Exploring the Solar System (IV): What Future for Space Science?

The space program enjoyed considerable popular and political support throughout the 1960's. Among scientists, however, it was skeptically viewed as a technological spectacular largely devoid of scientific content. But now that planetary science and other space sciences are riding high on the successes of a series of far-ranging spacecraft, the space program has gained the grudging respect and support of much of the scientific community. Among space scientists themselves enthusiasm is at a peak, and there is talk of a golden age of planetary exploration and a virtual revolution in space astronomy in the 1980's.

But times have changed in other respects too, and space is no longer perceived as glamorous enough to warrant extensive television coverage nor important enough to be a major political plum in Congress. The $3.5 billion a year space effort is not directly relevant to the energy, food, and economic crises that plague the nation—a fact that has not escaped notice on Capitol Hill; nor does a new and cost-conscious administration have a strong stake in the program.

The National Aeronautics and Space Administration has ambitions for a vigorous program of space flights on into the 1980's and beyond, centered on the completion of the space shuttle but also including a significant expansion in unmanned exploration of the solar system (see box on page 1012). Planning is well advanced for the planetary science missions already approved—the 1975 Viking flight to Mars, the 1977 Mariner mission to Jupiter and Saturn, and the 1978 Pioneer flight to Venus—and there are high hopes for future missions.

The Viking flight will extend exploration of Mars into a new dimension, the search for life; the Venus mission, the first specifically designed to explore the high temperature environment of that planet's massive atmosphere, will attempt to find out why it is so hot. Plans for what should come after are by no means set, but thinking among the optimists within NASA (what one more cynical observer called "the real dreams") is that the major thrusts in planetary science might include (i) placing long-lived satellites in orbit around all the terrestrial planets to move beyond the descriptive phase of study and into detailed comparative planetology; (ii) missions to satellites of the outer planets in a search for the early history of the solar system; (iii) studies of the effects of solar variability on weather and climate; and (iv) an expanded search for life in the solar system and beyond, possibly including a rendezvous with a comet to look for organic molecules or other evidence of the chemical evolution of life.

Uncertain Political Prospects

Whether these programs have much chance of being funded is another question. The impression gained from a series of interviews is of a political climate distinctly unreceptive to new space projects. There is, moreover, the possibility that cost overruns on the shuttle or budget cuts for the space agency as a whole could lead to cancellation of the planetary science program—a possibility that is a source of considerable concern to planetary scientists.

There is no present indication of any major retrenchment in space. In the $4.6 billion cut that President Ford is requesting from this year's federal budget, NASA only stands to lose a modest $72 million, of which $16 million is to be taken from space science and applications. What the Ford Administration's ultimate intentions toward space will be are still unclear. According to one NASA official, the agency has at present only fuzzy lines of communication with the White House, which is still in the throes of reorganization. Indeed, because of the chaos of the last year of the Nixon Administration, the agency has had no clear instructions from or reporting channels to the top since its link with Treasury Secretary George Shultz (who held a number of additional positions, including counselor to the President for economics and science) was severed by his resignation 2 years ago. In the ensuing vacuum, the Office of Management and Budget (OMB) has assumed an increasing role in overseeing NASA, and, while it has questioned budgetary requests, it has not attempted to change the agency's mandate or overall direction.

Whatever the Ford policy on space turns out to be—and at least one close observer and supporter of NASA believes that space will be cut—Congress seems certain to have a larger voice in space, just as in many other areas of national policy. So far, at least, there appears to be considerable support for the space program in the House and the Senate. "The Hill hasn't wavered much," was how one committee staffer assessed the situation. Another believes that bold new initiatives would probably be defeated, but that the support is there for something like the present program. He cautioned, however, that "space is not perceived as one of the country's pressing needs."

A major intangible is the influence of the new budget committees, established just this year, which are to set overall spending priorities for the Congress. These are not yet staffed or functioning entities, and whether they will in fact be able to perform as intended is an open question. There seems to be general agreement, however, that space will not escape renewed scrutiny. There may, moreover, be some competition for money and staff attention with energy research programs in the existing space-related committees. [The House Committee on Science and Astronautics has jurisdiction over part of the new Energy Research and Development Agency (ERDA) as well as NASA, and the Senate Aeronautics and Space Committee is among those bidding for ERDA jurisdiction]. Several observers predict that the next Congress will be faced with a choice between the shuttle and a continuation of the space science and applications program.

The last real test of Congressional support for the space program came about 2 years ago when an attempt was made in the Senate to kill the shuttle. The deciding factor in the ensuing vote of confidence was the support of organized labor. "As long as labor sticks with us," one Senate Aeronautics and Space Committee staff member said, "we'll have no problem." The space program supported some 400,000 jobs at the peak of the Apollo program; the number of space-supported jobs is now estimated at about 110,000, most shuttle-related.

