Letters

Mill Tailings: Reclamation Costs

Mark Crawford's article "Mill tailings: A $4-billion problem" (News and Comment, 9 Aug., p. 537) incorrectly states that "milling companies, many of which are owned by major corporations like . . . Exxon . . . , want to shift 55 percent of the reclamation costs to the electric utility industry and another 30 percent to the federal government."

We are not a supporter of such legislation and have stated so when asked. I regret that we were not called to clarify our stance. The two uranium properties we are reclaiming are being done so at our expense and in compliance with applicable state and federal standards.

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Hydroelectricity: Environmental and Social Effects

The editorial, "Electric power from the north" by Philip H. Abelson (28 June, p. 1487) said little about the adverse environmental and social effects of northern hydroelectric development. Robert Carson's letter (30 Aug., p. 815) lists several environmental considerations related to dam construction (including flood control and recreation), but does not discuss other environmental matters of importance in the subarctic.

One kind of environmental disaster that could result from northern hydroelectric projects occurred when 2200 caribou drowned while attempting to ford the Caniapiscau River (*1*). Two weeks earlier, Hydro-Quebec had opened a spillway, and water from a reservoir had discharged into the river.

But the more important social consequences of northern development were not mentioned by Abelson, or by Carson. During the James Bay project, much of the homeland of 9000 Cree and Inuit people was flooded and therefore taken from them. These people were not involved in any of the planning of the project and were firmly opposed to it (*2*). I trust that Americans, when they buy cheap and "clean" power from the North, will bear this in mind.

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References and Notes

1. Toronto *Globe and Mail*, 4 October 1984, p. 1.
2. B. Richardson, *Strangers Devour the Land* (Macmillan, Toronto, 1975).

Exporting Education

In Gina Kolata's article "Americans scarce in math grad schools" (News and Comment, 15 Nov., p. 787), it seems to be taken for granted that the substantial number of foreign graduate students in Ph.D. programs in American universities represents a *problem*. It seems that the implicit explanation for this phenomena is that there are insufficient incentives for American students to pursue Ph.D.'s and that the American labor market for mathematicians is being filled with Japanese, Indian, and Mexican graduate students; the jobs in mathematics are analogous to "stoop labor" jobs, taken by legal or illegal immigrants. There may be some truth in this, and if so there may be a "problem," the solution to which is to make mathematics a better paid profession, for example.

But I strongly suspect that a quite different explanation is at least as likely, and that is that American universities are the world's lowest-cost providers of advanced training in the mathematical sciences. And just as we have turned to the Japanese to supply us with video cassette recorders, because they provide the best product for the lowest cost, so the Japanese and others have turned to us to supply them with the service of training mathematicians. The fact that half of the students return to their homes bears this out. We should regard this as an opportunity, not a problem! Why shouldn't the United States become (if it isn't already) the leading exporter of the service of education in the world? Let the Japanese make VCR's and the Koreans make steel; we will sell education. We need to be careful with pricing, of course, so that we don't sell for a price lower than our costs. But the benefits of exporting educational services, it seems, are both financial and political.

Perhaps the headline for the article should have been, "Foreign students eager to purchase American math training."

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The Space Station

The article by K. J. Frost and F. B. McDonald (21 Dec. 1984, p. 1381) attempting to justify a permanent manned space station on scientific grounds deserves detailed comment because it presents a weak case for such a facility.

One major proposed use of a space station is for in-orbit assembly, refurbishment, and repair of astronomical observatories such as the Space Telescope, the Gamma-Ray Observatory, and some proposed but not yet authorized facilities, such as the Advanced X-Ray Astronomy Facility (AXAF), the Space Infrared Telescope Facility (SIRTF), and other observatories. These facilities can be serviced by a space station only if their orbits intersect that of the space station and preferably if their orbits are nearly identical. However, identical orbits may not be scientifically optimal or even desirable. For example, the currently operating x-ray satellite, EXOSAT, has a very eccentric orbit to maximize its dwell time on specific sources. Other eccentric orbits, each in its own optimal plane, may be desirable for AXAF and SIRTF. Furthermore, observatories such as the Space Telescope are designed for infrequent repair and refurbishment missions—about once every 5 years—which can be accomplished by a much less costly shuttle mission. Of the various space observatories listed in table 1 of the article by Frost and McDonald, only the large deployable reflector appears to have the dimensions that might require space station assembly rather than a shuttle launch and assembly.

