move away from training students in narrow areas of specialization, Breneman believes.†

†Breneman expands on the problems involved in forecasting in *Outlook and Opportunities for Graduate Education* (National Board on Graduate Education, Washington, D.C., December 1975).

However, if for no reason other than to oil the machinery of bureaucratic decision-making, there is a demand for projections such as those made by the NSF and the BLS. The glaring differences between the two reports may, then, serve the useful purpose of exposing the projections for what they are, thereby leading users of the projections to look more closely at the underlying assumptions of the models. This may discourage users from placing blind faith in the numbers.—GINA BARI KOLATA

Brigham Young University: An Alternative R & D Style

During the expansionary heyday of higher education in the 1950's and 1960's, no aspiring university was complete without a progressively bigger and better science research and graduate education program funded primarily by the federal government. One exception has been Brigham Young University, whose budget is heavily underwritten by the (Mormon) Church of Jesus Christ of Latter-Day Saints (LDS). BYU, with more than 25,000 students, has gone through a period of growth and development in many ways typical of American higher education since World War II. But throughout this period, as a result of LDS attitudes, BYU, located in Provo, Utah, has sought to minimize dependence on support from federal agencies.

Independence has a price. BYU's attitude toward federal funding has limited its horizons as a research university. BYU has a relatively small graduate program—about 2000 students—and only about one in eight graduate students is in doctoral programs. BYU has no medical school nor is it strong in "Big Science" sectors—high energy physics, for example—which typically require large injections of federal funds.

Given BYU's spirit of abnegation toward federal funding, however, some of the research efforts at the university seem surprisingly ambitious. Two examples are research on synthetic diamonds and a fusion project (see box, page 366). As for BYU's place in the academic community, it seems to be a member in good standing of the usual scholarly and accrediting organizations and appears to be viewed by academics in other universities in the region as a solid, middle-quality, if somewhat exotic, place.

BYU recognizes that its policies on federal funding place it at a disadvantage with respect to research and has sought systematically to maximize its R & D program. In addition to relying on generous funding from the LDS church, the university has encouraged faculty to undertake outside research to a degree that is unusual today. Within the university, through a combination of cooperation and austerity, efforts are being made to compensate for the restrictions on federal R & D funding. BYU, in effect, is seeking to demonstrate an alternative to the federal model of research financing.

The attitudes which prompted BYU to cut down on federal research are deeply ingrained. They have roots in the value the Mormons place on self-reliance, reinforced by government persecution in the 19th century. The LDS church is conservative in its social and economic outlook. For example, since the 1930's it has taken a dim view of federal relief and welfare programs and has provided its own program of assistance for its members, strongly stressing self-help. At BYU the influence of the LDS church, reflected most obviously in a rigorous code of conduct and appearance for students, faculty, and staff, has made both campus life and the academic program differ from those at other universities. These differences inspired BYU to challenge federal regulations on sex discrimination (*Science*, 16 January). The church has been suspicious of federal aid to education at any level on the grounds that strings would inevitably be attached.

At BYU, federal R & D funding was never permitted to grow very large. The total of federal grants and contracts reached a peak of about $3.5 million in 1971 and was growing rapidly when a decision was made to cut back to a level of under $1.5 million, mostly in basic research funds.

BYU's criterion for accepting federal R & D grants and contracts is, so to speak, value for money. BYU president Dallin H. Oaks says that the aim is to provide research results which will help directly to meet national problems. An underlying assumption seems to be that, for a private, religiously based university, the less the reliance on federal support, the smaller the basis for federal intrusion.

Because BYU is an avowedly religious institution, outsiders often raise the question of the effect of church doctrine on teaching, particularly of evolutionary theory. Some BYU critics are convinced that Mormons believe in the literal truth of the Old Testament account of the creation and that this is reflected in teaching at BYU. When this question is raised, the answer from BYU faculty is that the Mormon church has no official stand on the mechanism of evolution and that BYU's teaching, textbooks, and reference books dealing with evolutionary theory are no different from those at most universities. They acknowledge that some Mormons, including members of the BYU faculty, take a fundamentalist view and that some students not in the sciences may therefore believe that the church has taken such a stand. One biology professor noted that this view is "founded firmly in the air." The latest doctrinal word from the church, which was pronounced in 1909, holds that Adam and Eve were "the first parents of the race," but leaves open the question of how humans evolved.

