BASIC RESEARCH AND THE DEPARTMENT OF DEFENSE

(Talk given by Dr. Harold Wooster, Director of Information Sciences, Air Force Office of Scientific Research, Office of Aerospace Research, Department of the Air Force, Arlington, Virginia 22209, before Dallas Salesmanship Club, Dallas, Texas, 9 March 1967)

Mr. Chairman, distinguished guests, members of the Dallas Salesmanship Club:

It was with some trepidation that I accepted General Bethune's kind invitation to appear before you today--a trepidation that changed into panic as I tried to pick a topic large enough to be worthy of the great state of Texas. I could talk about the research program I manage for the Air Force, but that's only about $3 million a year; at about this time last year I was up to my elbows in rubber cement completing a study for the White House of all information sciences research and development efforts sponsored by the Federal Government--but I was able to find no more than 1300 efforts, at a total rate of no more than $166 million a year. But then the March Reader's Digest came out with a staff article, "The Great Research Boondoggle", talking about $16 billion of Federally sponsored research and development. I trust the Reader's Digest- in only to tell me what the public is interested in--and $16 billion seemed a big enough sum of money to be worth talking about in Texas.

I must confess that I have a little trouble in visualizing even one billion dollars--I can see the $3 million my Directorate spends all too clearly, and can even pretend to understand the $35 million or so which my organization, the Air Force Office of Scientific Research, spends each year in buying basic research for its headquarters, the Office of Aerospace

Research and, through them, for the Department of the Air Force--but I start blurring somewhere on this side of a billion dollars--so I made up this little chart:

I couldn't fit the gross national product of $787 billion into my brief case, so you will have to visualize this as a black square about so (holding hands 650 mm apart) wide. Then the orange square represents the FY 68 National budget of $135 billion:

The light blue square the Department of Defense budget of $76 billion

The AF blue square the Air Force budget of $13 billion

The yellow square the AF research, development, test and engineering budget of $3.4 billion.

The smaller AF blue square the AF basic research budget of $157 million.

And the grossly exaggerated aluminum dot in the center (which really should be only 0.2 mm square), my own budget of $3 million.

Having given you some indication of what a billion dollars is like (and of my own importance in the Federal government) let me return to the topic of my talk this afternoon. There are three things I would like to discuss:

1. What is basic research?
2. Why is basic research a Good Thing for the Federal government to support?
3. Why is basic research a Good Thing for the Department of Defense to support?

1. <u>What is basic research ?</u>

The National Science Foundation defines basic research as "the search for an understanding of the laws of nature without regard to the ultimate

application of the results."

We, in the Department of Defense, operate under a definition of "research" as "those efforts directed toward increased scientific knowledge of natural phenomena and environment and toward solution of scientific problems that have no direct military application."

And, in industry, basic research is defined as "original investigations for the advancement of scientific knowledge that do not have specific commercial objectives, though such investigations may be in fields of present and potential interest to the reporting company."

Note that all three of these definitions share one common aspect: they lean heavily on the motives of those conducting and those sponsoring the investigations. And I don't have to tell an audience like this that motives are awfully tricky things to deal with: it is relatively easy to find out what a scientist is doing, but almost impossible to find out why he is doing it. Elaborate, highly developed scientific apparatus may be used for routine testing, or for investigations into the fundamental properties of matter--and the clean white lab coat beloved of television commercials usually only shows that the scientist was expecting visitors!

Another problem. People, scientists or not, want love, sex, power, prestige, freedom and money, in various proportions depending on the person. Scientists typically put more emphasis on prestige and freedom than other people do. And prestige, in science, comes about from doing basic research. This is not money prestige, mind you. The top scientific salaries in the country are, I believe, the $100,000 Albert Einstein professorships in New

York state, which actually pay the holder about $50,000 a year. The average scientist is a salary earner, not an entrepreneur; he takes gambles with his science, not his money. He expects a comfortable middle class income, with a ceiling of perhaps $25,000 to $30,000 a year (the median is a lot closer to $12,000). The prestige is shown by appointments to important committees, to professorships in better schools, and by awards from his professional societies. And all this comes about through publication of basic research. So the average scientist would prefer to work on basic rather than applied problems and, sometimes, to call what he is doing basic research even if someone else, doing more basic work, might call his research applied.

