

# STANFORD RESEARCH INSTITUTE

MENLO PARK, CALIFORNIA



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Proposal for Research  
SRI No. ESU 67-48

ENGINEERING CHANGE TO CONTRACT AF 30(602)-4147 FOR  
APPLICATION OF INTELLIGENT AUTOMATA TO RECONNAISSANCE

Prepared for:

Rome Air Development Center  
Griffiss Air Force Base  
New York 13440

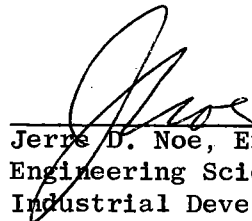
Request for Proposal No. I-8-4727

Prepared by:

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## I INTRODUCTION AND STATEMENT OF WORK

In response to RADC Request for Proposal No. I-8-4727, entitled Engineering Change to Contract AF 30(602)-4147 For Application of Intelligent Automata to Reconnaissance, Stanford Research Institute herewith proposes the following changes.

### A. Addition of Paragraph f to Item 1, Phase 2

Develop a general plan to conduct sets of experiments which utilize results of the study to date and consider at least the following additional aspects:

- (1) Conduct of experiments in which an obvious intermediate objective (subgoal) shall be discovered by the automaton system; missions in which some significant change is made to the environment during the experiment; and missions in which navigation about an area is not the principal "intelligent" task.
- (2) The ability to monitor the status of system elements (e.g., hardware registers, property lists, preprocessed visual scenes) during operation. Reduction of system speed during monitoring is acceptable.
- (3) Utilization of equipment or techniques to enable access of the vehicle to a variety of environments (e.g., via radio link), interaction with human operators, improved "intelligence" (picture processing, machine learning), or increased speed.

### B. Phase 3

Experimentation and evaluation of the complete (automaton) system in increasingly complex environments and missions in accordance with the test plan developed in Item 1, phase 2, paragraph f above.

## II METHOD OF APPROACH

### A. Phase 2

The proposed addition to Phase 2 calls for development of a plan of experiments demonstrating specific capabilities of the automaton system. Provision of some of these capabilities requires the additional research and instrumentation described below.

We propose to develop techniques allowing the execution of missions in which navigation is not the primary "intelligent" task. Examples of missions in which more than the mere ability to navigate is required include:

- (1) Exploration and mapping of an initially unknown real environment
- (2) Location and identification of specified objects in the environment
- (3) Transporting (by pushing) objects from one place to another in the environment.

Successful execution of tasks more elaborate than navigation, will require development and integration into the system of heuristics and data structures for handling a number of other interrelated jobs. Among these are:

- (1) Object recognition and classification, including strategies for persistent examination of objects, as an aid to recognition and classification
- (2) Precise surveying of environmental features
- (3) Reorientation of the vehicle (if it becomes lost because of cumulative measurement errors or environmental changes)
- (4) Development of grasping, pushing, or other manipulative abilities to modify the environment
- (5) Task planning--in which a complex task must autonomously (without human intervention) be decomposed into a chain of subtasks to be executed sequentially.

It will usually be necessary for the automaton system to discover a sequence of intermediate objectives or subgoals in the execution of these complex tasks. Our experimental plan will include such definite missions as transporting of objects in which a subgoal--such as removal of a barricade--will be discovered by the automaton system. In addition we propose to carry out some of these experiments under such changing environmental conditions as rearrangement of the positions of environmental objects during the experiment.

An excellent start on many of these enhanced abilities has already been made in the work that has been done under the present contract. Simulation studies have demonstrated the feasibility of certain initial approaches toward generation of subgoals in complex tasks, e.g., mapping of an initially unknown environment. (See the appendix for a

brief review of some of these simulation experiments. For further details of progress to date on the present contract see Refs. 1 and 2.)

A key item necessary for the successful execution of the advanced experiments will be the development of a problem specification language. We propose to develop a logically consistent language, that is simultaneously general enough to express a large class of interesting tasks and easy to learn and use. A scheme for translating statements in this language into a machine-oriented procedural language will have to be developed in conjunction with the development of the problem-specification language itself.

