The Skylab Is Falling and Sunspots Are Behind It All

Bermuda. Sometime before October of next year, the 85-ton Skylab satellite sent into orbit 5 years ago by the National Aeronautics and Space Administration (NASA) will begin to drop down into the earth's atmosphere. Some of the satellite, which is roughly the size of an eight-story farm silo, will burn up when friction heats the outer hull. According to NASA, however, many internal components and part of the overall structure will survive reentry and come crashing down to the earth's surface. These parts include such things as pressurized gas and liquid capsules and large, lead-lined film boxes. As of now, NASA can predict neither where the reentry will begin nor where the satellite parts will fall. Because of a skipping effect that occurs as a satellite hits the atmosphere, a NASA official says "there will be a pattern over several thousand miles of pieces reentering and falling to earth."

Naturally, NASA would like to avoid this if it can, particularly in light of the worldwide attention accorded the 24 January fall of the Russian Cosmos 954 spy satellite over Canada. That dramatic incident sensitized the agency in short order to the political implications of great chunks of metal falling unpredictably from the sky. Since January, NASA officials have spoken carefully about Skylab, seeking to minimize whatever risk may exist to the populated areas that lie beneath the satellite's orbit.

At the same time, they quickly dispatched a team of engineers to the NASA tracking station in Bermuda, where efforts were begun to communicate with Skylab and to try to slow its rate of orbital descent. From a room jammed with sophisticated computers and electronic equipment, the team members sent Skylab a sequence of commands to report back the condition of equipment that had been dormant for 4 years. Initially, their efforts were unsuccessful, but after a week it was learned—to the team's surprise—that most of the equipment could still function. "We're getting computer word down," a team member said at the instant the satellite began responding fully. "The batteries are going like a champ." In April, the contact will be renewed, and the team will attempt to prolong the satellite's life by several months.

All of this is made necessary by the fact that up until last fall, NASA refused to acknowledge that Skylab would come down earlier than expected. Indeed, Skylab was not supposed to come down at all—at the end of the last manned mission to visit it in 1974, Skylab was boosted into an orbit supposedly high enough to keep it from reentering the earth's atmosphere until at least 1982 or 1983. By that time, the space shuttle, a reusable orbiter that will be the workhorse of the space program for the next two decades, was expected to be fully operating. After docking with Skylab, a shuttle craft could boost it to whatever orbit is necessary to keep it around for another decade or so of experimentation. Alternatively, if a decision was made that Skylab was no longer useful, the shuttle could control its return to earth so that its parts would land in a remote portion of an ocean. This plan apparently has been rendered useless by the likelihood that Skylab will fall not only before 1982 but before even a test shuttle can get to it in the fall of 1979. According to the most optimistic prediction, the chance of Skylab being there—in the sky—at the time NASA can get to it is no better than one in two.

NASA Disregarded Warning

The explanation for how the agency became entangled in such a mess is partly economic—in the development stage, Skylab, like most recent NASA projects, was constricted by congressional budget-tightening. The explanation also is political and scientific, however, for the 3-year error in the prediction of Skylab's fall hinged both on the rather esoteric art of sunspot prediction and on an unwillingness by NASA to acknowledge warnings in 1976 that sunspot activity would be greater than predicted and thus that Skylab would fall sooner than predicted.

The warnings came from the National Oceanic and Atmospheric Administration (NOAA), which through its Space Environmental Services Center in Boulder, Colorado, is in the business of making predictions of solar activity for a variety of government and private organizations. Sunspot predictions are critical to the prediction of satellite orbits because the incidence of sunspots is related to solar radiation, which heats the atmosphere, raising its density, and increasing the amount of drag on a satellite floating in space. The greater the number of sunspots, which literally are irregular areas on the solar surface, the more Skylab or any other satellite can be expected to be slowed by atmospheric drag and the sooner their orbits will decline.

Scientists at both NASA and NOAA freely admit that an error was made in 1974 in predicting the number of sunspots that would occur during the expected 10-year period of Skylab's orbit. "At the time Skylab's last manned mission boosted it to its highest orbit, we expected it to remain in space well into the shuttle operations in 1983 or 1984," says Robert Aller, the deputy director at NASA who is coordinating his agency's efforts to prevent Skylab from falling. "Our predictions of sunspot activity and our predictions about the atmospheric density up there were inaccurate." Both turned out to be greater than expected during the last 5 years.