Fletcher Sees Major Thrust in Space Science in 1980's

A golden age for planetary exploration is a realistic possibility, according to National Aeronautics and Space Administration director James C. Fletcher. In an interview with *Science*, he singled out planetary and other space sciences as likely to be one of the major thrusts of the space program in the 1980's. He expects to see a huge step forward in this field, although "whether there will be money to support everything that ought to be done is another question."

Any look into the future raises the question of NASA's devotion since its founding to manned space flight. Asked about the directions in which the agency might evolve after the space shuttle is completed, Fletcher appeared to rule out any major new manned programs other than the shuttle on grounds of political feasibility. "The emphasis in the 1980's of men in space will be in helping other programs. As far as going to Mars or establishing bases on the moon, that doesn't look like it's in the cards right now." Fletcher cautioned that the situation could change; but unless it does the focus of the space effort will be on other programs. He also ruled out any major role for NASA in energy R&D.

James C. Fletcher

Such statements would have been tantamount to heresy in the glamor days of Apollo, and their calm utterance would seem to indicate that Fletcher is relatively secure in his job and confident in his vision of the agency's future. Fletcher, who has headed NASA since 1971, seems to combine several of the characteristics of his predecessors James Webb, renowned as the manager who built the Apollo system, and Thomas Paine, a transitional director who was also a scientist of considerable standing. Fletcher does have scientific credentials, including a Ph.D. in physics from the California Institute of Technology. His career (he is now 53) has not been devoted to research, however; rather, he has been an aerospace executive and university president. He was, in addition, well wired into the Washington science adviser network as a member of the President's Science Advisory Committee (from 1958 to 1970) and of other groups. In person, he is direct and relatively informal, and gives the impression of being a realist about his agency's prospects.

Asked about rumors that space science might be cut to maintain the shuttle, in the event of serious money problems for NASA, Fletcher responded, "We have so far stoutly maintained that there needs to be a balance between the programs, and we have pretty well kept that balance. . . . If we were starting to squeeze down on space science, we would have to squeeze down on the rest of them too." Besides, Fletcher maintains, the space science program is nowhere near the minimum level of effort needed to keep it healthy. He did say that expensive space science missions—for example, the Viking probe to be launched toward Mars next year—will not be attempted again until the economy improves, and that others, like the large space telescope, may have to be trimmed down to a less ambitious effort. The focus, he indicated, is likely to be on less costly programs and space vehicles.

Space science would thus appear to be one of the major beneficiaries of the postshuttle era. "Planetary science will be high priority," Fletcher said, "but applications will be also." Yet another activity that may grow from its present, insignificant status to become a major one, according to Fletcher, is materials processing in space—manufacturing things that are more readily made in space than on earth. And although space science will have to compete for funds and spacecraft with applications and materials processing, Fletcher believes that the level of activity "will be way more than we've been able to do in the 1960's and early 1970's."

One area in which NASA will not play a major role, as things stand now, is in developing high technology for energy, ground transportation, or similar nonspace systems. "Not because we don't think it important," but rather, Fletcher indicated, because other agencies have been given the nod and NASA has not. Thus, hopes that NASA could expand its jurisdiction and become an all-purpose technology development agency seem to have been squelched.

As to prospects for the space program as a whole, Fletcher agreed that the agency and its large budget are more vulnerable now than they were in the 1960's. But not, he claimed, any more vulnerable than at the conclusion of the Apollo program when sentiment to close up the space program and go home was at its peak. "I think we've now got a fairly sound program which Congress so far has pretty well accepted, and I think the White House too." Rather than wholesale cancellation of the space program, Fletcher indicated, the problem will be to survive the more modest cuts of the annual budget cycle intact. Fletcher agrees that space is likely to get cut a little more than others.

Whether such cuts might prohibit new missions from being started in the next few years, Fletcher didn't want to say. He did say that, under the circumstances, "the number of new starts is going to be held to a minimum." But he indicated that he believes the situation is only temporary, and not unique to space, pointing out that the pinch is on throughout science in regard to major new projects and that a low profile is a tactical necessity at present.

What are the prospects, then, for continuing the exploration of the solar system and the concomitant revolution in planetary science? "Very good," Fletcher claims, "and I can't say that lightly, although I also can't say that with absolute confidence. We've got to make a special effort to keep that a viable program, because a lot of people have devoted their careers to it. If we suddenly cut off the program, they'll have wasted a fair number of years. But we have encouraged them to make it a career, and we also feel an obligation to continue it." Which is, no doubt, good news for planetary scientists.—A.L.H.