The second major item in the proposed addition to Phase 2 work calls for the ability to monitor and control the status of system elements. The automaton system then would be a much more effective experimental tool. This monitor and control system would make use of a TV monitor, CRT display, light pen, and the teletype keyboard and printer to permit intimate interaction between an experimenter and the active automaton system. The experimenter will be able to select the manner and extent of his monitoring activities, depending upon the needs of the particular experiment or demonstration. The levels and options of monitoring activity could include:

- (1) Observation of a continuous teletype printout of "stream of consciousness" reports from the automaton
- (2) Interruption of an experiment, with the ability to modify key program parameters and thus influence future behavior.
- (3) Display on the CRT of visual images after various stages of processing
- (4) Diagrammatic display on either teletype or CRT of the automaton's model of specified portions of its environment, permitting the experimenter to correct errors or introduce "phantom" obstacles
- (5) Manual insertion of typical responses from hardware sensors or software modules that may not be working properly, thus avoiding disruption of an experiment with the rest of the system

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1. C. A. Rosen and N. J. Nilsson, "Applications of Intelligent Automata to Reconnaissance," Interim Report 1, Contract AF 30(602)-4147, SRI Project 5953, Stanford Research Institute, Menlo Park, California (November 1966).
  2. C. A. Rosen and N. J. Nilsson, "Applications of Intelligent Automata to Reconnaissance, Interim Report 2, Contract AF 30(602)-4147, SRI Project 5953, Stanford Research Institute, Menlo Park, California (March 1967).

- (6) Monitoring of all automaton sensors and manual control of all effectors, thus permitting an experimenter to "compete" with the automaton by trying to solve the same problems while receiving comparable sensory data.

A monitoring system such as this is essential to enable an experimenter to understand and try to improve the behavior of a system as complex as the automaton. Because of its fundamental importance to the project we propose that work on the design, development, and use of the monitoring system be carried out in close coordination with RADC project personnel.

The third major item proposed for the addition to Phase 2 calls for certain extensions of the general abilities of the automaton system. First among these is sensory perception. Most of our effort will be directed toward the most important of the senses, vision.

Two categories of techniques are proposed. The first is the use of additional descriptors, such as depth, color, and texture. The second is the use of external information about the environment. This information may come from encyclopedic, a priori facts built into the system and/or from the representations of the world based upon information acquired by the automaton through its accumulated experience.

Specific techniques to be tried include:

- (1) The use of existing models of the environment to predict objects and to identify background clutter
- (2) The use of other descriptor types--e.g., depth, color, texture, and local velocity--to differentiate figure from ground
- (3) The collective use of these descriptor types, in addition to shape, on property-list descriptions of objects, and improvements of the reliability of shape descriptors
- (4) The use of partial list-matching routines or superimposed coding techniques to allow recognition of partially viewed or represented objects
- (5) The modification and application of various model-matching techniques with possible extension to non-planar surfaces.

The above techniques can be used in a higher-level software structure that may verify anticipated visual scenes--i.e., look for specified objects rather than respond passively in some fixed way to all of the current visual stimuli. Although more susceptible to mistakes in unusual circumstances, this approach is expected to realize systems that are, on the average, more efficient and useful to the automaton.

It is therefore proposed to design and fabricate any additional required preprocessing hardware and to develop the above techniques. Furthermore, studies will be made to define critical problem areas pertaining to more complex visual environments.

A second extension to the automaton facility is the addition of a radio link between the vehicle and the SDS 940 computer system. The present contract provides for a cable connection between the vehicle and computer-preprocessing hardware. While this communication channel will be adequate (and even desirable) for debugging the system, it imposes serious constraints on the vehicle's mobility and range of operation. For example, it is desired to perform missions such as "Move all of the cubes out of room 14 and into room 16." Performing such missions with a trailing cable is impossible. Accordingly, the interface (software and hardware) between vehicle and fixed equipment has been designed to permit replacement of the cable by a radio link composed of two channels for video and telemetry. It is proposed to implement this design as soon as the cable-connected system is checked out.

A third extension is improved overall "intelligence" of the system itself, particularly as this might be achieved through learning techniques.\* We plan a specific effort to develop and study a variety of techniques that would enable an automaton to learn to improve its performance. Wherever possible, the techniques developed under this study will be implemented to improve the capabilities of the evolving automaton system. We intend to investigate application of the following specific learning techniques:

- (1) Rote learning and model building
- (2) Clustering techniques
- (3) Generalization learning
- (4) Reasoning by analogy and concept formation.