Part of the prediction difficulty stemmed from the fact that the number of sunspots wax and wane throughout a solar cycle, which usually lasts about 11 years. Because a new cycle began in March 1976, it was difficult to predict in 1974 how many sunspots would appear after 1976. As one NASA scientist explained, "Predicting what the sun will do is a chancy business, particularly when the prediction is made just before the start of a new solar cycle." It is one of the many ironies surrounding this affair that studies conducted during the three manned visits to Skylab in 1973 and 1974 have increased the ability of scientists to predict the activities of the sun, but the results of the studies were not available at the time of the last of these missions.

Solar scientists contacted by *Science* agree that the initial error, which was not made solely by NASA, was understandable. Several of them were less understanding, however, about NASA's refusal 2 years later to act on new, more accurate predictions by NOAA of much greater sunspot activity. Specifically, in the autumn of 1976—when initial observations had been made of sunspots in the current solar cycle—NOAA predicted a peak sunspot frequency that was nearly double what had previously been predicted. The prediction suggested that Skylab would fall not in 1982 but in early 1980. "At some point in 1976, they should have considered the new predictions of greater solar activity and started to make contingency plans to prevent Skylab's uncontrolled fall," a NOAA official told *Science*.

NOAA's prediction, which was published openly, as well as specifically con-

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veyed to NASA's Marshall Space Flight Center in Huntsville, Alabama, was ignored by NASA for political reasons, according to several sources at both agencies. One suggestion is that, at the time of the new prediction, scientists at Marshall were taking part in studies that they hoped would demonstrate the value of reusing Skylab for experiments in the 1980's. The Marshall center stood to gain a large slice of the financial pie from any reuse of Skylab, which primarily had been that center's project during the time it was operating. "Marshall was pushing reuse of Skylab because it would provide new business for their center," according to one NASA scientist. To acknowledge early on that the satellite would fall in 1980 would have made top NASA officials less inclined to conclude that Skylab was still useful. Obviously, this was a dangerous game: By delaying acknowledgment of NOAA's predictions as long as they did, scientists at Marshall may have lost their opportunity to gain from Skylab's reuse anyway, because their efforts to prevent its fall may have been started too late.

A second suggestion is that the Marshall center resisted acknowledging NOAA's prediction because it was to be in charge of the $40 million NASA Teleoperator Retrieval System, or remotely controlled booster. The booster would be attached to Skylab by a shuttle craft and then used either to prevent the satellite's fall or to control its reentry into the atmosphere. Funding for the booster is now before Congress in the 1979 NASA appropriations bill and, according to several NOAA and NASA sources, scientists at Marshall were concerned that Congress would not fund it unless there were a reasonably high expectation that Skylab would still be in the sky at the time the shuttle could reach it.

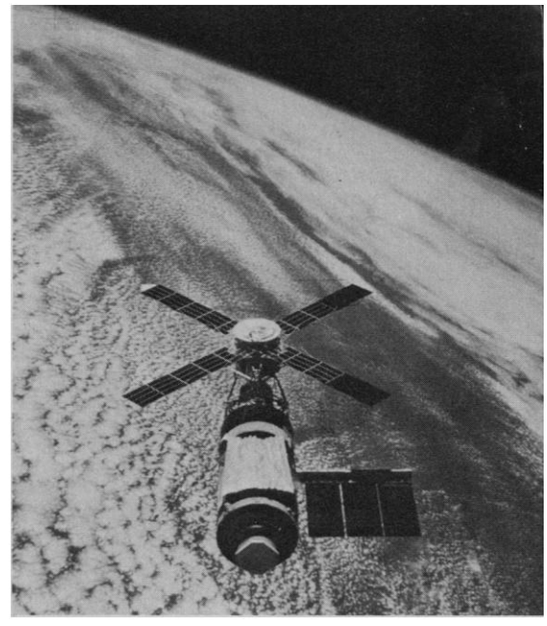
Charles Lundquist, who has directed the Marshall center's predictions of Skylab's orbit since last fall, contests both these accounts. The difference between NOAA and NASA predictions can be attributed to the use of different models, he told *Science*. Specifically, Lundquist said, NASA modeled its prediction of sunspot activity on statistical observations of sunspots during the last 20 solar cycles, comparing the rates of rise in sunspot activity in those cycles to the rate of rise in the cycle that began early in 1976. "NOAA's model was simply different; they compared the current cycle only to the last 13 solar cycles," Lundquist said, adding that "there is no generally accepted theory about whether or not the first seven recorded cycles should be included in a predictive model."

