NRC Report on the Space Station

The recent National Research Council (NRC) report on the space station (*1*) (News & Comment, 18 Sept., p. 1403) finds that the management structure is not adequate, a better cost estimate is needed, the transportation system required is marginal, the estimated cost just to get the system in place has grown to close to $30 billion, total system studies do not exist which allow estimation of the probably equally large operational and experiment costs, the program is still in a state of flux, and the long-term objectives have yet to be set. The latter is especially important since the station is planned to be the focus for the U.S. space program for about three decades. Even a modest grant or research proposal having such shortcomings would be unlikely to win approval without overriding political or scientific justifications.

In spite of these shortcomings the NRC report recommends starting the space station primarily for prestige purposes and because of its value for microgravity life sciences and materials research. The justifications given, however, are not overriding. For example, not addressed in the report are such questions as what the importance is of such microgravity research relative to the very major cost of the space station, what effects space station costs will have on all the space sciences with the current budgetary constraints, how the station can follow the U.S.S.R. station by a decade and still accomplish the prestige objectives, and whether the station being recommended is capable of supporting the full range of possible long-term objectives from which a selection must eventually be made. As one example, if the primary objective selected is that of being a step in the manned exploration of the solar system (*2*), then the present station appears inadequate from at least the standpoints of life sciences and space technology: the only gravity level it can probably ever place man in for long durations is zero. A zero gravity space environment for man is no more a requirement than a zero pressure environment and may well be the wrong approach (*3*). Similarly, without knowing the station's long-term objectives, there is no way of knowing in what orbit it should be placed. Once it is in orbit, its inclination probably cannot be significantly changed.

While the NRC report has done an important service in assessing the status of the space station program, a comparable effort that focuses on the programmatic aspects of the space station is sorely needed before its initiation, since the station will not only directly affect many current science programs but will also be a legacy left for future generations of scientists. Unless the legacy is both affordable and more than just "useful," it will be counterproductive.

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Braced for countless screams of outrage, I propose that we save $50 billion by not building a space station. Instead, let's get one many years sooner at perhaps one-tenth the cost by contracting with the U.S.S.R. to build for us an addition to its space station. Earth does not need two space stations. It does need more international cooperative endeavors.

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Mass Bleachings on Atlantic Coral Reefs

Mass mortalities of tropical marine animals may be increasing in frequency, geographic range, and number of species and individuals involved (*1, 2*). Recent mass mortalities of fishes in 1980 (*2, 3*) and urchins in 1983 and 1984 (*4*) occurred throughout the Caribbean Sea. In 1983 extensive bleaching (loss of zooxanthellae or pigments, or both) and mortalities of corals occurred in the eastern Pacific, and smaller scale bleaching and deaths of corals and other coelenterates occurred in Panama, Costa Rica, Colombia, and Venezuela in the Caribbean (*5*). Local bleachings of corals are sometimes reported after heavy rains (*6*). A minor outbreak of bleaching of corals was examined in Puerto Rico in 1981, and a ciliate, found in the tissues of the affected corals, seemed to be attacking the zooxanthellae (*7*).

Coelenterate bleaching far more extensive than any ever before reported in the Atlantic is now occurring. For the first time some sponges and many species of corals are being affected. The process is occurring in depths of from 1 to 40 meters. Tissue sloughing and mortalities are beginning to occur, and a mass mortality of corals and other coelenterates may be imminent. In the last 4 months in Jamaica (*8*), throughout the Florida Keys (*9*), and in south Florida (*10*); the last 2 months in Puerto Rico; the last 7 weeks in the Bahamas (*11*), and the last 6 weeks in St. Croix (*12*) and St. John (*10*), stony corals (Coelenterata: Scleractinia), fire corals (Milleporina), gorgonians (Gorgonacea), sea anemones (Actiniaria), zoanthids (Zoanthidea), and sponges (Porifera: at least two orders) have become bleached. The phenomenon seems to be spreading both geographically and in extent. If the bleaching is a precursor of mass mortalities (as it was in Pacific corals), then the ecology of many Atlantic coral reefs could soon be profoundly different.

In Puerto Rico, 12 species of scleractinians and 2 species of hydrocorals were observed bleached off the southwest coast. In one of the major reef builders, *Montastrea annularis*, portions of colonies showed necrosis. Gorgonians (for example, *Erythropodium caribbaeorum*) and zoanthids (including *Palythoa caribbaea*) have also suffered extensive bleaching. A greater incidence of intra- and intercolonial bleaching has occurred in *M. annularis* and *Agaricia agaricites* on surfaces more directly exposed to light (*7*).

