

TRENDS IN AMERICAN SCIENCE

by *Vannevar Bush*

Despite a national tradition of technology and invention we have turned to the support of basic research. Will it continue?

We have progressed far enough since the war to be able to delineate trends in the pattern of science in this country, so that it becomes well worthwhile to take stock and examine whether on the whole it is a sound pattern that is being formed for the future. Much that is salutary is immediately apparent. The conspicuous swing that has occurred toward greater emphasis on the physical sciences was inevitable, in view of the startling effects produced by their application in the waging of war, and especially since the tension did not lift with the coming of formal peace. Yet the form which this emphasis took in this country is, in retrospect, a bit surprising.

The American public was impressed by the applications of physical science; it was these that provided powerful weapons in the form of radar, proximity fuzes, and all the rest. Moreover this country has always been active and strongly interested in the practical aspects of affairs. The inventor continues to be something of a popular hero even if the industrialist is not. The youngster of today needs no teaching in how to repair an auto or a radio any more than the farm boy of a generation ago needed to be taught to harness Ned. The very youth of the nation itself, with its recent geographical frontiers nurturing the jack-of-all-trades, produced a public alert to clever novelties, avid for gadgets from washing machines to television, but on the whole not particularly aware of or responsive to the philosophical aspects of science. Ever since the days of the colonies we had drawn our basic science largely from Europe, and only within the last generation had we even begun to produce our proportionate part in the advancing of fundamental knowledge. In these circumstances it might well have been expected that there would be a clamor, after the war, for intense support by government of all forms of

gadgeteering, for helping the poor inventor, or for trying out this wild scheme or that, whatever happened to catch the public fancy, by means of congressional grants of one sort or another.

There was some of this of course. But, surprisingly enough, it gave way before a conviction, apparently deep and widespread, that the whole gamut of the scientific effort is worthy of support, and that basic science in particular should be furthered. This is a very healthy sign, and it may indicate that we acquired a considerable amount of intellectual maturity, as well as a shock, at finding ourselves, from our war experiences, an inseparable part of a turbulent world.

There are indications that this broadening of the approach also is having the effect of ensuring public interest, and hence eventual support, not only in the physical sciences from which most of the war implements were evolved, but also in science generally. The results of the applications of the medical sciences during the war were just as far-reaching, in their way, as those of the physical sciences; in fact it is probable that, during a generation, their effects will be greater in saving and extending life than was the effect of the destructiveness of physical weapons in terminating or abbreviating it. But a buzz bomb is a more intrusive affair, in the public consciousness, than an antimalarial drug, and the saving power of modern medicine does not command the headlines in the way that rockets or target-seeking bombs do, so that only those GI's who had direct experience, and their friends, were fully impressed with the medical advances. Yet the interest of the public today seems to be fully as much in the biological sciences, which are the basic source of medical advance, as in physics or chemistry. It even seems to be true that the dawning appreciation of the wisdom of furthering science gen-

erally extends to the social sciences, although the public here is probably baffled by difficulties of definition, as indeed are the social scientists themselves.

Signs

The signs of this extended interest are important to note. They extend much further than a mere increase in the space devoted to scientific subjects in the press, or in the time given to expounding science over the radio. In fact if the volume of effort of this kind is taken as a barometer, it needs to be used with a great deal of caution, for even although the public conviction is clearly not of the type that craves sensationalism, our progress toward a more mature treatment of science for the layman is slow indeed. The true evidence needs to be sought elsewhere.

The GI bill of rights, with its opening of educational opportunities for the veteran, has been a success, both for the colleges and for the veterans, and it has improved both of them. It has had its surprises. In the first place the returning veterans have not been a drag on the college standards, quite the contrary; for they have proved to be serious students on the whole, and far more likely to be impatient of mediocrity in teaching than of stringent standards. Second, they have not demanded a welter of practical applied courses. Some have, of course. But in general, if the evidence of my friends in the field of education is conclusive, they have been remarkably catholic in their tastes. In the field of science, in particular, there has not been a rush to courses in gadgeteering, rather a wholesome inclination to try to get to the bottom of things scientific in one way or another.