Stanford Research Institute has made some excellent beginnings at implementing in simulation some of these learning methods already during the present project and in past work. The appendix to this proposal reviews some of the rote-learning techniques. Clustering and generalization learning have been thoroughly investigated in past work on pattern-recognition techniques. In addition, a small effort is now under way on techniques for concept formation and reasoning by analogy.

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\* "Learning" may be defined, generally, as any process by means of which performance is changed (hopefully, improved) as a function of previous experience.

### B. Phase 3

Work in Phase 3 will proceed as dictated by the test plan developed in the proposed addition to Phase 2. This work will be conducted using the automaton vehicle itself, special monitoring equipment as required, special visual preprocessing equipment, and the SDS 940 time-shared computer.

Initially, the automaton experiments will be conducted in a simple, highly-constrained environment: A small laboratory room containing simple rectilinear objects. This environment will be enlarged in size when the radio link is added. At the same time it will be populated with increasingly complex-shaped objects.

One step up in complexity will be an environment consisting of the offices and corridors adjacent to the computer room. Again this environment will be highly rectilinear, but it will be populated with objects common to office and laboratory, such as desks and chairs. Here it begins to be necessary to replace the cable link with the radio link.

A considerably more interesting situation would include humans within the automaton's field of view. Perhaps some quite complex tasks, such as: "This is Sam; follow him," could be given to the automaton at this stage. Probably outside the range of possible environments during the proposed extension is that provided by the "outside world" of the SRI parking lot, consisting of automobiles, trees, buildings, and people. However, every effort will be made to proceed toward the goal of an automaton functioning in such an environment.

### III SCHEDULE OF WORK

It is proposed that the addition to Phase 2 be begun on 1 November 1967, to continue for five (5) months. Phase 3 should begin immediately after the successful completion of Phase 2f. This would provide continuity of work, thereby eliminating unproductive staffing and computer costs which would result from a 30-day waiting period as contemplated in Proposal Request No. I-8-4727. The experiments to be conducted under Phase 3 could be completed in four (4) months. Thus, acceptance of this proposal and its initiation by 1 November 1967 would extend the duration of the research program to 31 July 1968.

### IV REPORTS

Stanford Research Institute will prepare and submit reports in accordance with the requirements set forth in Proposal Request No. I-8-4727.

### V CONTRACT FORM

It is requested that any contract resulting from this proposal be written as a Supplemental Agreement to Contract No. AF 30(602)-4147.

## VI ESTIMATED TIME AND CHARGES

The estimated time required to complete the proposed work is nine (9) months. The results will be reported within one (1) month thereafter. The attached cost breakdown details the estimated costs for the changes to Item 1 and the estimated resulting additional costs to Items 2 and 3.

## VII ACCEPTANCE PERIOD

This proposal will remain in effect until 15 November 1967. If consideration requires a longer period, the Institute will be glad to consider a request for an extension of time.

## VII PERSONNEL

Key personnel will be drawn from the Engineering Sciences and Industrial Development research area, directed by Dr. Jerre D. Noe. Supervision of this project will be under the direction of Dr. Charles A. Rosen. Biographies of key personnel are given below.



## VII PERSONNEL

Key personnel will be drawn from the Engineering Sciences and Industrial Development research area, directed by Dr. Jerre D. Noe. Supervision of this project will be under the direction of Dr. Charles A. Rosen. Biographies of key personnel are given below.

Noe, Jerre D. - Executive Director  
Engineering Sciences and Industrial Development

Dr. Noe holds a B.S. degree from the University of California at Berkeley, and in 1948 received the Ph.D. degree in Electrical Engineering from Stanford University.

Dr. Noe came to Stanford Research Institute from Hewlett-Packard Company, Palo Alto, where he was engaged in the development of broad-band amplifiers from 1946 to 1948. For two years prior to joining this organization he was a Research Associate at the Radio Research Laboratory of Harvard University, concerned with jamming transmitters, search receivers and airborne direction-finders. During 1944 he was with the Laboratory's affiliate, American-British Laboratory, in Malvern, England. In early 1945 he was assigned to the Mediterranean Theatre of Operations as Senior Technical Advisor for radar-countermeasures.