The bleachings may be caused by unusually high temperatures (*8, 9*)—a suggested cause of the mass mortality of fish (*3, 13*); by light-related phenomena (*7*)—ultraviolet radiation is known to damage zooxanthellae (*14*); or by secondary pathogens following physical stress, as was also suggested in the case of the fish mortality (*15*). Disease (other than of the zooxanthellae) seems unlikely to be the primary cause, as does sediment damage (*16*). The bleachings are studied in Puerto Rico, St. Croix (*12*), Jamaica (*8*), the Bahamas (*11*) and Florida (*9, 10*). Our Caribbean Aquatic Animal Health Laboratory (*17*) is very interested in documenting the geographic extent, timing, species affected, and other details of this phenomenon and in making the data quickly available to all interested researchers. This information may be vital in finding the cause of the event.

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Oil and Gas Discovery Rates

I would like to point out an omission in William L. Fisher's discussion of the future productive potential of the U.S. oil and gas resource base (Articles, 26 June, p. 1631). Fisher draws strong conclusions about past and future trends in oil and gas discovery rates that were presumably based on two different data sources. Fisher notes that Root's (*1*) projection of future natural gas discovery rates for the 1980s underestimated actual discovery rates. However, Root's analysis was based on discovery data reported by the annual reserve and discovery report of the American Petroleum Institute (API) and American Gas Association (AGA) (*3*), a series that ended in 1979. The data source for Fisher's "update" of Root's model [figure 2 in (*1*)] is not referenced, but presumably his post-1979 data is from the Department of Energy's (DOE's) annual report of reserves and discoveries, which began in 1977 (*3*).

Differences between the two data series may affect Fisher's conclusions about gas discovery rates for the period from 1978 to 1985 because the two series are not strictly comparable. For the 3 years that the data series overlap (1977 to 1979) the DOE series shows consistently higher levels of reserves and discoveries than the API series. It is highly likely that the observed differences were due to the different methodologies used in collecting the data rather than a change in actual reserves (*4*). Combining the two data series in a discovery rate analysis covering the post-1979 period will therefore tend to show an increase in that rate due simply to the shift in the data source alone, regardless of any real changes in the discovery rate. Two attempts have been made to produce linked time series that join the two time series (*4*).

Changes in petroleum discovery rates in response to price and drilling conditions of the early 1980s are important to an asessment of the potential to expand or at least maintain production. As Fisher describes, there undoubtedly was a real increase in discoveries due to unprecedented drilling rates from 1980 to 1984, but the magnitude of that change relative to the pre-1979 period is more difficult to assess precisely than Fisher's analysis suggests because of the lack of consistent data.

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Fisher gives a clear account of the effect of reservoir heterogeneities on producibility of a significant portion of our domestic petroleum reserves and points out the consequent need for more infill drilling. But any recovery from the one-half of our reserve base that he classifies as "immobile" he relegates to high-cost, advanced-case, tertiary techniques that will alter either the character of the rock or the physical state of the fluid.

There is, however, growing evidence that enhanced versions of conventional secondary (flooding) processes may recover a large fraction of such oil at low cost. In this industry we tend to ignore the effects of chemical properties of the oil on producibility while concentrating on reservoir parameters. Almost all petroleum contains surface-active constituents that are strongly adsorbed at water, rock, and other high energy surfaces. This leads to oil wetting of rock and, possibly, to in situ formation of water-in-oil emulsions. These adsorbed constituents—generally lumped under generic names as "asphaltenes," "maltenes," and "petroleum resins"—form thick, viscous, or solid interfacial films that create high energy barriers to the displacement processes of water-wetting and demulsification (*1*).

The difficulties of obtaining realistic relative permeability data, a historical bias toward the assumption of water-wet conditions, and our inability to account accurately for the large increases in reservoir oil phase viscosity resulting from in situ emulsification lead to an explanation of the general finding of much lower actual secondary recovery production than that predicted from fractional flow theory.

Work on enhancement of secondary processes is advancing on a wide front. Recent progress has been made in enhancing wet-steam stimulation systems with a class of low-cost, nonionic, nonmicelle-forming surfactants (*2*). At low concentrations they appear to form thin, hydrophilic films at oil-rock and oil-water interfaces and to bring about large increases in production of oil that, it appears, would otherwise be immobile.

The first study of these reagents in a full-scale waterflood was recently completed (*3*). Their use resulted in a substantial increase in production and calculation of a threefold increase in the relative permeability ratio of oil to water.

Such findings strongly suggest that progress in the design of enhanced secondary processes will eventually allow the mobilization of a large fraction of the 240 billion barrels of reserves now labeled "immobile." Enhanced secondary processes conceivably could add 80 billion barrels or more of low-cost producible reserves to the 80 billion barrel addition that Fisher visualizes for infill drilling.

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