KEYNOTE ADDRESS

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I am highly honored to be asked to speak to such a distinguished group of international scientists, engineers, and scholars. In behalf of the Office of Aerospace Research, I would like to extend a special welcome to our visitors from overseas and Canada, as well as to those from the United States. I understand we have representatives in the audience from Great Britain, Australia, Germany, Holland, and Belgium. We are glad to have you with us, and I hope your stay with us will be pleasant.

When I accepted the invitation to speak this morning, I did so not with the idea that I could tell you something new or even something of passing interest about matrix methods in structural mechanics. I knew I would have to leave that responsibility to the authors of the papers you will hear presented during this symposium. I accepted your invitation because I felt very strongly about the importance of mathematical research and what it promises. I wanted to let you know how I and my organization, the Office of Aerospace Research, view the work you and your fellow scientists and engineers are doing and indicate some of the areas where we believe your contributions can be most helpful to the United States Air Force.

I am reminded of a story told by Major General Marvin Demler, during a speech he made early this year at the University of Detroit. It concerns the famous Bernoulli family in Switzerland, who were distinguished in scientific and mathematical history during the 18th century.

Legend has it that each of the Bernoullis lived in hope that he would create a mathematical abstraction of principle that had no application. Five of them died disappointed because somebody always found good use for everything they produced. The sixth one, it is said, died happy because he thought he had finally produced a principle that was thoroughly useless. What was it? It was the theory of the solution of simultaneous equations (now the basis of so much of our advanced mathematics in daily use all over the world). Whether or not this legend is based on facts is immaterial. It does illustrate a point, a point that we in the Office of Aerospace Research keep constantly in mind. Any mathematical discovery, will likely eventually contribute to the solution of some problems that are the concern of man.

Mathematics, "the Queen of the Sciences," constantly provides intellectual tools for scientists in their search for new knowledge or a new approach to an old problem. And just as science is the key to technology, so is mathematics the key to science. It is the single most important tool, and perhaps the only one, by which our environment can be described, predicted, and eventually controlled.

In recognition of the importance of mathematical research, the Office of Aerospace Research has consistently supported mathematicians through grants and contracts — as well as performed research in our own laboratories. Currently, our Office of Scientific Research has 175 contracts totaling approximately $5 million in mathematical research; in addition we have an active in-house research program in applied mathematics at the Aerospace Research Laboratories and at the Frank J. Seiler Research Laboratory. Our program in the mathematical sciences is concentrated in three major areas: theoretical, applied, and the information sciences.

Since you are concerned with applied mathematics, it might interest you to know our objectives in this area. We attempt to produce mathematical results which can be applied to questions arising in the broad areas of Air Force technology or the natural sciences.

In this case it should be noted that there are established areas in mathematics which have proved important in many fields of science. Examples are the theory of complex variables, the theory of special functions, the theory of differential equations, and, of special interest to this symposium — the theory of matrices. We consider research in these areas, even when pursued from the point of view of a pure mathematician, to be bona fide research in applied mathematics.

We are especially interested in research in computational analysis techniques, such as approximation and interpolation theory, matrix theory, and numerical analysis, which permit many problems to be attacked that could not otherwise be approached by analytical methods. We need investigations in mathematical programming and numerical methods which seek to use the capabilities of modern electronic computers. There are still problems which cannot be solved on even the most advanced computers. Therefore, increased emphasis is being placed on research in the theory of machines. In particular, an abstract characterization of machine capabilities and problems is sought to aid in the establishment of methods for designing sequential and nonsequential computational schemes.

In our applied mathematics program, we are supporting research in a variety of optimization problems, including those associated with (1) optimal control systems, (2) optimal trajectories for re-entry vehicles, (3) optimum aerodynamic shapes in the supersonic and hypersonic regimes, and (4) the shapes of optimum rocket nozzles with maximum thrust. We also support mathematical investigations involving the reactions in plate structures to various applied forces, the determination of eigenvalues for vibrating plates, and the response of elastic structures to moving loads.