In many ways, doing basic research is like drilling for oil. You make your best guesses where to drill, and keep plugging away until you hit something or decide to quit. Nobody wants to drill a dry hole, but it's one of the risks of the trade. And there's no guarantee that someone else can't drill where you have drilled and keep at it a little longer and make a hit.

And the qualities of a successful research man (Editorial, Chemical & Engineering News, 27 Feb 67, quoting Dr. Vladimir Haensel, v.p. of Universal Oil Products Company) are those you'd like to hire in a successful oil prospector--a thorough background in fundamentals, a good sense of reasoning, insatiable curiosity, ability to make decisions and perseverance.

There is one major difference, though. With a well, you know

immediately whether drilling it was worth the money. Even a very good piece of research may take decades to pay off. And these days you have to dig deep to make a strike. You can still drill for a barrel-a-day result in a well explored field, but the real pay-offs take deep drilling in unexplored fields.

Basic research, by whatever definition you use, takes no more than 13 per cent of the FY 67 Federal research and development budget (Federal Funds for Research, Development and Other Scientific Activities, Vol XV. NSF 66-25 so that the $16 billion the Reader's Digest talks about shrinks to no more than $2.1 billion, or slightly more than 1.5 per cent of the total Federal budget. American industry, by way of comparison, spends about $607 million for basic research (Basic Research, Applied Research and Development in Industry, 1965. NSF 66-33)which is about 4 per cent of the 14.2 billion spent on industrial research and development. With the exception of the aircraft and missile industry, where basic research is financed almost equally by the Federal government and company funds, this industrial basic research is financed with company funds. And the industry which leads all others in the proportion of funds, 15 per cent, devoted to basic research is petroleum refining and extraction! Any company in a reasonably competitive field--say petrochemicals, or pharmaceuticals or electronics, which spends only 1 per cent of its sales on research can't be planning to stay in business for very long.

So perhaps those of us concerned with managing the basic research

programs of the Federal government have other than purely selfish reasons for wanting to see the Federal basic research budget increased--the United States lives in a competitive environment too, and I hope it's around for a long long time.

2. But why should it be the Federal government that sponsors basic research!

I should begin this section by pointing out that I am a great believer in the free enterprise system--more so than, apparently, most of the industrial representatives who show up in my office seeking research support.

The only place where science and the useful arts are mentioned specifically in the Constitution are in Section 8 of the First Article, which gives The Congress the power to: "promote the progress of science and the useful arts" by, very specifically, "securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries." Since, by practice if not by definition, a basic law of nature can not be patented--only its application--this doesn't do much for research, whatever it may do for development. And, since I am currently involved in the revision of the copyright law, I can assure you that whatever it may do for authors and publishers, copyright doesn't do much for science!

I'm afraid, then, that we have to fall back on the Preamble--"We the people of the United States, in order to...."provide for the common defense, promote the general welfare, and secure the blessings of liberty to ourselves and to our posterity, do ordain and establish the Constitution for the United

States of America."

I do not think that it is necessary to make the case for Federal support of basic research in the grandiose tones used by some of the spokesmen for Big Science. (The following quotation is via "Developments in Federal Policy Towards University Research" Harold Orlans, Science, 10 Feb 67, pp 665-668). It may or may not be true, but I think it hardly polite to say, as Victor Weisskopf (Bull At Sci 21, No 4 (1965)) does in speaking of the new 200 BEV accelerator, that:

"The value of fundamental research does not lie only in the ideas it produces. There is more to it. It affects the whole intellectual life of a nation by determining its way of thinking and the standards by which actions and intellectual production are judged. If science is highly regarded and if the importance of being concerned with the most up-to-date problems of fundamental research is recognized, then a spiritual climate is created which influences all other activities."

