an "in-orbit infrastructure" that might even rival NASA's plans for a space station, although the scale of the project has yet to be defined. In parallel with ESA's efforts, the Centre National d'Etudes Spatiales (CNES), the French national space agency, is also studying space transportation systems using robots rather than men in space.

ESA plans to assess the results of its own studies and those of CNES in 1984 in time for an operational launch system by the mid-1990s. But NASA's invitation introduces a new dimension. Clearly, the agency must choose between the independent route and collaboration. That will be a difficult political decision that could make the much discussed, although as yet unscheduled, conference of European space ministers particularly opportune.

The NASA invitation will also sharpen the division between those in Europe who advocate almost total independence in space and those who would rather spend their money on hardware for launch systems developed largely with US money. Much will depend on the price of European space independence, certain to be tempered by what assurances the United States can give that the space station project will not be abandoned when funds have been committed. ESA will be looking for an intergovernmental agreement that provides greater security than the memorandum of understanding in force when NASA decided to abandon the spacecraft it was due to launch as part of the international solar polar mission.

Judy Redfearn

US nuclear power

Risk underestimated?

Washington

A Nuclear Regulatory Commission (NRC) study of actual nuclear power plant operations from 1969 to 1979 has concluded that the likelihood of a major accident — one that could lead to severe damage of the reactor core — has been seriously underestimated.

According to the new findings, a major accident could have been expected every 200 to 600 reactor-years during the period under study. The United States has at present 74 commercial reactors, so that translates to one major accident every three to nine years. NRC's 1975 Reactor Safety Study (also known as WASH-1400, or the Rasmussen report), which has been frequently criticized for underestimating the risks of nuclear power, put the frequency of major accidents at one every 20,000 reactor-years. NRC recently set a safety goal of one every 10,000 reactor-years.

The new study, *Precursors to Potential Severe Core Damage Accidents*, was prepared for NRC by Oak Ridge National Laboratory's Nuclear Operations Center. It sifted through nearly 20,000 "event reports" that plant operators are required to file with the commission, and identified 169 of these as possible "precursors" to a major accident. In only one of these cases — the March 1979 accident at Three Mile Island Reactor 2 — did severe core damage, as defined by the study, actually occur.

In 52 cases, however, the events were considered to hold a significant risk of leading to severe core damage under the right conditions — particularly if emergency back-up systems subsequently failed. The operator reports include reports on all emergency system failures, including those discovered during routine tests; thus is was possible to calculate the frequency of such failures. This information, combined with the frequency of the "precursors", was used to calculate the overall frequency prediction for a major accident.

The director of NRC's Division of Risk Analysis, Robert Bernero, stresses, however, that the uncertaintly in this estimate is large. For one thing, the single accident at Three Mile Island is responsible for about half of the frequency estimate. The study also notes that the estimate is on the conservative side; it "could be too low by a factor of two to three or too large by one or two orders of magnitude", according to William Cottrell, director of the Oak Ridge analysis centre.

Nor does the report take into account the equipment modifications and procedural modifications ordered after the Three Mile Island accident. A second report, now in preparation, will analyse 1980–81 event reports, and should provide a clue to how effective these modifications have in fact been.

The discrepancy between this study and the earlier Rasmussen report seems to hinge on two factors. According to Bernero, the most important is that the earlier study had little actual operating data to go on. Its approach was to think up possible accident scenarios and to use known failure rates of components such as pumps and valves. Inevitably, this approach is incomplete. A striking example of the sort of accident that cannot be anticipated was the bizarre sequence of events at Rancho Seco in March 1978 that began with a dropped light bulb and ended with a loss of main feed water to the reactor.

The second factor is that the Rasmussen report seems to have made some mistakes even in the scenarios it did consider. Bernero says that although there is "general agreement" between the two reports on failure probabilities, the new data show that the Rasmussen report made a "poor fire analysis" and a poor analysis of certain minor loss-of-coolant accidents that result from pump-seal leaks.

It is significant that the new findings did not reveal any pattern of accidents among plants of any particular vendor, architect-engineer, power rating or age. Thirty-eight per cent of the precursor events involved human error.

NRC hurriedly released the study last week after the Critical Mass Energy Project, a Ralph Nader anti-nuclear group, made public a draft of the study.

Stephan Budiansky

Accident	Date	The most significant "precursors"
Three Mile Island 2	28 March 1979	Loss of feedwater; open pilot-operated relief valve. Human error involved.
Browns Ferry 1	22 March 1979	Cable tray fire. Human error involved.
Rancho Seco	20 March 1978	Failure of non-nuclear instrumentation; steam generator dryout. Human error involved.

Soviet research careers

Pay impediments

Low pay scales are hampering recruitment into Soviet science, according to a Moscow specialist in economics, Dr G. Lakhtin, writing in *Pravda*. The average salary of a scientist, he said, is less than that of a worker in transport or industry. A major overhaul of the pay structure, he says, is necessary if science is to be productive.

The need to implement the results of "scientific and technical progress" in the economy is a frequent theme in the Soviet press. Recently Vadim Trapeznikov, a former deputy chairman of the state committee for science and technology, published in *Pravda* a blistering account of delays and bungling in diffusing the results of research and development to the shop-floor level. Hitherto, however the problem has been treated as one of organization and planning — in particular, of drawing scientists into closer links with industry. Lakhtin, however, pinpoints another basic problem — how should scientists be rewarded?

Not everybody is badly paid. Lakhtin quotes the example of a worker holding the degree of Candidate of Sciences, head of laboratory in a "First Category" institute and with a service record of more than 10 years, who receives 400 rubles a month, "neither more nor less", compared with the national average montly salary of about 170 rubles.

Soviet salaries are rigidly defined by academic qualification and job. Past attempts to set a salary range for each grade came to nothing, for individual salaries in each range soon drifted back to the mean. As Lakhtin explains, administrators raised the salaries of younger at the expense of the older workers, thus blunting the incentive to improve qualifications and job status.

Academic qualifications play a major part in fixing salaries, and the degree of Doctor of Science can be worth as much as an extra 100 rubles a month. Doctors of Science are, however, relatively rare, owing to what now appears to many Soviet

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