STANFORD RESEARCH INSTITUTE
MENLO PARK, CALIFORNIA

DIVISION OF ENGINEERING RESEARCH

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Dr. Marshall C. Yovits, Head
Information Systems Branch
Department of the Navy
Office of Naval Research
Washington 25, D. C.

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Proposal for Research
SRI No. EU 60-160

RESEARCH IN SELF-ORGANIZING MACHINES

Dear Dr. Yovits:

In accordance with our discussions, we are herewith submitting a proposal to cover continuing research in the field of self-organizing machines. At present, research in a specialized area of this field is being sponsored at SRI by the U. S. Signal Corps (Contract DA-36-039 SC-78343, Graphic Data Processing Research Study & Experimental Investigation). This work deals primarily with the machine recognition of non-alphanumerical geometric shapes for military purposes. It is hoped that from this work will evolve a small multistage parallel-operating machine, with some relatively simple self-organizing features. We are also conducting a limited amount of additional research, internally sponsored by the Institute, in several technical areas pertinent to the general self-organizing machine field. This latter work forms the technical basis for this proposal, which is limited to the continuation and extension of these research studies.

Proposed Research

The four areas of present interest are described in the attached appendices; it is proposed to continue work in each of these areas as time and funds permit. A brief description of the proposed work in each area follows:

1. Neural Element Development

Simple neural elements capable of performing the functions of summation, multipole gating with known thresholds, and analog memory with non-destructive read-out will be further developed. It is planned to extend the utility of

the elements already developed (multiaperture magnetic cores, "MADS") to include other geometrical shapes and other functions--such as, selective gating involving time delay and the ability of one such element to drive several elements with no other device interposed. Thin magnetic film devices will be investigated in an effort to reduce these elements to their simplest form consistent with least cost.

2. Integral Geometry Studies

These studies have considered the application of known and newly-developed theorems in integral geometry for the determination of those features of a geometric pattern which are invariant under rigid motion in a plane. If the notion of "pattern" is generalized to include forms of information other than mere geometric shapes, then the methods may be extended to these forms also, provided that the information to be recognized is transformed into suitable geometric patterns. It is proposed to continue the development and application of these techniques.

3. Distributed Memory Studies

A fundamental part of self-organized machines is the requirement for a long-term memory. It appears desirable that such a machine should process and store data in a parallel rather than a serial manner. Furthermore, a considerable degree of redundancy or other form of equivalent organization must be incorporated if very large scale memory is to be practicable. The appended paper describes one approach to this problem, postulating use of the presently-developed multistate neural elements. It is essentially a study of interconnections.

It is proposed to continue this study with a view to determining critical operating parameters--such as, the information storage capability as a function of number of storage elements with due regard to failure of elements or interconnections. It would also be important to determine how such a memory could be integrated into a self-organizing machine compatible with similar parallel-operating elements.

4. Photographic-Optical Simulation of Neural Nets

The development of a photographic-optical technique for simulating large systems of neural nets is described in the appended paper. It is expected that such a system, when developed, will facilitate the simulation of machines of significant size (initially, the equivalent of at least 1000 neural elements) with the ability to investigate, relatively inexpensively, the organization of neural nets. In particular, it will be relatively easy to change the interconnection scheme and neural element functions.

It is proposed to build a prototype system after determining the limitations imposed by photographic films, processing, and geometry.

Personnel

This work will be conducted primarily by members of the Applied Physics Laboratory and the Mathematical Sciences Department of the Engineering Research Division. There will be available consultations from members of the Computer Sciences Group of the Computer Techniques Laboratory. Negotiations are under way to obtain the services of several consultants whom we hope will be able to contribute substantially to our proposed program. The biographies of key personnel on this project follow:

Charles A. Rosen - Manager, Applied Physics Laboratory

Dr. Rosen received a B.E.E. degree from the Cooper Union Institute of Technology in 1940. He received an M. Eng. in Communications from McGill University in 1950, and a Ph.D. degree in Electrical Engineering (minor, Solid-State Physics) from Syracuse University in 1956.

During 1940-1943 he served with the British Air Commission as a Senior Examiner dealing with inspection and technical investigations of aircraft radio systems, components, and instrumentation. From 1943 to 1946 he was successively in charge of the Radio Department, Spot-Weld Engineering Group, and Aircraft Electrical and Radio Design at Fairchild Aircraft, Ltd., Longueuil, Quebec, Canada. During the period 1946-1950 he was a co-partner in Electrolabs Reg'd., Montreal, in charge of development of intercommunication and electronic control systems. During this period he also acted as a self-employed consulting engineer in these fields. In 1950 he was employed at the Electronics Laboratory, General Electric Co., Syracuse, New York, where he was successively Assistant Head of the Transistor Circuit Group, Head of the Dielectric Devices Group, and Consulting Engineer, Dielectric and Magnetic Devices Subsection. In August 1957 Dr. Rosen joined the staff of Stanford Research Institute, where he has been working on applied physics projects.