At Stanford Research Institute his early work was in system studies for aircraft blind landing equipment. Following this, he was in charge of the ERMA project, the first large-scale data processing and automatic character recognition system for the banking industry.

In his present position, Dr. Noe directs a group of laboratories concerned with computer hardware and software for control and information processing.

He is a member of Sigma Xi, Eta Kappa Nu, Tau Beta Pi, and The Institute of Electrical and Electronics Engineers.

Dr. Noe served as a member of the National Joint Computer Conference Committee in 1953-54. In 1954 he was appointed to serve on the National Administrative Committee of the IRE Professional Group on Electronic Computers. He became National Chairman of the PGEC for 1956-1957.

Rosen, Charles A. - 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 (with a minor in Solid-State Physics) from Syracuse University in 1956.

Since December 1959, Dr. Rosen has been Manager of the SRI Applied Physics Laboratory, engaged in directing a program including major projects in microelectronics, learning machines, and artificial intelligence.

From 1940 to 1943 he served with the British Air Commission 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, and Aircraft Electrical and Radio Design at Fairchild Aircraft, Ltd., Longueuil, Quebec, Canada. From 1946 to 1950 he was a partner in Electrolabs Reg'd., Montreal, engaged in the development of intercommunication and electronic control systems. From 1950 to 1957 he was employed at the Electronics Laboratory, General Electric Co., Syracuse, New York, and 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 was shortly given responsibility for developing the Applied Physics Laboratory.

His fields of specialization include learning machines, dielectric and piezoelectric devices, electromechanical filters, and a general 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).

Dr. Rosen is a Senior Member of the Institute of Electrical and Electronics Engineers, and a member of the American Physical Society and the Scientific Research Society of America.

Nilsson, Nils J. - Head, Artificial Intelligence Group  
Applied Physics Laboratory

Dr. Nilsson has been on the staff of Stanford Research Institute since August 1961 where he has participated in and led research in pattern recognition, learning machines, and artificial intelligence. He has taught courses on learning machines at Stanford University and at the University of California, Berkeley. McGraw-Hill published, in March 1965, a monograph by Dr. Nilsson describing recent theoretical work in learning machines.

Dr. Nilsson received an M.S. degree in Electrical Engineering in 1956 and a Ph.D. degree in 1958, both from Stanford University. While a graduate student at Stanford, he held a National Science Foundation Fellowship. His field of graduate study was the application of statistical techniques to radar and communication problems.

Before coming to SRI, Dr. Nilsson completed a three-year term of active duty in the U.S. Air Force. He was stationed at the Rome Air Development Center, Griffiss Air Force Base, New York. His duties entailed research in advanced radar techniques, signal analysis, and the application of statistical techniques to radar problems. He has written several papers on various aspects of radar signal processing. While stationed at the Rome Air Development Center, Dr. Nilsson held an appointment as Lecturer in the Electrical Engineering Department of Syracuse University.

Dr. Nilsson is a member of Sigma Xi, Tau Beta Pi, the Institute of Electrical and Electronics Engineers, and the Association for Computing Machinery.

Baer, James A. - Research Engineer, Computer Techniques Laboratory

Mr. Baer received a B.S. degree in Electrical Engineering from Washington State University in 1951, and the Master of Electrical Engineering degree from Syracuse University in 1957.

From 1951 to 1958 he was employed by the General Electric Company. During most of this period he was an Engineer in the Dielectric and Magnetic Devices Subsection of the Electronics Laboratory, Syracuse, New York. His major field of research centered around ferroelectric ceramic devices, in particular, electromechanical devices using the piezoelectric property of these dielectrics.

In 1958-1959 he was a Senior Engineer with the Lenkurt Electric Company, San Carlos, California. He was engaged in the design of quartz crystal vibrators, and quartz crystal filters for carrier communication systems.

In May 1959 Mr. Baer joined the staff of Stanford Research Institute where his major field of research centers around all-magnetic logic devices. His activities include investigation of the properties of magnetic materials, investigation of the effects of nuclear radiation on materials and components, the development of new digital and analog devices, the development of new magnetic and magnetic/semiconductor circuits, and the development of new logic systems.