I don't want to knock this approach. It certainly works beautifully in selling encyclopedias, or $600 sets of Great Books, to people who somehow think that owning books is as good as reading them. But I'm certainly not going to come before you today and say that basic research should be supported because it is (Warren Weaver) " a supreme adventure of the human spirit." I tend rather to agree with Ivan Bennet of the Office of Science and Technology who says (quoted via AFCRL Newsletter Supplement, 27 Jan 1967): "Science can no longer hope to exist, among all human enterprises,

through some mystique, without constraints or scrutiny in terms of national goals, and isolated from the competition for resources which are finite... Unless we are prepared to examine our endeavors, our objectives, and our priorities, and to state our case openly and clearly, the future will be difficult indeed."

There are good hard questions--the kind every industrial research manager should be prepared to ask himself, and answer to his management of what kinds of research, in what scientific fields, and how much should be spent? There are at least five Congressional committees and subcommittees: the House Committee on Science and Astronautics; the Senate Aeronautical & Space Sciences Committee, the Government Research Subcommittee of the Senate Government Operations Committee; the Research & Technical Programs Subcommittee of the House Government Operations Committee, and; the Science, Research & Development Subcommittee of the House Space and Astronautics Committee, not to mention the Senate & House Committees charged with overseeing the budgets and activities of the separate Departments and Independent Agencies who are engaged in asking just such questions.

I think the fundamental premise, that the Federal government has a responsibility to support basic research under the general welfare clause of the Preamble, can be defended fairly easily on three grounds:

(1) The more basic the research, the more general its applications. The results of basic research transcend state and national boundaries.

(2) Basic laws of nature can not be patented. The discoverer may reap certain tangible and intangible benefits (but the Nobel Prize, the top prize in science, only pays $40,000, admittedly tax-free, and the odds against any given scientist winning a Nobel prize are 1:10,000). Money which pays taxes to keep the country going is made by those clever enough to apply these basic laws of nature.

Let me give you an example. Most of you have heard of the laser, which is being used these days for everything from drilling James Bond through the crotch (in Goldfinger) to drilling holes in diamond dies for drawing copper wire to performing the most delicate of opthalmalogical surgery, reattaching retinas.

Our office sponsored the basic research by Dr. Charles Townes which led to the invention of the laser. We spent, perhaps, $100,000 in supporting the research. Dr. Townes shared the 1964 Nobel Prize in physics with two Russians, who made the discovery independently--say he got $20,000 after the split. According to an article in Chemical and Engineering News (27 Feb, 1967) $150 million will be spend on lasers in 1966, growing to perhaps $500 million to $1 billion in 1970. Granted, the Federal government is spending 70 to 75 per cent of this money. But, and I think this is even more important than the overall figure, this includes $29 million in commercial sales of hardware in 1967, and George Stephan, marketing manager for lasers at Westinghouse, who I assume is no more optimistic than most marketing managers, predicts that this figure will quadruple by 1970 to $110 million.

So in this special case--and I'll admit that it's a very special case indeed--the investment of $100,000 by a Federal office in supporting basic research, plus the contributions of American industry in developing and applying this idea, has created a new source of industrial, and of tax income.

At least as far as commercial applications go, most of the holes drilled in basic research are very dry indeed. But I think it's just plain good business for us to pay for drilling the dry holes, and let industry then move in to exploit those where there's a practical pay-off.

(3) There are certain large, research tools and facilities which are just too expensive for private industry, or any state or combination of states to build. The best known, of course, are the giant accelerators of the Atomic Energy Commission, but we of the Air Force Office of Scientific Research, have a few of these of our own, such as the National Magnet Laboratory at MIT, which has cost us perhaps $12 million to build and operate. This facility, unique in the Free World, can create and sustain larger magnetic fields--up to 250 kilogauss--than have ever been possible before. This laboratory is a national resource already making important direct applied contributions to the defense effort, which would have been impossible to build without Federal financing.