Gary Heckman, the chief of NOAA's solar forecast center, disagrees. "A number of published reports have discounted the reliability of the observations recorded during the first seven cycles," which occurred in the latter part of the 17th century, Heckman said. "NASA traded reliability for a model with more data in it, by using the observations from all 20 recorded cycles."

Where these charges and countercharges leave the real answer is not clear. Ultimately, NASA rejected NOAA's model. "We just felt that the 13-cycle data base was too low, although admittedly it was a trade-off against pinpoint accuracy," Lundquist said. Scientists at NOAA, with perhaps some distress at having their prediction ignored and then finally proved correct, maintain that the Marshall center simply chose the model that gave it the results it wanted. Other solar scientists told *Science* this was possible, but that something less than a professional consensus existed on which was the better model to use.

Eventually—after NASA headquarters had decided to look aggressively at reuse of Skylab but before Congress had approved funding for the booster—the Marshall center accepted the substantial accuracy of NOAA's predictions. The shift occurred in November 1977, after a second opinion had been provided by the North American Air Defense Command's (NORAD's) satellite tracking system headquartered outside of Colorado Springs. NASA had requested the projection of Skylab's orbit in August, and when provided, it substantially confirmed NOAA's earlier prediction that Skylab would reenter the atmosphere at the end of 1979 or the beginning of 1980. (This is not a tremendous surprise, since NORAD's model plugged in data on sunspot activity supplied by NOAA.) The critical word is *substantially*, however, because the NORAD supersensors picked up what has proved to be the icing on a poisonous cake: On top of everything else that made it likely that Skylab was coming down sooner than expected, NORAD found that the satellite was rolling as it moved through space, that its attitude, or pitch, made the drag even worse than expected, and that it was likely to reenter the atmosphere not in early 1980 but in mid-1979.

This dramatic new prediction raises the question of why NORAD had not predicted Skylab would fall that soon at some earlier point, with or without a request from NASA. NORAD has an abundance of sensors and computers, and it routinely records the position of every man-made object in space three times a day. Presumably, NORAD could have noticed earlier that the rate of decline in Skylab's orbit was faster than what everyone had assumed back in 1974. NORAD officials are reluctant to discuss the subject. One candid NORAD official offered a possible explanation for the reluctance: "We have to coordinate any information we provide on Skylab with NASA. We want to be sure that our responses don't have any adverse impact on congressional approval of the NASA rescue mission [the teleoperator retrieval system]." NORAD did say, through its public relations office, that it does not routinely make long-term orbital predictions and that its concern in an orbiting object is not really aroused until shortly before the object's reentry.



The winglike panels on Skylab are solar cell arrays. The satellite, which weighs 85 tons, is the largest man-made object circling the earth.

The fact that NORAD was not expected to look closely at Skylab raises the question of why NASA headquarters in Washington failed to monitor either the satellite's declining orbit or the early NOAA prediction. Apparently, the answer to part of the question is that NASA had no money to watch the satellite closely once the last manned crew had left it. One day after the crew departed, NASA shut down all of the satellite's systems with the exception of one command receiver and then coasted along on the assumption that the original prediction of Skylab's orbital lifetime would prove true. In the summer of 1977, when the subject of Skylab's current status was finally broached, it came up not as the result of any direct concern, but in the context of planning for missions of the shuttle orbiter in the 1980's. According to Aller, at NASA headquarters, "We were looking for missions for the

shuttle, so we began to look closely at reutilization of Skylab." Lundquist agreed: "It was the summer of 1977 before any vigorous review of Skylab's situation took place."

This left the agency in no small fix, because at the time Skylab was engineered and built, NASA failed to assure that after a passage of 5 to 10 years, the satellite would be able to correct its orbital decline or pitch by itself. According to several NASA officials, the agency left the satellite in 1974 with a definite intention to return to it in the shuttle, but without any specific idea about what Skylab would be used for after the shuttle got there. As a result, NASA made no attempt in the design process to assure that in 10 years' time, Skylab would still be operable. William Schneider, a deputy associate administrator at NASA who

Briefing

Doctors' Fees—Free from the Law of Supply and Demand

When the professionals in any field can set their fees virtually without regard to the law of supply and demand, they have a nice thing going, at least for themselves and their bank accounts. According to *A Study of Physicians' Fees* made public on 22 March by the Council on Wage and Price Stability (CWPS), this is very much the kind of situation physicians now enjoy and have been enjoying for some years.