Mr. Baer is a member of Sigma Tau, the Scientific Research Society of America, the Institute of Electrical and Electronics Engineers, and the IEEE Professional Groups on Magnetism and on Electronic Computers. He has contributed to the book Solid State Magnetic and Dielectric Devices, edited by H. W. Katz.

Chaitin, Leonard J. - Systems Programmer, Applied Physics Laboratory

Mr. Chaitin received a B.S. degree in Chemical Engineering from the Pennsylvania State University in 1959.

From 1959 to 1962 Mr. Chaitin was employed by C-E-I-R, Inc. as an EDPM Programmer. From 1962 to 1966 he was employed as a Programmer for Stanford Research Institute. From March 1966 to October 1966 he was employed by Programming Services, Inc. Mr. Chaitin returned to the Institute in October 1966 as a Systems Programmer in the Applied Physics Laboratory.

Mr. Chaitin has done utility, systems, and specific programs. Among these were the first pass and modifier of an "SOS" type compiler (CEIRCORDER), a FORTRAN preprocessor for such a compiler, a system for estimating the thermodynamic properties of gaseous substances at unusual temperature ranges, tracking and orbit control of satellites, data-reduction programs, a statistical survey for the Federal Aviation Agency, a gasoline-blending program, and various chemical design and unit processes and operations programs.

At the Institute Mr. Chaitin has implemented an input-output package and monitor for a large-scale war-game simulation program, developed a program to change digitized analog data into reducible form and added a package to facilitate its reduction, worked on an information-retrieval program as part of a "man-machine" system, and written a number of statistical programs concerned with power spectral density and hypothesis testing. As a Systems Programmer, he has worked on software modifications to the B-5500, the dissemination of programming information, and writing utility routines. Other projects include a test and diagnostic system for General Electric Company, text editor for a Government agency, and a feasibility and damage-assessment program for the Navy. Mr. Chaitin is currently responsible for software implementation on the SRI Automata project.

Mr. Chaitin has programmed for the IBM 650, IBM 704, IBM 709, IBM 7090, IBM 1620, Burroughs 220, CDC 1604, RCA 501, IBM AN/FSQ-32, GE 435, GE 625, GE DATANET 30, and SDS 940.

Coles, L. Stephen - Research Mathematician  
Applied Physics Laboratory

Dr. Coles received his B.S. degree in Electrical Engineering from Rensselaer Polytechnic Institute in 1962, his M.S. degree in Mathematics from Carnegie Institute of Technology in 1964, and his Ph.D. degree in Systems and Communication Sciences from Carnegie Mellon University in 1967.

Dr. Coles held a New York State Regents Engineering Scholarship and a Rensselaer Scholarship at R.P.I. from 1958 to 1962. At Carnegie Tech he held an ARPA Research Assistantship and was elected to the Society of Sigma Xi in 1966.

Dr. Coles has been involved in the field of computing (both analog and digital) in one form or another since the summer of 1960, when he began programming at Republic Aviation Corporation in Farmingdale, New York. While employed by the System Development Corporation in 1962-63, he aided in the design of the Strategic Air Command Control System. During the summer of 1965, he acted as assistant to the Director of Information Processing at the Advanced Research Projects Agency of the Department of Defense. During the summer of 1966, he was awarded a National Science Foundation International Travel Grant to attend the NATO sponsored Summer School in Man-Machine Interaction at the University of Edinburgh. In addition to his current research at SRI, Dr. Coles is also serving as a Lecturer with the Department of Electrical Engineering and Computer Science at the University of California at Berkeley and with the Computer Science Department at Stanford University.

Dr. Coles is a member of the Association for Computing Machinery, the Institute for Electronic and Electrical Engineers, the Association for Machine Translation and Computational Linguistics, and the Society of Sigma Xi.

Duda, Richard O. - Research Engineer, Applied Physics Laboratory

Dr. Duda received a B.S. degree in 1958 and an M.S. degree in 1959, both in Electrical Engineering, from the University of California at Los Angeles. In 1962 he received a Ph.D. degree from the Massachusetts Institute of Technology, where he specialized in network theory and communication theory.