In the development of the research program at BYU, church doctrines have been less of a limiting factor than finding a substitute for federal funds, and BYU's R & D budget falls far below the budgets of many universities of comparable size. For example, the University of Utah, with a somewhat smaller enrollment, has a total operating budget of about $100 million. Utah's R & D budget is about $40 million, most of it federal money. The LDS church is secretive about its financial affairs, and budget figures for BYU are not made public. Fairly reliable estimates, however, put the BYU operating budget at little more than half the University of Utah budget. Informed sources at BYU estimated that with federal funding running at less than $1.5 million annually, the total BYU R & D effort is at about the $3.5 million level it had attained in the early 1970's with double the present federal support.

Current dollar figures may be somewhat misleading, however. Faculty members are

encouraged to work up to quarter time on research projects outside the university. Fresh efforts are being made to increase private funding of research, and ties with industry are being strengthened. There is no impediment, incidentally, to faculty members working on federally funded research projects outside the university.

Research Across Campus Boundaries

Maintaining a full-fledged research effort in the face of university-decreed curbs on federal R & D funding has required enterprise—private enterprise in some cases—on the part of BYU scientists. Two areas where on-campus research has led to off-campus activity are fusion and the development of synthetic diamonds.

A major "inside-outside" effort centers around Tracy Hall, distinguished professor of chemistry at BYU, who was the principal figure in the development of synthetic diamonds two decades ago at the General Electric labs in Schenectady. Hall moved to BYU in 1955 after his research became entangled in proprietary wraps and a government secrecy ban. In a few years at BYU he invented another high-pressure apparatus for synthesizing diamonds—a "tetrahedral anvil press"—which differed sufficiently from the original process to justify new patents, and he succeeded in freeing the work from the secrecy ban.

In the next decade, Hall and his colleagues developed what they call the "megadiamond," a superhard, synthetic substance created from natural or synthetic diamond dust which can be formed into desired shapes for use in machine tools to cut and shape hard metals.

Because of Hall, BYU has become the center of synthetic diamond research. Hall and some of his colleagues formed the private Megadiamond Corporation in Provo, which manufactures "sintered" diamond shapes for industry. Since Hall began work on the subject, about 30 doctorates have been awarded in the specialty and more than 100 scholarly papers published. About 50 BYU science and engineering students work at Megadiamond on design and operations tasks.

Because BYU has forsaken the federal funding usually necessary for large-scale projects it is somewhat surprising to learn that BYU physicists are deeply involved in a fusion power research project. Working without federal funds, a team headed by physics professor John H. Gardner seems to be making headway in interesting the fusion research community, which has hitherto appeared indifferent to BYU's project.

The BYU physicists are claiming a theoretical advance which could help control one of the persistent problems that has plagued fusion researchers for more than a decade. To sustain a fusion reaction, researchers have sought to design a "bottle" which will confine intensely hot gasses—plasma—in a magnetic field. These experimental devices, most of them variations of a doughnut-shaped cylinder, have proved subject to violent instabilities which disrupt the magnetic fields and permit the plasma to escape to the walls of the vessel.

The BYU approach is based on the idea of theoretician Robert W. Bass. Bass and his colleagues believe he has established the conditions for topological stability and that the theorem can be applied successfully to the problem of confinement. Bass, who joined the BYU faculty in the 1960's and is now a professor of physics and astronomy, convinced his colleagues and, in turn, LDS church authorities that the idea was worth substantial support, and in the last 2 or 3 years, some $300,000 has been spent on the project.

The funds to date have largely supported work on the computer design of the "topolotron," the BYU containment apparatus. An agreement has now been concluded between BYU and Billings Energy Research Corporation in Provo for a partnership venture to develop hardware with which researchers hope to demonstrate a structurally stable magnetic containment field. Billings has agreed to invest between $200,000 and $1 million in the project over several years. Billings will be the general partner and BYU the limited partner in the venture with Gardner acting as project manager. Billings president Roger Billings is a pioneer in the utilization of hydrogen fuel for automobiles, and the fusion project is related to the company's interests because successful fusion reaction would generate vast quantities of molecular hydrogen.