His fields of specialty include dielectric and piezoelectric devices, electromechanical filters, and a detailed acquaintance with the solid-state device field. He has contributed substantially as co-author to two books, Principles of Transistor Circuits, R. F. Shea, editor (John Wiley and Sons, Inc., 1953) and Solid State Dielectric and Magnetic Devices, H. Katz, editor (John Wiley and Sons, Inc., 1959). Three patents have been awarded and assigned; application has been made for five more and 15 are in process for application.

Dr. Rosen is a Senior Member of the Institute of Radio Engineers, a member of the American Physical Society, American Institute of Electrical Engineers, and the Research Society of America. He has organized and been the co-chairman of the Dielectric Devices Subcommittee (28.5 IRE).

Albert B.J. Novikoff - Mathematician, Mathematical Sciences Department

Dr. Novikoff received an A.B. degree from Brown University in 1945 and a Ph.D. degree from Stanford University in 1949, both in Mathematics. He was an Atomic Energy Commission Pre-Doctoral Fellow in Mathematics. From 1950 to

1952 he was an Instructor of Mathematics at Johns Hopkins University. In 1952 he became a Research Associate in the Radiation Laboratory of that university, where his work included the applications of probability and Fourier methods to noise problems and also the study of signal analysis. From 1956 to 1958 he was an Instructor of Mathematics at the University of California, especially concerned with Lie theory and differential geometry.

In June 1958 Dr. Novikoff joined the staff of Stanford Research Institute, where he has been working on probability applications to antenna measurements, theoretical network analysis, equipment location, and classical mechanics, signal discrimination, and character recognition.

In 1960 he is for the second summer an invited lecturer at the Intensive Course in Random Processes given at the University of Michigan.

Dr. Novikoff is a member of Sigma Xi, the American Mathematics Society, the Mathematics Association, the Canadian Mathematics Congress, the Societie Mathematique de France, the Society for Industrial and Applied Mathematics, and the Institute of Mathematical Statistics.

A. Robert Tobey - Staff Scientist, Division of Engineering Research

Dr. Tobey received from Yale University a B.S. degree in 1942, an M.S. in 1946, and a Ph.D. in 1948, all in Physics. The subject of his dissertation was "Neutron Production by Cosmic Rays." While an undergraduate he was a Research Assistant. From 1942 to 1945 he was a staff member of the Radiation Laboratory of the Massachusetts Institute of Technology. During 1947-1948 he was an Assistant in Research at Yale. He was Assistant Professor of Physics at Washington State College from 1948 to 1950. From 1950 to 1953 he was employed by the Armour Research Foundation in Chicago as Supervisor, Electricity and Magnetism Research, Physics Department; and Senior Scientist, Electrical Engineering Department.

Dr. Tobey joined the staff of Stanford Research Institute in September 1953 as a Supervisor in the Television Laboratory. He became a Group Head in September 1956 and Staff Scientist in September 1959. His fields of specialty include nuclear physics, cosmic rays, analysis and synthesis of electronic systems, radar, television, and the application of physics concepts and techniques to engineering problems. In particular he has applied the principles of Information Theory to the solution of problems of bandwidth compression, modulation, and signal-to-noise analysis. Patents pending are in the field of bandwidth reduction.

Dr. Tobey is a member of the American Physical Society, Sigma Xi, and the Scientific Research Society of America.

Alfred E. Brain - Research Physicist, Applied Physics Laboratory

Dr. Brain received a B.Sc. degree in 1943 and a Ph.D. degree in 1949, both in Physics from the University of Sheffield, England. From 1943 to 1946 he served at the Royal Aircraft Establishment, Farnborough, as a Junior Scientific

Officer, developing anti-jamming devices for radars. During the period of 1946 to 1949 he was a Circuit Engineer at the E.M.I. Research Laboratories, Middlesex, England, working on multistage, wideband video amplifiers. In 1949 Dr. Brain joined the staff of the Department of Physics of Sheffield University, as Ellison Research Fellow. He carried on research on the magnetic properties of semiconductors and supervised undergraduate teaching laboratories. In 1952 he returned to the E.M.I. Laboratories as a Physicist. He set up a section to do work in solid-state physics and directed the construction of a pilot line to make transistors.

In 1956 he became a Physicist in the Electronics Laboratory of the General Electric Co. in Syracuse, working on photoelectric cells, thin magnetic film, phase correction of delay lines, and the design of feedback amplifiers.