Between 1955 and 1958 he was engaged in electronic component and equipment testing and design at Lockheed and ITT Laboratories. From 1959 to 1961 he concentrated on control system analysis and analog simulation, including adaptive control studies for Titan II and Saturn C-1 boosters, at Space Technology Laboratories.

In September 1962, Dr. Duda joined the staff of Stanford Research Institute, where he has been working on pattern recognition and related topics in artificial intelligence. He has taught a course on learning machines for the University of California Extension and has been the author or coauthor of several papers in this field.

Dr. Duda is a member of Phi Beta Kappa, Tau Beta Pi, Sigma Xi, the Institute of Electrical and Electronics Engineers, and the Association for Computing Machinery.

Forsen, George E. - Research Engineer, Applied Physics Laboratory

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

He was employed part time from 1954 to 1956 by the General Electric Company, on the Cooperative Plan with MIT. While with GE he worked on non-destructive testing methods, and measurement techniques for heat flow in power transistors.

From 1958 to 1959 he was a Research Assistant and staff member of the Communications Biophysics Group, Research Laboratory of Electronics at MIT. There he designed electronic instrumentation for the study of neurophysiological phenomena. From 1957 to 1959 he was also employed by the Electrical Engineering Department of MIT as a Teaching Assistant.

In October 1959 Mr. Forsen joined the staff of Stanford Research Institute where he has been engaged in the study of neuron-like devices and adaptive, cognitive systems. He is currently working on mechanizing vision of three-dimensional environments. He has authored several patents and papers in these fields.

Mr. Forsen is a member of Sigma Xi, the Institute of Electrical and Electronics Engineers, and the IEEE Professional Group on Electronic Computers.

Green, Milton W. - Senior Research Engineer  
Computer Techniques Laboratory

Mr. Green received a B.S. degree in Electrical Engineering from Purdue University in 1947. From 1947 to 1959 he was a member of the technical staff of RCA Laboratories Division, Princeton, New Jersey. At RCA Mr. Green was at first engaged in the design and fabrication of special-purpose vacuum tubes having application to nuclear radiation measurement and infrared detection. The first of the velocity selector infrared image tubes was designed and built by him at this time.

During the years 1950-1957 Mr. Green was engaged in semiconductor work, where he was responsible for the design of power-semiconductor devices and their associated enclosures. His hermetic enclosure for RCA developmental power transistors was standard for some time and is still in wide usage. Further semiconductor experience was gained in investigations of ferroelectric and electroluminescent materials in computer applications.

Subsequently Mr. Green became interested in the application of cryogenic devices, particularly those involving superconductivity, to computer memory systems and logic networks. During this period, he designed a novel, all-superconductive, content-addressed memory system and demonstrated the feasibility of the component logic devices.

Fifteen patent assignments have been made in the electron tube and semiconductor fields. Approximately ten more patents are pending in the areas of superconductivity, semiconductor, and ferroelectric devices and systems.

In June 1959 Mr. Green joined the staff of Stanford Research Institute, where he has been concerned primarily with research on devices for computer logic and memory systems. He was project leader on a research program for achieving high-speed logic with magnetic thin films, and more recently was project leader for the neuristor research program. In 1965 he became a member of the Computer Sciences Group where he presently leads two projects. One of these (a sub-group of the Automata program) seeks to define the basic tasks to be carried out by a mobile automaton and to devise strategies and programming tactics for their execution. The other project (internally sponsored by SRI) investigates new heuristic programming techniques with a view toward greater utilization of human intuition in the man-computer problem solving process.

Harris, Joyce C. - Computer Programmer, Applied Physics Laboratory

Mrs. Harris graduated from Stanford University in 1965 with a B.S. cum laude in mathematics.

From 1965 to 1967 she was employed by the Stanford Electronics Laboratories at Stanford University, where she worked on pattern-recognition problems, simulations of adaptive systems, and special-purpose computers. The computers primarily used for this work were the IBM 7090, the Burroughs B5500, and the IBM 1620. Since February 1967 she has been with Stanford Research Institute working on the SDS 940 computer.

