building. When employment was no problem, the general attitude among engineers in the defense industry was that they were doing recognized engineering jobs, so that they were obviously professional engineers.

As in the case of the medical practitioners during the depression of the 1930's, the present financial hardships thrust upon engineers may be the irritant required to cause them to think seriously about what their profession is, what it should be, and what their societies should do to bring about a correspondence between the two.

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The Space Shuttle

The conflicting analyses of the costs and benefits of the space shuttle that were carried out by Rand and by Mathematica (News and Comment, 11 June, p. 1112) have stimulated controversy over this space transportation system. The costs and benefits of the shuttle constituted a major topic of discussion at the recent Space Systems Meeting of the American Institute of Aeronautics and Astronautics.

The cost of the full operational space transportation system is now put at $12.7 billion, although new cost-cutting efforts may reduce that figure. This cost includes shuttle development, test, and production; establishment of facilities; and a reusable orbit-to-orbit shuttle or "space tug" that would be used to emplace and retrieve satellites in orbits up to the geosynchronous.

According to the Office of Management and Budget (OMB), the shuttle must be wholly justifiable on the basis of economic return, and the system must generate this return at a 10 percent discount rate. Such a conservatively high rate reflects the relatively low priority now afforded to space ventures.

Lindley (*1*) reports that the OMB specifications would be met by a traffic rate of 39 flights per year, much lower than the recent rate of launches by all users (NASA, Department of Defense, Comsat, and so forth). The specifications would also be met by a continuing level of space spending, again by all users combined, of $3 billion per year—much lower than is the case even today. Woodcock (*2*), analyzing shuttle design requirements after the methods applied to new commercial jet transports, also concludes that the current designs are adequate to meet the OMB requirements.

Shuttle benefits include reduced launch costs, elimination of launch losses through an intact-abort capability, on-orbit refurbishment and checkout of satellites with attendant simplification of satellite design, and optimal use of man in spaceborne investigations. Two types of payloads would be carried: those physically separated from the shuttle and those which remain attached, subsequently returning to Earth. These classes are referred to, respectively, as "automated satellites" and "sortie missions."

The automated satellite represents a development of the classic unmanned satellite. Salee (*3*) proposes an analytic method for determining the cost reductions such satellites might achieve. He suggests maintenance of the satellite by routine shuttle revisit, rather than relying upon redundant or high-reliability design. Salee concludes that such satellites should use available hardware, with new development eschewed in favor of proven designs. The resulting payloads would feature low technological risk, high credibility of cost prediction, and lower research and development cost. He reports a saving of 50 percent in a typical case, the High Energy Astronomical Observatory.

The sortie mission represents a fundamentally new mode of space operation. Bader and Farlow (*4*) propose that scientific sortie flights could resemble the experiment-carrying aircraft flights of the NASA program; their conclusions are echoed by Stuhlinger and Downey (*5*). In sortie flights, the scientists themselves would furnish the instruments, which could be of standard laboratory design, and they would accompany them to orbit. The instruments would require little or no space-qualification, and the scientists would require no astronaut training.

This approach contrasts with current methods, in which space experiments require the involvement of hierarchies of designers, managers, review and evaluation boards, contractors, and NASA centers. The time from experiment proposal to flight is 3 to 5 years; the cost, $30,000 per pound and up. Shuttle sortie experiments could be carried out at an equipment cost of $100 to $1000 per pound. Time from proposal to flight would be months or even weeks. Most important, the scientist could spend his time actually preparing his experiments, rather than overseeing exchanges of documents with contractors and designers.

Specialized research on research and application modules, or RAM's, would also take place (*6*). Hook and Carey (*7*) discuss the discipline areas that would benefit. In astronomy, the shuttle could support x-ray and infrared studies, as well as a 3-meter, diffraction-limited, optical telescope (900 to 10,000 angstroms) (*8*). Life sciences research at zero gravity could yield new insights. In materials science investigations, large crystals and unique composites might be produced at zero gravity, with possible commercial application. Engineering investigations in space technology and communications research could also use the shuttle in the sortie mode.

In the field of earth observations (*5*), high-quality, low-cost information could be gathered about crop yields and diseases. Other observations might involve earth physics, forestry and resource management, land-use patterns, and locations of new mineral or seafood resources. Water resource management and hydrology, geography and cartography, and oceanography might also benefit, as well as air and water pollution research. Disaster relief would benefit from the quick response time of a sortie mission for surveys of the damage and coordination of relief.

The scientific benefits of the shuttle do not in themselves justify its development; the $12.7-billion cost to establish this system is larger than the amount the National Science Foundation will receive during the same time. Defense, commercial, and applications benefits combine as well to furnish the justification. Nevertheless, the scientific benefits should not be overlooked. For the first time, laboratory-type investigations may be carried out in space, not by scientist-astronauts, but by scientists.

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2. G. R. Woodcock, *AIAA Paper 71-810*.
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5. E. Stuhlinger and J. H. Downey, *AIAA Paper 71-814*.
6. W. L. Breazeale and J. T. Milton, *AIAA Paper 71-813*.
7. W. R. Hook and W. T. Carey, *AIAA Paper 71-812*.
8. R. J. Kirby and R. S. Johns, *AIAA Paper 71-815*.
9. The above reports are obtainable from the American Institute of Aeronautics and Astronautics, Order Department (JF), 1290 Avenue of the Americas, New York 10019. Price per copy, $2.