The author of the study, Zachary Y. Dyckman, a CWPS staffer, even puts forward the plausible hypothesis that in some circumstances fees have actually gone up in some areas in part *because* the number of physicians per capita has increased. With fewer patients to go around, many physicians are believed to set a "target" income and raise their fees sufficiently to attain it.

The CWPS report says that, last year alone, physicians' fees rose 9.3 percent, or 50 percent more than other consumer prices. "The 1977 increase followed a pattern that spans nearly three decades," it says. "In fact, ever since 1950, physicians' fees have consistently outpaced overall inflation except during the 1971–1974 period of wage and price controls." Indeed, the study indicates that over the entire 1950–1976 period, physicians' fees have increased 75 percent faster per year than prices for other goods and services.

Consumer outlays for physicians' services have increased from $2.7 billion in 1950 to about $35 billion in fiscal 1978, with 60 percent of the increase attributable to higher fees and the rest to population growth and an increase in the type and frequency of services. In 1939, physicians' earnings were less than twice as high as those of a broad category of other technical and professional people, but in 1975 their earnings were four times as high.

In 1976, the median income of self-employed physicians was $63,000. Hospital-based pathologists and radiologists whose incomes are based on a percentage of their departments' revenues in 1975 earned $138,000 and $122,000, respectively, and are said to represent the highest paid medical specialties.

According to the CWPS study, the principal cause of the rapid rise in physicians' fees has changed "dramatically" since the mid-1960's. During the 1950's and early 1960's, the rise in fees "could be traced in large part to anti-competitive practices of organized medicine," as for instance through efforts to restrict the growth of medical schools and the supply of doctors (there were fewer physicians per capita in 1960 than in 1950).

"At the same time, state and local medical societies put additional upward pressure on doctor bills by discouraging both price competition among physicians and the establishment of prepaid medical group practice, the forerunner of the health maintenance organization," the study observes.

Since 1965, it says, anticompetitive practices "have ceased to be an important source of physicians fee inflation," although those "past practices" partly account for the high fees today. (As a matter of fact, regulatory authorities are still uncovering and rooting out significant vestiges of anticompetitive behavior. On 20 March, the Federal Trade Commission announced that it had just entered into a "consent agreement" prohibiting the California Medical Association from influencing fees through preparing and circulating among its 25,000 members studies as to the "relative value" of various treatments and surgical procedures and suggesting how, by applying appropriate "conversion factors," fee schedules can be arrived at. The FTC approved a similar consent order last fall with the Minnesota State Medical Association.)

From the mid-1960's to the present, the inflation in physicians' fees is ascribed chiefly to the growth in private and public health insurance coverage and changes in methods of insurance payment. With about 60 percent of the cost of all physicians' services covered by insurance, and with the physicians being allowed essentially to determine the price of those services, physicians' fees have been largely "exempted . . . from the usually restraining effects of market forces that exist for most other consumer products and services."

The CWPS study describes and analyzes the problem of fee inflation without offering any nostrums for correcting it. The Public Citizens' Health Research Group has suggested, as a long-term approach, abandoning the fee-for-service system and going to the kind of fixed-fee service provided under health maintenance plans. Although the AMA has not, at this writing, issued a detailed critique of the CWPS study, it has said that some of the study's major findings and conclusions are not supported by the body of the report and that it will speak to these alleged deficiencies later.

Another Ford Energy Study: A Hard Look at Coal

Twice already, the Ford Foundation has created something of a stir by issuing reports on energy policy, and it is now announcing a third energy study—this one comparing coal with other energy options available to the United States over the next two decades.

The study will be conducted under a $600,000 grant to be administered by Resources for the Future (RFF), a nonprofit research organization in Washington, D.C. Hans H. Landsberg, codirector of RFF's Center of Energy Research, will direct the study.