Then note the remarkable phenomenon of the military department of government supporting fundamental research by contract with universities. One might have expected a program of grants in the hands of the Public Health Service, or an increased support of university research in aerodynamics by the National Advisory Committee for Aeronautics. But who would have expected, looking forward from, say, 1939, to find the United States Navy vigorously furthering a program in fundamental science, including nucleonics, genetics, and mathematics? Moreover, the venture has been well carried out, with a salutary relationship between military and academic men, and with avoidance, to

an extraordinary extent, of the pitfalls that abound in government contracting. The present system, effective as it is, still is not the ultimate form which government support of fundamental research should take, no doubt. But it is indicative of a sound, broad point of view, and it is to be hoped that whatever changes may occur the Armed Services will always continue to support this basic work to some extent, if for no other reason than that it provides beneficial contacts between officers and researchers, and stimulates the whole range of military thinking.

The history of legislation looking toward the establishment of a National Science Foundation affords another example. I have no intention of reviewing this history from the standpoint of the controversy regarding the form of administrative organization that that legislation should provide, a controversy that happily promises to end soon in the enactment of sound legislation, but rather to comment on the content. If science legislation of this general type had been enacted in the middle thirties, I think it is a foregone conclusion that it would have been heavily weighted in the direction of aid to inventors, pilot plants for new processes considered likely to provide an immediate public benefit in goods or materials, and applied affairs generally. The discussion in the last Congress, however, revolved almost entirely about the support of basic science, and there seem to be no dissenters from the thesis that this is the stage most suitable for federal support, leaving applied science to government laboratories and industry. It is devoutly to be hoped that this point of view will continue, and that a highly representative Foundation will soon be established and actively on its way.

Enough for Now

It should not be assumed from the above that fundamental science in this country is already being overemphasized; far from it, for we have a long distance to go in this direction. Moreover, if we are ever to reach the point where this aspect of our endeavors receives its reasonably proportionate emphasis, the present trend will need to continue for a long time, for the amount of truly significant basic research that can be carried on effectively depends upon the number of able researchers available. In fact support this far has probably been close to the optimum, and needs at the moment only

moderate extension in order to ensure that all those now truly able in fundamental science have the opportunity to work effectively, and that a reasonable proportion of the gifted youth of the land is attracted to the pursuit of science in its more philosophical aspects.

This same comment applies to the support of research and development generally. In dollar volume we are now conducting about four times as much work in this whole field as before the war, considering the universities, industry, and government, and especially the military and atomic energy programs. We are doing this with a cadre of trained scientific and technical personnel that is not greatly expanded over that of the pre-war years, for scientists and engineers grow old just as fast as anyone else, and we foolishly ceased to train during the war, as those who battled to keep research laboratories going even on essential war research in the face of the immediate ideas of small men in power well realize. In fact, during the last two years, many who know the demands of research and development have feared that this abrupt expansion would backfire, that money would be wasted by placing research in mediocre hands, that absurd projects would be furthered, and that the final result would be disastrous. It has not happened. Money has been wasted, certainly; it always is in any broad research program, and there have been expensive projects that were more or less unproductive. But, on the whole, the program seems to have gone rather well thus far, in spite of the shortage of manpower which is everywhere evident. Part of the fact that more dollars have not greatly overextended the limited personnel has been due to increased costs of operation so that a dollar increase is not fully significant by itself; part to greater emphasis on prototype development which uses dollars fast and calls for relatively little high caliber research talent; part to the fact that research workers have become trained in numbers in unorthodox ways, thanks to the general adaptability of American youth. Still it is evident that we expanded radically, if not recklessly, and that we are absorbing the expansion with some difficulty, so that continuance for the present at about these levels is indicated, until training can again supply enough manpower for another advance, if all our experience then convinces the public, which determines trends in this country, that further expansion is warranted. This should be the

case whether or not international tension forces concentration on military development, as it does at present, for research has its place and its value whether we seek to protect ourselves in a hazardous world, or are privileged to approach more completely the task of raising our standards of health and well being.

