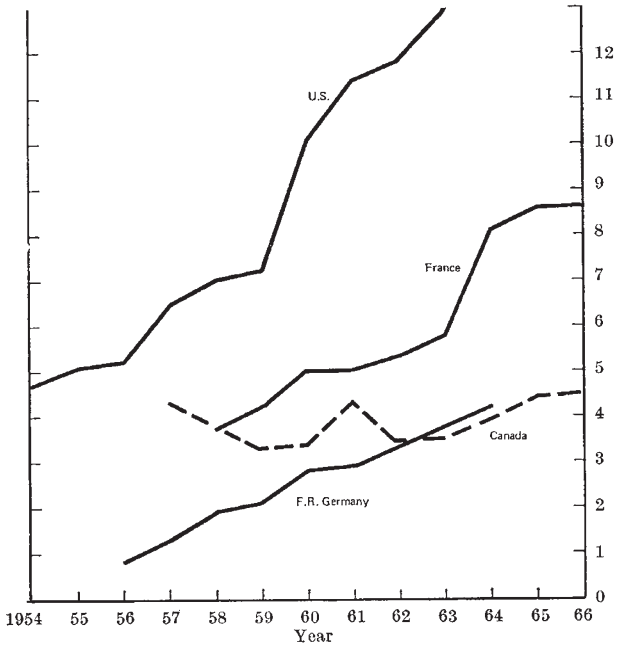
the US Air Force something interesting to do with all the equipment it has manufactured. But for the rest, there is a great need for a sober and balanced programme of research. The chances are that this is what Dr DuBridge will be pushing for. There will be lots of people on his side.

SCIENCE POLICY

Growth Ahead in Canada

THE Science Council of Canada clearly believes in getting its opinions off its chest before it publishes the figures which back them up. The document published some months ago which gave guidelines for Canadian science policy has now been followed by a valuable collection of statistics, prepared by R. W. Jackson, D. W. Henderson and B. Leung of the Science Secretariat. The study falls into three parts: the supply of qualified manpower, the inflation–sophistication factor, and estimates of the gross expenditure on research and development in Canada until the year 1978.



The figures suggest that this year a total of 10,760 Canadian students will graduate with a degree in science, mathematics, or engineering, out of a total graduation of 58,300. By 1977–78, the numbers will be swollen to 20,000, from a total of 115,000 graduates. To this will have to be added the substantial net immigration of scientists and engineers which has been a feature of the past few years; in 1966, for example, Canada gained just over 3,000 scientists and engineers by immigration, over a third of the number graduating. The report suggests that from 1970, net immigration will represent about 20 per cent of the numbers graduating, but this figure is clearly subject to a great deal of uncertainty—the course of the Vietnam War, for example, could be a very significant factor. Another uncertainty is whether Canada will experience the swing away from science which has been observed elsewhere; the report concludes that so far there is no evidence for a pronounced shift in the total numbers reading for science and engineering. Within the total, however, there are shifts out of engineering and into pure science.

The section of the report devoted to calculating the "sophistication–inflation factor" for Canadian research relies heavily on reports published elsewhere. Canadian science statistics have not been sufficiently reliable to enable a characteristically Canadian figure to be extracted, but it is probably fair to assume that Canada will follow the United States pattern. The authors conclude that the costs of research and development will grow at the rate of 6 per cent a year over the next few years, a figure which takes into account both inflation and the growth of sophistication; roughly one third of this annual increase is attributed to inflation and the rest to sophistication. If anything, the authors say, this figure is likely to prove conservative.

The manpower predictions and the rate at which research becomes more expensive come together in the third section of the report, which attempts to predict gross expenditures on research and development in Canada projected to 1978. It is first assumed that the GNP will continue to grow at around 5 per cent a year until 1970, and 4·75 per cent a year after that, giving a GNP of $127·7 thousand million in 1978. By taking an arbitrary proportion of this and devoting it to research and development, a series of very simple trends can be drawn as extrapolations of the present growth curve. These show, for example, that if R and D is to represent 5 per cent of the GNP in 1978, it will have to grow at a rate of 19·2 per cent per year. A more likely prediction—that R and D costs will represent 3 per cent of the GNP—implies a growth rate of 14·2 per cent (compared with an average since 1957 of 11·0 per cent). An alternative approach is to make estimates of the proportion of the qualified manpower which will be engaged on research and development, and then to calculate what will be needed to support these numbers at any point in the future. As things are, 14·3 per cent of Canadian scientists are engaged on research and development; if this proportion is maintained, it will imply a rate of growth of expenditure of 14·6 per cent a year, to a total of about $4 thousand million by 1978. If the number of scientists in research and development is expected to increase to, say, 17 per cent of all scientists, this would call for a growth rate in financial terms of 16·2 per cent a year, and would have Canada spending nearer $5 thousand million by 1978. If as many as 30 per cent of all scientists were in research and development, the budget by 1978 would be $8 thousand million, no less than 6·2 per cent of the GNP, a level which most people (though not the authors of the study) consider improbable. But some growth is clearly vital; the report publishes curves which show that Canadian expenditure on R and D as a proportion of total federal expenditure has actually declined since 1957, an experience shared by few other advanced countries.