Gardner feels that the initial $300,000 put into the project at BYU produced results which would have required an investment of perhaps $1 million elsewhere. Resources were used frugally and team members did much of the work on the project on regular university salaries. Although no federal funds were used, the BYU physicists feel that the Energy Research and Development Administration may well be looking favorably on the project.—J.W.

One timely development providing opportunities for off-campus involvement in research was the establishment of an independent, nonprofit research institute in Provo 2 years ago. The Eyring Research Institute is named for Henry Eyring, distinguished professor of chemistry at the University of Utah and a former president of both AAAS and the American Chemical Society. Eyring, who is a member of the institute's board, says he was not involved in the planning of the institute, and that he has "neither received nor donated a dollar," but that he approves of the idea and feels it will help to attract good people to BYU.

The institute's chief executive officer, Ronald G. Hansen, says that the enterprise has already passed the break-even point—a considerable feat, since nonprofit research institutions characteristically have "cash flow" problems in their early stages. The initiative for the institute came from Carlyle Harmon, a retired Johnson & Johnson vice president. Harmon provided the start-up funds and serves as institute director. The cumulative value of contracts won by the institute is $2.5 million. The annual budget is now about $2 million and Hansen says there is a reasonable expectation of doubling it soon.

The institute has its own building, which it is expanding, in downtown Provo. It rents some space on the BYU campus and runs a coal gasification research project at U.S. Steel's Geneva plant nearby. The staff now numbers about 50—half of them faculty and graduate students from BYU—with several BYU professors running projects.

On campus, it is not unusual for research projects to have some tie with church interests or with regional problems—in agriculture or environmental sectors, for example. A pronounced case of the former is a computer-assisted translation program. In the 1960's there was a general disenchantment with computer translation projects, which had been heavily funded by the federal government. Recently there has been a revival of interests, with efforts at purely automatic translation largely out of favor. The BYU approach is to team computers with human translators.

The program at BYU is based on a theory of language structure called Junction Grammar developed mainly by Eldon G. Lytle, an associate professor of linguistics. Lytle and his team believe that, by converting English into a system of numbers representing the grammatical rules of the language, it will be possible to establish a "code," manipulate it, and then convert

English sentences into sentences in different languages.

The project is still very much in the experimental stage, but the researchers feel they have made a promising start and have set a goal of producing a "processor" for translating English into four target languages—French, German, Portuguese, and Spanish—by 1978.

The early work on computer-assisted translation at BYU was supported by Department of Defense grants, but BYU's effort to restrict federal involvement caused a disengagement from such funding. Since 1972, the work has been supported by institutional funds, private donors, and the LDS church. (LDS church translation projects to support its missionary effort amounts to about 15,000 pages a year in 50 languages. It now takes about 6 years to translate the literature in the basic kit carried by Mormon missionaries.)

More typical of the research pattern at BYU is the work carried out in the College of Biological and Agricultural Science. Traditionally, BYU has emphasized undergraduate education, and the agriculture program has a history of sending people back to the farm and ranch and, more recently, preparing them for agribusiness jobs. Because of the necessity to work within the limitation on facilities and equipment imposed by the restraints on accepting federal funds, biology at BYU is strongest in the traditional disciplines, says the college's dean, A. Lester Allen. BYU has been successful in the "natural history" areas of biology. For example, biologists from the university are now engaged in a biome study in connection with a proposed massive power plant development on the Kaiparowits Plateau in southern Utah. A team from BYU is making a baseline study in the Huntington Canyon area designed to be part of a "before-and-after" record of the environmental impact of the power plant project. The work is supported by the utility companies involved.

Efforts are also being made to cultivate excellence in newer disciplines, and special pride is taken in microbiology and the work done in electron microscopy at BYU.