3. But why the Department of Defense?

Those of us who manage basic research programs for the Federal government must compete for our funds in two different ways. One, which

is within our Departments, is standard to any large organization, stressing the importance of our particular activity to the overall organization, and pleading for our fair share of the budget.

This has been going on in the Air Force at least since 1949, when a special committee of the Air Force Scientific Advisory Board, headed by the late Louis Ridenour, pointed out that Air Force research and development could not be maintained at the highest level of competence without being closely related with the general research efforts of the Nation's universities, and recommended that a fraction of the Air Force R&D budget be consistently assigned to contracts with educational institutions in broad general fields on problems which, without being directed towards definite goals or applications, are of definite interest to the Air Force.

It took a lot of faith in basic research to set up AFOSR back in 1955. Since then we've been able to come up with works to justify this faith. I've already mentioned our support of the research which created the laser, and our National Magnet Laboratory. We can also show that:

AFOSR research in probability and statistics has led to direct improvements in such fields as communication theory, reliability theory and weather forecasting.

Improved education and training methods research, which started with our support of the first symposium ever held on automatic teaching, back in 1958, which has had a very significant impact on teaching machines

and on military education and training techniques in general.

Cosmic ray physics studies which have made valuable contributions to knowledge of the space environment. These studies include the world's highest cosmic ray laboratory at Mt Chacaltaya in Bolivia, and an antenna array covering 100 square miles, the largest ever built.

Seismology research, managed by AFOSR and funded by ARPA, which has provided significant contributions in recording instrumentation and techniques for studying seismic source properties and nuclear detection.

Combustion research, which has had broad impact on such important areas as fuels and oxidants for high-energy missile propulsion, and combustion stability in operating rocket engines.

Information handling and retrieval studies supported by my own Directorate, which have led to such useful systems as the computerized management control data systems in use by various Department of Defense agencies (our agency, for example, was to the best of my knowledge the first Federal agency to install a computer-based system for handling research contracts some 8 years ago--something which several major agencies have still not figured out how to do!)

The phenomenon of favorable three-dimensional interference, which has been used by Grumman to design the air inlets for the F-11F-1F aircraft, resulting in a considerable increase in the power available.

AFOSR sponsored research at Columbia University on chemical reactions in the tail flame of a high intensity arc led directly to a novel process for producing uranium monocarbide, which has been used commercially to

produce UC in many-ton lots for use in nuclear reactors.

And I am sure that my friends in the Office of Naval Research, and in the Army Research Office, are able to show equally great benefits to their respective services.

But this is only part of the problem--our day-to-day and fiscal year-to-fiscal year fight to justify our budget within the Air Force.

Because, very properly, the entire national budget for basic research is viewed as an entity by the Bureau of the Budget and the Office of Science and Technology, and there are now 16 Federal departments and agencies that conduct or support basic research, although five of them are scheduled to obligate 90 per cent of the total funds in 1965 through 1967. The Big Five are the National Aeronautics and Space Administration, the Department of Health, Education and Welfare, Department of Defense, the Atomic Energy Commission, and the National Science Foundation. Of the remaining 10 per cent of the funds, half are expected to be obligated by the Department of Agriculture, and the rest by the Departments of Commerce, the Interior, Labor, the Treasury, and Housing and Urban Development, the Civil Service Commission, the Smithsonian Institution, the Veterans Administration, the Office of Economic Opportunity, and the Small Business Administration.

There are considerable differences among the agencies in the levels of support provided basic research. In DoD, basic research represents only 4 per cent of the total agency R&D budget for 1966; in NASA only

12 per cent, and in the AEC, 23 per cent. For HEW the share is 33 per cent and for NSF 99 per cent.