EARTH SATELLITES

Satellites Applied

FEARS that a two year study of applications satellites carried out by the US National Research Council would

jump on the bandwagon of Earth resources satellites have not been borne out. A brief report of the study, which involved nearly 200 people, was published last week and recognizes the technical and economic uncertainties which cloud the issue (*Useful Applications of Earth-Oriented Satellites, Report of the Central Review Committee*, National Academy, $2). Compared with the report on Earth resources satellites prepared for a subcommittee of the science and astronautics committee of the House of Representatives (*Nature*, **221**, 611; 1969), which strongly criticizes NASA's stewardship of the Earth resources programme, the NRC report is gentleness itself. Even so, it cannot help digging at the "leisurely" pace of the project.

The report deals not only with Earth resources satellites but with other Earth-oriented applications such as communications and meteorology satellites, where the economic benefit can be readily recognized. Its recommendations in this field include the setting up of multi-channel distribution systems for public and private television networks and for educational broadcasts, and satellite navigation and traffic control for ships and aircraft crossing the North Atlantic. But the report is more cagey about Earth resources systems. It is clear enough that discussions of what Earth resources satellites could achieve are hampered by lack of knowledge of what the capabilities of remote sensors are likely to be. The report does no better with its economic assessment. Once again, uncertainty about what type of satellites and sensors are going to be available in the future and what use they will all be confounds conventional cost–benefit analysis. The economists called in by the study conclude that basic exploratory research will involve substantial risks with highly conjectural benefits but that there is a case for carrying some programmes to the development stage. Basic research is also the least expensive stage, and the NASA approach—to try out possible Earth resources instrumentation in aircraft flights—is probably correct. Indeed, NASA receives a pat on the back for generating "a variety of exploratory studies in Earth resources, meteorology, oceanography, and communications that present many choices for further effort", deemed to be an excellent basis for a broader national programme.

The chief recommendation of the review committee is to double or treble the present programme of applications satellites to an annual support of $200–$300 million. The budget for 1970 asks for $135·8 million for NASA's applications programmes, chiefly Nimbus meteorology satellites, applications technology satellites and the first Earth resources satellite planned for 1971. But despite occasional eulogies of the hypothetical benefits of earth resources satellites, the report seems to support the more cautious approach.

PLOWSHARE

Outlook for Plowshare

THE United States Atomic Energy Commission is to cooperate with its Australian counterpart in a study of the feasibility of creating a harbour in North-west Australia by the use of nuclear explosives. Project Plowshare, under whose auspices the survey would be carried out, is enjoying unaccustomed popularity since the arrival of the new administration in Washington, but until the survey is complete it would be premature to conclude that the years of talk about using nuclear weapons peacefully are going to end with a bang rather than a whimper. Australia offers many advantages for an experiment of this sort; in recent years the Australians have come to regard the Americans as their natural allies, and have given loyal and apparently unquestioning support in Vietnam. Political difficulties would be unlikely to intrude (partly because the explosion would take place in an area singularly short of people) and the kind of opposition which would arise in similar circumstances in Latin America, for example, is unlikely to be significant in Australia.

The site chosen for the survey is at Cape Keraudran, on the north-west coast, at the southern end of the attractively named Eighty Mile Beach. The nearest large town is Port Hedland, and the new port would be well situated close to routes across Western Australia to Perth and Fremantle. So far, this is an area of limited development, but the past year or so has seen a great growth in mineral exploration, for which a new port might well be necessary. Otherwise, the area is notable only for its isolation, which simplifies the issues technically, but means that the return on the investment is unlikely to be very high.

According to Mr David Fairbairn, the Minister for National Development, the blasting of a harbour at Cape Keraudran would call for five simultaneous nuclear explosions, each as powerful as 200 thousand tons of TNT. This should produce a harbour 6,000 feet long, 1,300 to 1,600 feet wide and 300 to 400 feet deep, big enough for ships of up to 150,000 tons dead-weight. An Australian Plowshare committee has been set up to watch over the study, and the working body for the study will be the Cape Keraudran Project Committee, under the chairmanship of Dr A. R. W. Wilson, deputy director of the AAEC research establishment at Lucas Heights near Sydney. He has concentrated on the peaceful uses of atomic explosions for some years, and acted as an adviser to the Government of Panama on the safety aspects of the proposal to build another canal across the Panama Isthmus.

Whatever the results of the feasibility study, it seems already to have opened the door to the Australian market for American nuclear power companies. Mr John Gorton, the Australian Prime Minister, has announced that Mr Fairbairn is to visit the United States to "have discussions with appropriate State Ministers and Authorities regarding introduction of nuclear power into Australia in the future". Australia's nuclear power policy so far has been concentrated almost exclusively on natural fuelled heavy water reactors, like the Candu or modified SGHWR designs, which make no call on enrichment facilities. Like France, Australia has been determined to pursue a nuclear policy which does not rely on the supply of fuel from abroad, and, without any immediate prospect of cheap enrichment facilities, this means reactors which run on natural uranium. Unless the Australian Government plans completely to reverse its policy and buy American light water reactors, it is hard to see why Mr Fairbairn is going to the United States. AAEC staff members in Canada and in Britain observing the programmes aimed at developing natural fuel reactors are bound to wonder whether their mission is in vain.