Higher Education

To try to analyze the full range of present trends in science would of course require a book rather than a brief article, but one more is so apparent, and of such profound importance, that it should at least be mentioned. This is the effect which the present public interest in science is having on public support of higher education. This country has always been convinced that democracy and public education must go together, in fact that the democratic system cannot endure without the support of an enlightened electorate, aided in enlightenment by education supported from taxes. It has gone further than this, for the public has privately supported education in many ways in addition to paying through the nose for it. But there has always seemed to be a tendency away from the ideas of Jefferson toward a uniform dead-level in public institutions. His thesis, that successive eliminations by examination should be combined with continuing public support to the most advanced forms of study for those who prove capable of assimilating knowledge to be used for the general public good, has been overridden by the idea that whatever is supplied from taxes must be available to and usable by all comers. Now we seem to some extent to be swinging back. The trend has been evident for a generation, as the state universities have created graduate schools, and advanced scientific effort in particular, of a standing equal to the best provided by private institutions. But we have been far from the situation where any boy in the country, with brains and determination, could have at public expense all of the advanced education he could usefully absorb.

The present appreciation of the role of science in modern life, and the trend toward greater public support, seem to be carrying with them a trend toward providing just this opportunity. Present governmental contracts for research in universities provide opportunity for many a youngster to combine

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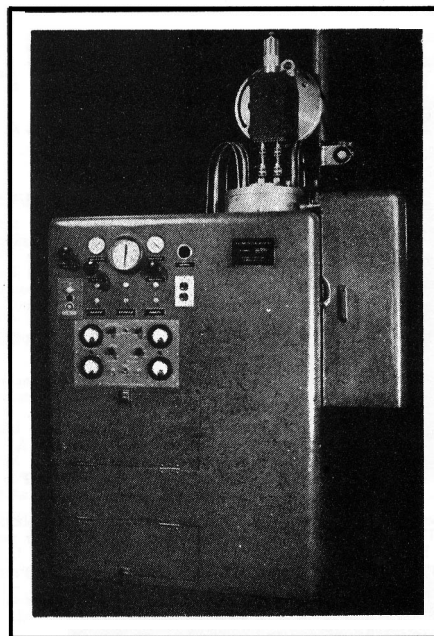
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graduate study with paid research, and thus to acquire advanced learning and degrees that he would otherwise go without, and the fact that this is the situation seems to receive general approbation. The plans of the military service for supplementing the programs of West Point and Annapolis by financially assisting students in regular courses of study will have some of the same effect. Every bill for a National Science Foundation, in recent years, has carried provisions for graduate fellowships on a liberal basis. The very remarkable support which some states have extended to their universities has been partly a result of boom times no doubt, partly an extension of the somewhat dubious idea of a college education for all, but also largely an expression of a conviction that advanced education for the relatively few who are thoroughly qualified should also be supported for the good of the state.

One might go on and consider the trend in regard to the preservation of freedom for fundamental research, a trend fortunately sound thus far, or the tendency of government to expand its efforts by contract rather than by great new government laboratories, a tendency which, by the way, should be strengthened. It would also be interesting to examine what a pickle this whole movement is getting us into in regard to publication of scientific results, for if we publish fully all that is now being done the libraries will not hold it, and if they could no scientist would have time to examine it all, even in his own rather narrow field. It would be still more interesting, if anyone could accomplish it, to examine what sort of a world all this is leading us into, quite apart from the nature of possible future war, with digital calculators expanding our mathematical power, and enzymes capable of all the chemical reactions that evolution ever found useful.

But it is sufficient for the moment to note that we are on our way, that public support of science apparently rests on a deep-rooted conviction that the public has apparently a sound conception of what science really is and what parts of it can best be furthered by public support, that the present expansion carries with it an emphasis also on advanced training, and that thus far at least the movement has proceeded reasonably soundly and free from regimentation of fundamental science. The results in a decade or two, if the trend continues, should be exciting.

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