In the 1960's NASA assumed the leadership in basic research support, and in FY 67 is scheduled to account for 31 per cent of all Federal basic research effort. However these figures are slightly (!) padded by the inclusion of the costs for expendable equipment in the forms of launch vehicles, spacecraft, and instruments used to obtain interplanetary data.

During the decade of the 1950's, DoD was the main Federal supporter of basic research, and AEC was second. But in recent years "civilian" programs as a whole have been receiving more basic research support than have those of a military nature. Since 1963 HEW has been second in basic research funds, largely the results of effort in the National Institutes of Health (administered by the Public Health Service), which sponsors a host of programs in the life sciences. The AEC and DoD, now third and fourth, respectively, have only grown slowly in the 1960's, while NSF, still in fifth place, has shown the fastest growth.

Most of the post-war policies and patterns for Federal support of basic research were established in 1946 with the formation of the Office of Naval Research. And when the National Science Foundation, headed by the Chief Scientist of ONR, was established in 1950 with the original mission of being the sole support of basic research in the government, an agreement was soon reached with the other agencies that NSF's role was to be the support of "uncommitted" or basic research not tied to specific

missions or objectives. We in DoD, NASA, HEW and AEC were and still are to support "mission-oriented" research--research directly or indirectly to the accomplishments of the missions of our agencies.

I don't feel that the research we do in the mission--oriented agencies is necessarily any less basic than the uncommitted research sponsored by the National Science Foundation. Granted, we have one extra series of hurdles--we not only, at the very least for our own professional satisfaction, have to make sure that it is good research, but we also have to be prepared to justify its support on grounds of Air Force need and relevance. This is, to say the least, sometimes a nuisance but I don't think that it's all bad. And there's a certain something to be said for keeping in close touch with the users of the product. Back when I was in industrial research I enjoyed talking to the salesman at least as much as I did to the V.P. for Research--it wasn't enough to turn out something from the laboratory, you had to find out how it stood up in the field.

So, one always hopes that when the national basic research money is divvied up, the fact that the Department of Defense has a certain professional competence in selecting and managing basic research programs won't be overlooked or forgotten.

Let me make one other point in this talk. Much of my time during the past 10 years has been spent in trying to figure out better methods of handling scientific and technical information. I assume that I am

one of those Mr. Schulz (Reader's Digest, op. cit.) refers to as a government publicist grandiosely speaking of a federally spurred "knowledge explosion." If so, I belong in very distinguished company, including the present Vice President of the United States. But by the union rules, which even a Vice President has to observe, you don't talk about a "knowledge explosion", you talk about an "information explosion". And, if you look closely at the "information explosion" you begin to wonder what happened to it?

It is legitimate to say--it's one of those numbers which it is too much trouble to disprove--that the world's scientific literature is doubling every 15, or 10, or 7 years. Let's assume, for the sake of argument, that the world's scientific literature does double every 10 years. At best, or worst, this would give us from 8 to 10 times as much literature to cope with in 1965 as we had in 1940. But, during that same period, the money for research and development spent by the Federal government alone, to say nothing of the private sector, increased two hundred times. So perhaps a better question would be to ask whatever happened to all that information we were paying for?

I feel very strongly that it is the duty of every investigator supported by public research funds to make a full and complete report of what he has or has not accomplished with these public moneys, just as I feel that it is the duty of the agency supporting his research to make sure that this record is publically available. We in AFOSR, for

example, encourage our investigators to publish in the open scientific literature, or in the report literature as we and they see fit. We are one of the few agencies which takes the trouble and resources to publish complete bibliographies of all the research we have supported--and just to give you an idea of the scale, last year our investigators published some 3,000 items--books, journal articles and technical reports. We send all of these in to the Defense Documentation Center, where they are made available without charge to the Defense community. And, since most of our research is unclassified, we send these reports for sale to the general public, via the Defense Documentation Center, to the Clearinghouse for Federal Scientific and Technical Information, which Mr. Schulz refers to as a "brick-and-glass monument to government's obsession with research."