Members of the 20-member study group will include an unusually diverse mix of personalities for a foundation-sponsored undertaking. Among the scientists and other scholars in the group are Kenneth J. Arrow, a Harvard economist and Nobel laureate; Francis M. Bator, a professor at Harvard's Kennedy School of Government; George W. Rathjens, a professor of government at the Massa-

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was the program director for Skylab in 1973, said, "When Skylab was designed, we told the contractors to be certain only that the parts would be operable for 9 months, the length of the period for the manned missions. We didn't design it any better because we couldn't identify a task for it that was sufficient to convince the Administration or Congress to spend extra money and keep it active over a long period of time." Scientists at NASA's Marshall center wanted to continue communicating with Skylab "but we just didn't have the money," Schneider said. Instead, the satellite was shut off, and a small parcel of film, food, cloth, paper, and electrical wire was left on board to determine the effects of long-term weightlessness, the only continuing Skylab "experiment." At the time, there apparently was a feeling that NASA

chusetts Institute of Technology; and Theodore B. Taylor of Princeton, a former nuclear weapons designer who more recently has been trying to work out practical visions for a solar world.

From industry there are individuals such as physicist Richard L. Garwin of IBM and S. William Gouse, chief scientist of the Mitre Corporation and former head of the old Office of Coal Research at the Department of the Interior. Other members of the group include an international civil servant, Edward R. Fried, an official of the World Bank, and two formerly high-level officials in the U.S. government, namely John C. Sawhill, one time administrator of the Federal Energy Administration, and Robert W. Fri, formerly deputy administrator and acting head of the Energy Research and Development Administration. None of the mainline environmental advocacy organizations are represented on the study group, but Grant Thompson, deputy director of the Washington-based Environmental Law Institute, is a member.

Among the questions to be considered in the study are:

- To what extent will greater coal consumption increase the risk of harm to human health and the environment?
- What are the technological, environmental, and institutional constraints affecting plans for increased coal production and coal conversion?
- What are the costs and benefits of increased energy conservation, particularly with respect to its effect on economic growth and welfare?
- To what extent can other energy options, including the nuclear and solar options, be expected to meet the nation's energy needs by the end of the century?

The first Ford Foundation energy study was the controversial one directed by S. David Freeman and issued in 1974. It was ahead of its time in its heavy emphasis on the need for conservation. The second Ford Foundation energy report was *Nuclear Power Issues and Choices*, published last spring. This report was notable chiefly for its recommendation for a deferral of nuclear fuel reprocessing and of development of the breeder reactor.

Briefing

An Alaska Lands Bill to Please Environmentalists

The environmental legislation that holds top priority this year with the Carter Administration, and with the national environmental groups themselves, is the Alaska lands bill. So far, prospects for passage of a strong measure that would give protected status to vast new areas are still looking up, as was demonstrated on 21 March when the House Committee on Interior and Insular Affairs reported legislation which the environmentalists' Alaska Coalition regards as a "good bill."

Enactment of legislation in 1978 to complete the "four systems"—that is, the systems of national parks, wildlife refuges, national forests, and wild and scenic rivers—would represent a final major step toward dividing up Alaska. The Statehood Act of 1959, which allowed the new state to select 103 million acres (or about a third of Alaska), and the Alaska Native Claims Act of 1971, which allowed the natives to select 44 million acres, represented earlier steps toward deciding what is to become of the United States' last great undeveloped frontier region.

There is little doubt that a bill will be passed, because final selection and patenting of most of the state's and some of the natives' land cannot proceed until Congress acts to complete the four systems. The real question has been how Congress will deal with potential resource conflicts, as in defining the boundaries and the degree of protection for new park and refuge areas that may contain significant mineral deposits or oil and gas reserves (*Science*, 4 November 1977).

