes are the Service's prime research arm, supporting some 60 percent of the nation's biomedical research. Independence has been as vigorously fought by Surgeon General William H. Stewart, who sees loss of the Institutes as a severe diminution of his jurisdiction.

The Public Health Service had its origin in 1798 as the Marine Hospital Service. NIH began almost a century later as a bacteriological laboratory in the Marine Hospital in New York City, and has been part of PHS since. Shannon, with his eye on basic research, feels that NIH should be separate from the service-oriented PHS. Forces in the other direction, notably President Johnson himself, would like to see more service, more applications, more payoff resulting from the research dollar.

Shanon has built NIH to its present eminence by sheer charisma. The fear at higher levels has been that his retirement would leave an administrative vacuum, and Stewart has moved his headquarters to NIH to prepare to fill it. Institute scientists fear a new director more devoted to bureaucracy than to science, and a consequent downgrading of the Institutes; thus the pressure for independence.

The reorganization now on ice would grant many of Shannon's wishes. About a year and a half ago Dr. John J. Corson, associated in one way or another with HEW since its birth and now a private consultant, was engaged by HEW Secretary John W. Gardner to help in drawing up the reorganization.

The plan calls for separation of PHS and NIH. The Institutes, the Bureau of Health Manpower, and the National Library of Medicine would be drawn together under a Research and Education Administration (the name is open to discussion still). The National Institute of Mental Health, severed recently from NIH, would be one of the more service-connected health functions of PHS gathered into a Health Services Administration. A Consumer Protection Administration would house the Food and Drug Administration and various environmental health control programs.

These three administrations would be directly under Stewart, presently chief of PHS. Stewart in turn would become deputy to Dr. Philip Lee, since 1965 HEW's assistant secretary for health and scientific affairs. Lee, subject to Congressional approval, would be named Undersecretary for Health.

While Shannon missed his objective of making NIH entirely independent of the Surgeon General, it is known that Shannon and Lee see more eye-to-eye than either does with Stewart.

One effect of the shakeup would be to separate the President's heart-stroke-cancer program from NIH. This service program was taken on by the NIH scientists after the President's demand two years ago that research start producing some tangible results. The program was seen as a way to provide widely scattered, top-flight medical centers where the latest fruits of basic research can be translated into clinical applications. Secretary Gardner believes that under the reorganization this swift translation will be accomplished by a tough, central administrator such as Lee, who would keep one eye on research and the other on service at all times.

The heralded reorganization hit a snag, however: Shortly after announcing the plan Gardner announced his resignation. As might be expected, such sweeping changes appear to have been held in abeyance, awaiting the arrival of the new secretary. However, if there is any substance to the suggestion that Gardner and the President did not part amicably, the picture may be complicated. The President, if he was in disagreement with Gardner, would be unlikely to replace him with a man holding the same views, and thus the new secretary may have his own ideas about the reorganization plan.

Also casting a shadow over the plan is the mandatory September retirement of Shannon, one of its strongest champions. There is talk of appealing to Congress for an extension of Shannon's tenure. If such an appeal is not made, or is unsuccessful, Shannon's influence over the plan may be weakened by his lack of involvement in its results.