The shuttle thus seems to be an established political reality. It will eventually open participation in space science to a wider group of scientists and may generate applications as yet undreamed of. Nonetheless, opponents of the shuttle—and most space scientists would be opponents if the issue came down to the shuttle versus science—argue that the volume of space traffic in the 1980's is unlikely to be large enough to justify the shuttle's cost, even including the military applications that now appear to be its main raison d'etre. It is widely acknowledged in military circles, moreover, that the shuttle will not reduce defense space costs substantially. The shuttle is vulnerable to attack, because the five orbiting vehicles and two landing sites could be quickly destroyed, so that the Defense Department will continue to stockpile enough rockets to launch spy satellites and other hardware without it.

With or without the shuttle, space scientists see a paradox in the fact that their field faces more uncertain prospects than ever before just when it is beginning to produce substantive results. There is a real threat, some believe, that the research groups built up in past years will be dispersed for lack of money. Some scientists in advisory positions are girding for an all-out fight to preserve the space science program, even to the extent of suggesting that a $1 billion cut in the NASA budget would be better for science than a $100 million cut, since the former would entail canceling the shuttle, in theory releasing lots of money for space science. Others are advocating that planetary scientists should seek to convince NASA to fund enough research to keep groups together, even if no new missions or spacecraft are approved. Thus, pessimism and optimism seem to coexist in the opinions of many of those associated with the space science program. This mixed view of the future was neatly summed up by one scientist who predicted that the space program will either phase out shortly or enter a very imaginative, and more scientifically-oriented era as the money now being used to build the space shuttle is poured into "doing" science in space.

It may be that such concerns are overdrawn, since, as one congressional aide pointed out, the modest cutback in the present NASA budget would seem to be inconsistent with a serious cut for next year. On a longer time scale, however, there is no doubt that space scientists will increasingly have to justify this expensive kind of research. There is good reason, as has been outlined in other articles in this series, to think that justification can be found, that exploration of the solar system and beyond is, as one scientist described it, "our obvious new frontier."—ALLEN L. HAMMOND

Developmental Neurobiology: Specificity in the Visual System

One of the major open questions in neurobiology is how nerve fibers make specific connections with other cells during the course of development. Some investigators believe that each nerve fiber must have a unique biochemical label. Others propose that the apparent accuracy with which nerves form connections can be explained by a well-defined temporal sequence of nerve growth and development. Results from studies of the visual systems of various species provide evidence that either explanation may be correct, depending on the organism. Since cells from the visual systems of certain species are thought to contain biochemical labels that mediate recognition, investigators are now developing ways to identify such labels.

The problem of explaining specificity in the visual system was popularized 11 years ago by Roger Sperry of the California Institute of Technology, in Pasadena. Sperry, studying regeneration of optic nerve fibers in amphibians, was impressed with the uncanny accuracy with which severed optic nerve fibers found their way through a maze of other neurons to their targets on the optic tectum of the brain. He advanced a hypothesis that this regeneration must be mediated by chemical labels on the cells.

In the decade since Sperry proposed his hypothesis, numerous investigators have searched for a simpler explanation of specificity that would not require so many chemical labels. One simple explanation is that specificity arises from a temporal sequence of growth and development of nerves. A nerve fiber would grow toward its target cells, contact those cells, and then the target in turn would differentiate so that it was receptive to the nerve fiber. Although it now seems unlikely that this hypothesis alone is sufficient to explain the visual systems of vertebrates, it can be used to explain specificity in the small crustacean *Daphnia*, according to Cyrus Levinthal of Columbia University in New York. Levinthal's results are of interest to neurobiologists because it is believed that phenomena observed in *Daphnia* may also be present in vertebrates, although vertebrates may have additional, more complicated, signals for cell recognition.

Is Cellular Communication Involved?

Levinthal and his colleagues find that nerve fibers grow outward from the eye of *Daphnia* in a certain temporal sequence while, concurrently, the target cells in the visual center of the organism's brain develop in a complementary sequence. Moreover, a group of target cells does not fully differentiate until it is touched by one of a bundle of eight optic nerve fibers. When such a nerve fiber contacts its target (which consists of five cells), each target cell in the group, in turn, wraps around the fiber. When a target cell is wrapped around an optic nerve fiber, small holes are formed between the membranes of the two cells (gap junctions); these junctions are large enough for molecules having a molecular weight of 300 to pass through. After a short period, the passageway between the two cells closes again. This process, Levinthal speculates, may be a way for the target cell and optic nerve fiber to communicate and may thus trigger the differentiation of the target cell. Levinthal points out that optic nerve fibers of vertebrates may also communicate with their targets to trigger differentiation of target cells.

It has become increasingly clear that specificity in the visual systems of vertebrates is not simply a result of temporal sequences of development. From data they accumulated while working with frogs, Marcus Jacobson and his colleagues at the University of Miami have ruled out such an explanation as have W. Maxwell Cowan and his colleagues at Washington University Medical School, in St. Louis, who worked with chicks.

Jacobson's group devised several experiments in which the time at which developing optic nerve fibers in the frog contacted their targets was later