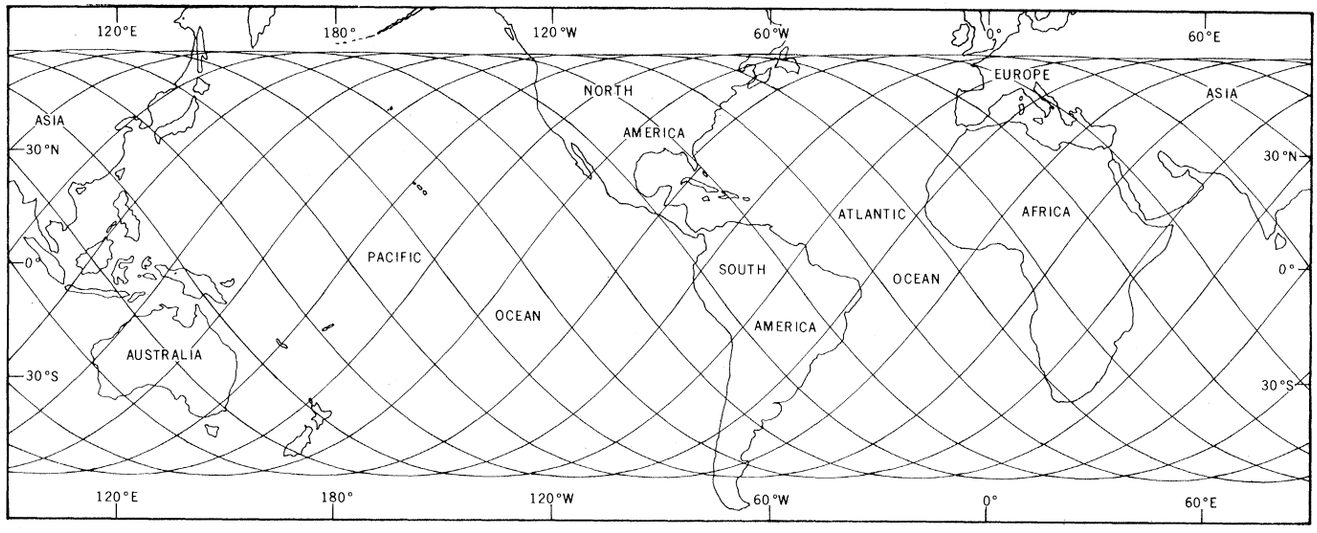
The Interior Committee bill, reported out on a 32 to 13 vote, would place another 95 million acres in the four systems. Counting the some 48 million acres already so classified, there would be a total of about 143 million acres in these systems altogether. Of this total, about 73 million acres would be designated as wilderness, from which all development would be excluded except where valid mining claims or oil and gas development rights have been established already. A proposal by Representative Lloyd Meeds (D–Wash.) to cut the wilderness acreage by 40 million acres had the support of mining industry and oil and gas lobbyists and failed by only four votes.

The environmental lobbyists did not prevail on all of the issues put to a vote. For instance, a major disappointment for them was the denial of wilderness classification for the spectacular Misty Fjords area—where the U.S. Borax Corporation has made a major molybdenum discovery—in the Tongass National Forest in southeast Alaska. With respect to the Arctic National Wildlife Range on the North Slope, which some petroleum geologists regard as favorable to the discovery of another "Prudhoe Bay," the environmentalists experienced some losses as well as gains. The range would be closed to commercial oil and gas exploration and development, but a significant part of it would be opened to a government-run program of exploration.

Sponsors of the bill, such as Representative Morris Udall (D–Ariz.), the Interior committee's chairman, say that access to about 70 percent of all of the land in Alaska that has mineral potential would not be affected by the legislation.

The Alaska lands bill now goes to the House Merchant Marine and Fisheries Committee, which has jurisdiction over wildlife refuges. If, as expected, the bill is sent to the floor with the strong support of this committee as well as the Interior committee, its chances for House passage in pretty much its present form are likely to be excellent. Its fate in the Senate, where it will go to the Committee on Energy and Natural Resources, headed by Senator Henry M. Jackson (D–Wash.), is an open question. Jackson represents a complex blend of conservationist and development tendencies, and nobody knows how he will finally come out on the Alaska lands issue. But the environmental lobbyists have shown that they can generate significant grass roots support on this issue, and this should count in the Senate as it has in the House.

Luther J. Carter



Only a portion of Skylab's flight paths, which are always between 50 degrees North and 50 degrees South latitudes, are indicated on the map. NASA has no idea where the satellite's parts will fall when it reenters the earth's atmosphere.

would one day have the funds to make use of it again: When the last signal was sent to Skylab, one of the flight controllers was said to remark, "Well, that ought to be good up there for the next 10 years, or at least into the next Administration."

Unfortunately, this prediction was wrong. Moreover, by the time NASA realized it, the agency had begun to develop ideas for the specific uses of Skylab that had proved so elusive earlier, during the budget process. The limitations of the shuttle for in-space experiments and long-term flights had proved to be severe, and Skylab was increasingly attractive simply because, in the words of one NASA engineer, "It is a large, potentially habitable volume, and what's more, it's already up there, in space." Among the possible uses for it are a docking with the European-built Spacelab and a docking with a mock-up of itself built to train the original Skylab crews. If attached to Skylab, the mock-up would be a forerunner to NASA's long-desired space station. The agency is intrigued by this possibility because the eagerly hoped-for infusion of new funds into the space program has not yet occurred. Indeed, it is a telling fact that the constraints in budget that originally prompted NASA to build a bare-bones Skylab now are forcing the agency to find ways to wring even more programs out of it.