The suggestion that the space station be used for future planetary probe assembly, fueling, and inspection is hard to

justify. No such large planetary probes are known to us to be on the drawing boards, and operations such as fueling could be accomplished by rendezvous at the most desirable altitude for the mission rather than at a fixed altitude for all missions. The suggestion of an inspection in orbit ignores the fact that engineers have developed a successful program of testing and inspection on the ground. It is not clear why a space crew would be instructed to open a carefully prepared spacecraft for inspection.

In summary, the *scientific* justifications for a manned space station are manifestly inadequate. There may be other justifications, such as a first step of a manned mission to Mars or desire to show the world that we can operate a manned space station, but those reasons should not be confused with scientific reasons. I agree with T. M. Donahue, chairman of the Space Science Board, who wrote: "We have not been able yet to identify missions that would be enabled by the space station, except possibly in the field of space medicine" (*1*).

When one considers the obvious economic necessity of maintaining careful control of the federal budget, it is clear that the need for a space station should be most thoroughly investigated before such a program is authorized and funds for its planning are appropriated.

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References

1. T. M. Donahue, paper presented at the AIAA/NASA Symposium on the Space Station, Arlington, Va., 18 to 20 July 1983.

In his thoughtful letter, Wallerstein stresses what appear to be some of the constraints associated with astrophysical observatories on platforms that co-orbit with the space station along with several other questions about the station. In my view, he underestimates the scientific impact of the "great observatories"—the Hubble Space Telescope, the Gamma-Ray Observatory (GRO), the Advanced X-Ray Astrophysical Facility (AXAF), and the Space Infrared Telescope Facility (SIRTF)—and the necessity to maintain these over a period of 10 to 15 years. Detailed studies concerning AXAF and SIRTF have shown that these missions are compatible with orbits that can be serviced from the space station. The Space Telescope and the GRO will also be accessible from the station. In our view the more complex servicing of these missions will extend significantly beyond what could be supported from the space shuttle. The Orbital Maneuvering Vehicle is planned as part of the station's initial operating capability and will provide the means for bringing the spacecraft to the station.

The position of the Space Science Board was somewhat different from what is implied in Wallerstein's statement. The Board's view can be summarized as follows: A space station is not needed to carry out the NASA science missions planned for the immediate future. "In the longer term, the Space Science Board sees the possibility that a suitably designed Space Station could serve as a very useful facility in support of future space science activities" (*1*).

Over the last 18 months, the scientific community has participated extensively in helping to define the Space Station's capabilities. In particular, the Task Force on Scientific Uses of the Space Station, under the chairmanship of Peter M. Banks at Stanford University, has had a significant impact. The task force has concluded that the space station can be of great value to the advancement of space research. Many other smaller-scale studies and working groups are also providing scientific support and guidance.

Frost and I tried to stress the point that our present limits on putting experiments in space are both technological and managerial in nature. The space station is an opportunity to move those limits with creativity and imagination. In the future we hope to get samples from Mars, Venus, and comets; fly large astronomical interferometers and gravity wave detectors; study collective phenomena in various forms; and do experiments in life sciences in particular, on cardiovascular problems and on calcium loss from bones, and, in general, on understanding the role that gravity played in shaping life on Earth. The space station as a laboratory, as a place for assembly and integration of new experiments and spacecraft, and as a center for maintenance and refurbishment provides us with a new capability that can be of invaluable service to science. It is important that we in the space science community make sure that this potential is realized.

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References

1. *Space Science Board Assessment of the Scientific Value of a Space Station* (National Research Council, Washington, D.C., 9 September 1983).