This year the United States will spend nearly $21 billion in research and development — 3.2 per cent of the gross national product. It is estimated that 800,000 scientists, engineers, and technicians, supported by an army of craftsmen, secretaries, and laborers, are presently at work in the research and development field. According to a recent issue of the magazine U.S. News and World Report, research and development in the United States now employ more people than banking, is four times the size of the air-transport industry, and one-third the size of the country's wholesale trade.

The funds spent for scientific work during the past 20 years have provided research opportunities on a scale heretofore unknown. As a result all fields of science have benefited from the better equipment, special facilities, greater freedom from constraints, and the larger number of workers made possible by the increased budgets. Unfortunately, this has resulted in a bewildering phenomenon — the fragmentation of scientific disciplines and the constantly accelerating production of scientific literature. The knowledge that has grown up in each scientific discipline is simply too large for the mind of a single man to encompass. Some scientists feel that these two phenomena, acting synergistically, have the power to figuratively strangle all future scientific progress unless, through the new field of information complexes, we can resolve the problems relating to the physical management of scientific data.

Science and technology flourish best when each scientist interacts with his colleagues and his predecessors, and when every branch of science interacts with other branches of science. Science must remain unified to be most effective. The ideas and data of science, which are the substance of science and technology, are embodied in the literature; only if the literature remains a unity can science itself be effective and viable. Yet, because of the explosive growth of the literature, there is danger of science fragmenting into a mass of repetitious findings, or worse, into conflicting specialities that are not recognized as being mutually supporting.

It is becoming increasingly difficult for the individual scientist to keep abreast of the full flow of information contained in the journals, reports, papers, and other documents relating specifically to his own sub-discipline. It has become impossible for him to keep up with, or even understand, those which relate to other fragments of his own field of science, let alone other sciences. Yet, at the same time, the success of any scientific investigation depends heavily on the knowledge and utilization of information which has been developed by other disciplines and sub-disciplines. This is a crucial problem to be solved for optimum scientific progress.

The Office of Aerospace Research is well aware of the critical need for scientific information to be made readily available to those who need it, or for scientists to be made aware of the existence of such information. Within the Office of Aerospace Research we have placed a high priority on getting our research information into the hands of potential users within the earliest possible time. Toward this end, we are spending approximately $2 million annually for scientific investigations in areas of the information sciences. This supports about 100 principal investigators, both in-house and through grants, who are examining some of the fundamental aspects of information storage, retrieval, and transfer. From these programs, principles are emerging for the design of information systems to achieve maximum performance from men and machines and their interworking relationships.

Research is in progress on how to instruct machines to recognize patterns, extract significant information from them, and discard the rest. Language is being reduced to sets of rules a machine can understand for automatic processing of the written word. We are investigating how man perceives and operates on information in an attempt to develop formalizations of at least some of these procedures, for we know that what can be formalized can be simulated by machines.

There is no question in my mind that new components and concepts of machine organization will be developed for more efficient handling of non-numerical information than can be achieved with our present-day digital and analog devices.

The Office of Aerospace Research laboratories, contractors, and grantees publish more than 4,000 articles, reports, and books annually. We support over 50 symposia a year. We operate five technical libraries and support some 13 information centers which provide services, not only to the Department of Defense, but to the entire technical community. However, this is only a small portion of what is needed before we can quickly place new scientific knowledge into the hands of the users and potential users.

While the research you are performing is of scientific value, it cannot be used until those who can use it are made aware of its existence and it is made readily available to them. You can help us by making the results of your work available to the scientific fraternity. You must devote some of your time and attention to seeing to it that your work is properly documented. This in turn, of course, can prove of immeasurable benefit to the entire scientific community and especially in areas of Air Force interest.

In closing, may I say, most sincerely, that it is with profound appreciation of the role of the engineering and mathematical sciences in our technology that I greet you this morning and wish you a most successful and profitable symposium.