Undoubtedly, the circumstances of these earlier constrictions haunted the team of scientists and engineers dispatched by NASA to its tracking station on the tip of St. David's Island in Bermuda in early March. In the face of growing agency interest in Skylab's reuse, as well as fear of the embarrassment that followed the fall of the Russian satellite, the team of eight men—four from NASA's Marshall center and four from NASA's Johnson center—faced a difficult assignment: They were to communicate with Skylab for the first time in 4 years and begin a series of steps that could slow the satellite's orbital descent, adding just enough time for the shuttle to dock with it. The lapse in time from the original Skylab missions caused difficulty in getting the team together: All of the original Skylab offices at NASA had been disassembled and the scientists dispersed, so for the eight team members, the Bermuda trip became a reunion.

The Bermuda tracking station, which is situated on an isolated portion of the American Kindley Naval Air Station, was chosen for the mission because it was the only one of NASA's 12 stations worldwide still able to transmit signals in the ultrahigh-frequency (UHF) wavelength range, which was used widely by NASA at the time Skylab was developed but since has been replaced by microwave communications. Skylab's passes over Bermuda on 6 March, the first day of contact, occurred in the evening and lasted 8 minutes each. During that time, the station's computers and big parabolic radar antennas, relying on last-minute data supplied by NORAD, had to pinpoint Skylab's location at the instant it came over the horizon and then administer what in effect was a prince's kiss: a command to the satellite's solar-powered receiver to turn on its telemeter after 4 years of sleep. The telemetry system sends back various indications of the health of the equipment on board.

On the first pass, the NASA team, which was headed by Herman Thomason and William Peters, proceeded cautiously. About 40 seconds into the pass, the telemeter in the large module that once housed the crews began sending back information. But, 2 minutes later, the stream of data suddenly stopped, and the controllers on the ground tried frantically to figure out what went wrong. Ultimately, they determined that the satellite was rolling so quickly—about 1 degree per second—that the large panel of solar cells on Skylab had stayed in the sunlight for only those 2 minutes, rotating out and then failing to reactivate the telemetry. Arriving at such a conclusion was not easy, however. Ascertaining exactly what is happening on an unmanned spacecraft floating 220 nautical miles above the earth requires substantial powers of inductive reasoning and no small amount of guesswork.

Eventually, by the week's end, the team was able to charge two of the satellite's batteries, receive information from the telemetry system, and determine that the craft's main computer still may be operated. According to Thomason, the efforts thus far were a success. The telemeter revealed that the pressurized bottles aboard Skylab, which could be vented in sequence to change the satellite's attitude and stop its rotation, contain an ample supply of gaseous nitrogen. The scientists also know the exact pitch of the craft and, therefore, how much it must be changed to minimize the atmospheric drag.

That will be the most difficult—and most critical—part of the effort. The attempt will not even be made until mid-April, when NASA scientists will have thoroughly studied the information gleaned in Bermuda, and after the necessary UHF communications equipment has been reinstalled at the Johnson Space Center in Houston and a NASA tracking station in Madrid, Spain. If the attitude correction, which will be at-

tempted from these two locations, is successful, NASA estimates it can add anywhere from 3 to 5 months to Skylab's orbital life-span.

This would ensure that the third test shuttle would reach it—*if* the shuttle program is started on schedule. And according to William Taylor, the shuttle's budget director at NASA, "The probability of launching the first shuttle on schedule in March is very, very low." In fact, the agency is said to be running 4 months behind on the first launch. As of now, the agency is behind on its testing program for the shuttle engine, and faces the probability of even further delay as a result of a critique of the shuttle engine's safety currently under way at the National Academy of Sciences. Aller says that if the third shuttle cannot be launched on time, the Skylab mission could be moved forward even further, to the second test shuttle.