In December 1958 Dr. Brain joined the staff of Stanford Research Institute.

Dr. Brain is an Associate Member of the British Institute of Electrical Engineers and a Senior Member of the Institute of Radio Engineers.

Kenneth R. Shoulders - Senior Research Engineer, Applied Physics Laboratory

Prior to joining the staff of Stanford Research Institute in September of 1958, Mr. Shoulders spent three years in applied research on microminiature data-processing components and systems at the Massachusetts Institute of Technology. His chief area of activity was the study and testing of micro-fabrication methods for field emission amplifiers, film cryotrons, magnetic film memories, and photoconductive and electroluminescent devices. During this period he also did research on digital computer components and systems, and served as a staff member of the Lincoln Laboratories and the Research Laboratory of Electronics, and as a consultant to industry on ultravacuum techniques and material processing methods.

Previous to this period at M.I.T. Mr. Shoulders had about ten years research and development experience which included development work on magnetic component design for microwave multiplex communication systems at Collins Radio Company; design experience as chief engineer at Digital Control Systems, Inc., where he was engaged in various aspects of digital computers and digital servo-systems; and a year working as an electronic engineer on subminiature droppable-radiac detecting equipment for Texas Instruments, Inc. During this period with Texas Instruments, research on a miniature electrochemical servo was undertaken as an individually sponsored program. At the Radioplane Company during 1951, Mr. Shoulders was involved with a guidance system for target drone aircraft, and at the Vacuum Tube Research Laboratories of Capehart Farnsworth Corporation, he worked as secondary emission project engineer on memory tube surfaces and infrared converter tubes.

His work on microelectronics is being carried on in the Applied Physics Laboratory of the Division of Engineering Research at Stanford Research Institute.

Marian F. Hirsch - Research Chemist, Applied Physics Laboratory

Miss Hirsch received a B.S. degree in Chemistry from Rosary College, River Forest, Illinois, in 1949, and later did graduate work in that subject at Northwestern University. During 1951-1953 she was employed by A. B. Dick and Company. From 1953 to 1955 she was a Chemist in the Nubian Division Research Department of the Glidden Company.

Miss Hirsch joined the staff of Stanford Research Institute in 1955. She has been instrumental in perfecting printing inks, Multilith techniques, and magnetic transfer paper for the Bank of America check reading program, and has worked on the encapsulation of electronic components. Recently she has been working on formation of thin films of magnetic semiconductor and ferroelectric materials by electroplating and other methods.

Her fields of specialty include the formulation and evaluation of pigments, varnishes, inks, paints and related products; light-sensitive coatings; color phenomena; paper-coating techniques; spectrophotometry; organic synthesis; and photo-catalysis.

Miss Hirsch is a member of the Scientific Research Society of America and the American Chemical Society.

George E. Forsen - Research Engineer, Applied Physics Laboratory

Mr. Forsen received both an S.B. and an S.M. degree in Electrical Engineering from the Massachusetts Institute of Technology in 1957, and the degree of Electrical Engineer from M.I.T. in 1959.

On the Cooperative Plan with M.I.T. he was employed part time in 1954-1956 by the General Electric Co. While with G.E. he was a member of the Small Aircraft Engine Department (Lynn, Massachusetts), the General Engineering Laboratory (Schenectady, New York), and the Electronics Laboratory (Syracuse, New York), working on standards, non-destructive testing methods, and measurement techniques for heat flow in power transistors, respectively.

In 1958-1959 he was a member of the Communications Biophysics Group, Research Laboratory of Electronics at M.I.T., as a Research Assistant and staff member. There he designed electronic instrumentation for the study of neuroelectric and psychophysical phenomena related to nervous systems. From 1957 to 1959 he was also employed by the Electrical Engineering Department of M.I.T. as a Teaching Assistant.

In October 1959 Mr. Forsen joined the staff of Stanford Research Institute. At the Institute he is currently engaged in the study of field emission and neuron-like devices.

Mr. Forsen is a member of the Institute of Radio Engineers and Sigma Xi.

Estimated Time and Charges

The estimated time required to complete this project and report its results is one year. The Institute could begin work on the project within one week following receipt of an executed contract. A detailed cost break-down is attached to this proposal.

It is requested that any contract resulting from this proposal be written on a cost-plus-fixed-fee basis.

This proposal will remain in effect until 30 September 1960. If consideration of the proposal requires a longer period, the Institute will be glad to consider a request for an extension in time.

Respectfully submitted:

C. A. Rosen, Manager
Applied Physics Laboratory

Approved:

J. D. Noe, Assistant Director
Division of Engineering Research