I was fascinated by Mr. Schulz' reference to piles of reports 15 feet high, since I have been unable to pile reports more than 2 ft high on my desk before they start falling over. I called the Clearinghouse to find out how they did it. They were as confused by Mr. Schulz' reference as I was. They do have 30,000 square feet of storage space, but this is filled with steel shelving, all of which is 7' 3" high. (This 30,000 square foot figure, by the way, includes aisle space.) In addition, they have another 7,500 square feet of storage space used for bulk storage of very popular reports in palletized boxes--and the height of these piles is limited by the stroke of their fork-lift trucks to 11 feet!

Mr. Schulz did show commendable restraint in one aspect, though. If he had been striving for cheap sensationalism, rather than making a quiet scholarly study of Federal support of basic research, he would not have referred to "half a million" federally financed scientific reports. The average number of copies stored at the Clearinghouse is a lot closer to one and a half million!

There's one little problem about these numbers. You have to keep in mind the difference between the title of a report, which is like a parts number, and the number of physical copies of the report, which are like the number of parts in a bin under a particular part number. The half million figure refers to the number of titles, or parts number, in the Clearinghouse catalogs. The number of titles that they have in inventory--it's the difference between ordering from the Sears Roebuck catalog and going to one of their big shopping centers--is a lot closer to 75,000. One and a half million is the number of reports they have on hand under these parts numbers.

The Clearinghouse is like Sears Roebuck in another way. The only way to get a report from it is to ask for it and pay for it. Last year they shipped out over two million copies of reports, at the rate of 5-6,000 reports a day. And a 100 per cent turn-over of inventory a year isn't too bad a figure!

Earlier in the article Mr. Schulz becomes properly incensed about the Office of Economic Opportunity's retaining authority to prohibit

publication of the results of a study it was sponsoring, and quotes an editorial from the Washington Post to the effect that "The public, which is paying for them, would like to see the adverse results as well as the favorable ones."

In our own experience at AFOSR we have found that we average about one report per 20,000 research dollars. This figure is probably on the low side. Even so, at this figure, the 500,000 titles in the Clearinghouse catalog represent the expenditure of some 7 billion of taxpayer's dollars. I hate to think of just how worked up Mr. Schulz could get if we in the Federal government kept these reports to ourselves, and did not set up a convenient mechanism to enable the taxpayer to get access to the results of the research he has bought and paid for!

SUMMARY

I am afraid that in trying for a Texas-sized topic I have put a Texas-sized strain on your patience, which I can only hope is also Texas-sized. Be only grateful that you don't have to listen to me when I start teaching at Drexel next month, and have to prepare three-hour lectures!

But what I have tried to do in this time, which was all too short for me to say the things I wanted to say, however long it may have been for you to listen, that I have:

Given you a cursory notion of what basic research is all about and perhaps that basic research is like the Irishman is supposed to have said

about whiskey "All of it is good, but some is better than others."

That it is not illegal and immoral (even if in my own case, slightly fattening) for the Federal government to support research.

That we in the Department of Defense in general, and the Air Force Office of Scientific Research in particular, are not completely and hopelessly incompetent as research managers.

And that if we in the Federal government didn't make every attempt we could to make the results of tax-supported research freely available, within the considerations of National security, the Reader's Digest would really have something to write about.

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13. ABSTRACT

In this talk, prepared for a general audience, the author discusses (I) What is basic research?; (II) Why is basic research a Good Thing for the Federal government to support?; (III) Why is basic research a Good Thing for the Department of Defense to support? (I) discusses the difficulties of definitions of basic research, and compares Federal and industrial research budgets. (II) leans heavily on the General Welfare clause of the Preamble to the Constitution of the US, with instances drawn from the research sponsored by AFOSR. III discusses the changing role of DoD in national research support. An addendum defends the Clearinghouse for Federal Scientific and Technical Information against an unwarranted criticism in a popular digest magazine.

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