Total Loss More Than $1 Billion

Such a move raises questions about the cost and safety of performing the mission with a craft that will have been flown into space only once before. Aller admits that "we would have liked to have more experience with it [the shuttle] if it was feasible" prior to the Skylab mission. Taylor said that no estimate of the costs of moving the mission up has been prepared, but that total costs to the shuttle program "will be less than $1 million." Added to this will be the cost of speeding up development of the teleoperator retrieval system, although no estimate of this total has yet been made either. Moreover, if Skylab cannot be rescued in time, NASA will lose the satellite itself, plus the benefits of two studies on Skylab's reuse, plus the cost of the efforts to slow the satellite's descent. The total loss would come in at more than $1.1 billion. The teleoperator retrieval system itself will have lost its primary justification if Skylab comes down, although Aller claims that it would be a useful device on hundreds of missions in the next decade, with or without the Skylab mission. However, a staff member on the Senate subcommittee on Science and Space, which has been monitoring the recent Skylab predictions, noted that "without the Skylab mission, an entirely new case will have to made before we approve any funding of the teleoperator."

For this reason, NASA officials are understandably nervous about the entire issue of Skylab's plight. Although NASA has known since last November that Skylab was in trouble, it made no formal announcement about it until the middle of the Russian Cosmos incident. In all of their public statements, NASA officials have emphasized that Skylab contains no nuclear materials, and that 70 percent of its orbit is over water (70 percent of the earth is covered by water). They claim that the chance of Skylab causing any physical damage on earth is slim.

Against this background the facts remain that NASA went to a lot of trouble back in 1974 to be sure that Skylab would be around 10 years later, and that trouble was all for naught. In failing to boost it to a high enough orbit, the agency was a victim of circumstances. Once this had occurred, however, the agency delayed acknowledgment of and action on a warning by another federal agency that it was proceeding headlong into a troublesome situation. Attuned as it was to the political environment in which it operates, and probably the fact that this Administration has yet to formulate a formal space policy, NASA has all along done what it considered best. Now, it seems, all that it did was not the best at all.—R. JEFFREY SMITH

Government Seeking Ways to Encourage Aquaculture

Americans are not big fish-eaters, consuming 12 pounds per capita each year, which is peanuts compared with the 70 pounds per capita consumed in Japan. Nonetheless, this country imports more than half its fish, and the domestic haul has not increased since 1970. Thus we are now witnessing what may be a timely surge of federal interest in aquaculture.

Most people, if they think about aquaculture at all, have the vague notion that if we ever needed to cultivate fish and shellfish it would be easy to do so. Not so. As a report released this year by the National Academy of Sciences* indicates, most coastal areas are unavailable for aquaculture because of pollution or competing uses. Much research, particularly interdisciplinary work, needs to be done on the raising of fish in controlled environments. New enterprises are hazardous economically and are discouraged by a maze of government regulations. And no federal agency has been responsible for coordinating research or developing national policies for aquaculture.

There are some people who have been trying to do something about the situation for several years. The Commerce Department's National Oceanic and Atmospheric Administration (NOAA)—which puts more than $8 million a year into mariculture (marine aquaculture)—has had an interagency committee working for 2 years on devising a national policy. Last year the omnibus farm bill (the Food and Agricultural Act of 1977) for the first time explicitly mentioned aquaculture and designated the Department of Agriculture (USDA) as "lead agency" for research, extension, and education thereon. Finally, a number of bills have been introduced in Congress to encourage aquaculture, one of which passed the House on 15 February. That bill, introduced by Representative Robert L. Leggett (D–Calif.), chairman of the fisheries and wildlife subcommittee of the Committee on Merchant Marine and Fisheries, would make hundreds of millions of dollars available for loans and insurance to aquaculture businesses. It also designates Commerce as the lead agency, thereby setting the stage for a turf battle between the USDA and Commerce.

Aquaculture responsibilities are now divided among three cabinet agencies, the third being the Department of the Interior. Most aquaculture research is conducted under the auspices of Interior's Fish and Wildlife Service (fresh water) and NOAA (salt water). The FWS, which is oriented toward sport fishing, operates research stations, development centers, and hatcheries. NOAA puts about $10 million a year into aquaculture through its Sea Grant program and through the laboratories of the National Marine Fisheries Service. The USDA's involvement in aquaculture research has been minimal, and services in the field have mostly been limited to pond-digging and advice for catfish farmers.

**Aquaculture in the United States: Constraints and Opportunities* (Board on Agricultural and Renewable Resources, National Research Council, Washington, D.C., 1978).

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