The necessity of maximizing resources is generally recognized at BYU. Traditionally, authority has been decentralized in the colleges and departments, and central coordination and direction of research has been limited. With the leveling off of growth and the cutbacks in federal funding, however, BYU has been going through a period of university-wide self-analysis. It was found, for example, that faculty members heavily involved in research were doing as much teaching as others. A new reporting system has been developed to reflect "productivity" more clearly. More weight is now given to a faculty member's publications and patents and to his success in attracting research funds and graduate students. All of this is considered in giving an individual researcher more leeway in his teaching schedule and in deciding on pay, rank, and committee assignments.

One administrator acknowledged, "We are pushing faculty more." Faculty members seem to agree that the squeeze in federal funding has not resulted in substantial cutbacks in programs but that there has been a general tightening up, evidenced in such things as the curtailment of sabbaticals. On the other hand, BYU researchers claim that they get more "mileage" out of available funds. Allen, for example, says that there is more sharing of equipment than on many other campuses. He attributes this to "a spirit of common brotherhood," an allusion to the fact that BYU faculty members are virtually all members of the LDS church.

How successful has BYU been in making up for the lack of federal research funding? No categorical answer can be given. BYU was last evaluated by the Western Association of Schools and Colleges in 1966, and there were some criticisms of BYU's programs and administration which triggered a controversy. One informed observer not at BYU says that the problems were in the normal range for rapidly expanding institutions and suggests that the furor was caused by the reaction of BYU's president at the time, Ernest R. Wilkerson, a lawyer not accustomed to academic give-and-take, who bridled at any criticism of his university. BYU was not put on probation and got the routine follow-up visit 5 years later. The university is due for another full evaluation this year.

BYU's faculty and administration acknowledge that their research effort and graduate program are of modest size and have some gaps, but argue that BYU also has areas of excellence. Faculty in other universities in the region seem to agree generally with that estimate. In the rating of graduate programs published in 1970 by the American Council on Education, BYU was one of 130 institutions selected on a regional basis for evaluation. In the ratings of "effectiveness of graduate programs" BYU was cited as a leading institution only in microbiology, joining 43 other institutions categorized as ranging from "adequate" to "attractive" in that field.

The faculty situation at BYU is really sui generis. Membership in the LDS for all practical purposes is a qualification for appointment to the faculty. As one faculty member put it, "The trustees want us to teach not only skills but a point of view." This gives BYU an advantage in recruiting able Mormon academics who feel what is tantamount to a "call" to teach there or LDS members who want to work and raise their children in the BYU-Provo atmosphere.

There are some disadvantages as well. Competent Mormon academics are not necessarily available in particular fields in which the university may need faculty. In addition, some BYU faculty members come to resent the stiff demands on them for financial contributions and service to the church and for exemplary behavior. Consequently they opt out.

The intellectual quality of BYU graduates is another elusive question. In preprofessional training, BYU cites its record as the sixth most successful institution in the number of applicants accepted in dental schools among institutions with more than 100 applicants and claims that its rate of medical school acceptances is about average for universities. BYU does seem to profit from the Mormon emphasis on education. Studies of the social origins of scientists, for example, consistently show that Mormon areas produce a disproportionately high share of scientists.*

What is perhaps most interesting about BYU's pursuit of its own goals is that its policies in several ways reflect a reversal of prevailing academic attitudes. While most universities vigorously seek federal funding, they have also been centers of criticism of government policy, particularly during the Vietnam war. BYU, on the other hand, is reluctant to take federal money, but the campus was almost entirely uninvolved in the protests of the 1960's and early 1970's. BYU, in fact, might be described as a hotbed of respect for government authority.

Most universities carefully circumscribe faculty involvement in consulting and research outside the university. Because BYU encourages such involvement, even entrepreneurial activities, the visitor gets the impression that its scientists are far from sharing the attitude common in other universities that applied research or direct ties with industry are professionally déclassé.

While BYU provides an example of an alternative to a total reliance on federal funding for research, it is not a model that can be widely imitated. Financial support on the scale provided by the LDS church is available from hardly any other private source, and Mormon fraternity seems to make scientists at BYU particularly willing to adapt to circumstances. But with relative hard times facing many university research programs, there may be some lessons learned from BYU's brand of pragmatism.—JOHN WALSH

*See "Social origins of American scientists and scholars" by Kenneth A. Hardy (*Science*, 9 August 1974, p. 497). Hardy is a professor of psychology at BYU.