Hart, Peter E. - Research Engineer, Applied Physics Laboratory

Dr. Hart received a B.E.E. degree in 1962 from the Rensselaer Polytechnic Institute, Troy, New York. He received the M.S. and Ph.D degrees in Electrical Engineering from Stanford University in 1963 and 1966, respectively.

His doctoral work was on the application of nonparametric statistics to the pattern-recognition problem. During the course of his graduate studies he was a Hughes Master Fellow, a participant in the Philco Honors Co-op program, and Research Assistant at Stanford University.

Dr. Hart is a member of Eta Kappa Nu, Tau Beta Pi, Sigma Xi, the Institute of Electrical and Electronics Engineers, and the Association for Computing Machinery.

Jackson, Barbara - Mathematician, Applied Physics Laboratory

Mrs. Jackson received an A.B. degree, magna cum laude in Applied Mathematics, from Radcliffe College in 1966.

During the summer of 1965 she worked as a scientific programmer for the Perkin-Elmer Corporation, Norwalk, Connecticut; she worked that summer with SDS 920, 930 and 9300 computers. While at Radcliffe in 1965-66, Mrs. Jackson worked part-time as research assistant in connection with the Harvard Program on Technology and Society. During the summer of 1966, she worked for Control Data Corporation, Palo Alto, implementing the NAMELIST facility for CDC 6000-series FORTRAN. From September 1966 to June 1967 she was a Research Assistant with the Mathematical Linguistics project of the Computer Science Department at Stanford University. Since joining the staff of SRI in June 1967, she has been working on the automaton project.

Mrs. Jackson is a member of Phi Beta Kappa and of the Association for Computing Machinery.

Kling, Robert E. - Research Engineer, Applied Physics Laboratory

Mr. Kling received a B.S. degree in 1966 in Electrical Engineering from Columbia University and an M.S. from Stanford University in the same field in 1967. He is presently completing his doctoral studies at Stanford, focusing upon artificial intelligence.

Since the winter of 1966 he has been developing a program for reasoning by analogy with applications to geometry and algebra.

Mr. Kling worked for Watkins Johnson during the summers of 1964 and 1965, first researching the beam properties of ultralow-noise traveling-wave tubes. Later he developed a design for an ultrahigh-speed microwave "scanning receiver."

Since June 1966 he has been working on advanced techniques of concept learning and problem solving for the SRI automaton in addition to his thesis effort.

Munson, John H. - Research Physicist, Applied Physics Laboratory

Since joining Stanford Research Institute in 1963, Dr. Munson has been engaged in computer and learning machine research and applications. He was primarily responsible for joining the MINOS II learning machine to a digital computer to provide a powerful learning-machine facility, used in theoretical studies and diverse pattern-recognition applications.



Dr. Munson received a B.Sc. degree (with honors) from the California Institute of Technology in 1960. He received an M.A. degree in 1962 and a Ph.D. degree in 1964, both in Physics, from the University of California at Berkeley. He held a National Merit Scholarship award as an undergraduate, and a National Science Foundation fellowship as a graduate student.

In his doctoral research in nuclear physics, Dr. Munson participated in the design and use of a computer-connected system (the Scanning and Measuring Projector, SMP) for measurements on bubble-chamber film. He was primarily engaged in mixed-language computer programming, real-time man-machine operation, and optical pattern recognition. In 1964 he created a time-sharing "executive" computer program for the SMP system, with the unique feature of allowing multiple on-line consoles to operate simultaneously within a single, user-written, processing computer program. Dr. Munson is the principal author or co-author of several papers related to both the SMP and the MINOS II facility.

In 1965, Dr. Munson led a project to investigate the state of computing facilities at SRI and to make recommendations for SRI computing in the next five years.

Dr. Munson is a member of Tau Beta Pi and the Association for Computing Machinery.

Raphael, Bertram - Senior Research Mathematician  
Applied Physics Laboratory

Dr. Raphael received a B.S. degree in Physics from Rensselaer Polytechnic Institute in 1957, an M.S. degree in Applied Mathematics from Brown University in 1959, and a Ph.D. degree in Mathematics from MIT in 1964.

Dr. Raphael held several scholarships at RPI from 1953 to 1957, and the Universal Match Foundation fellowship at Brown University in 1958. He received an N.S.F. honorable mention and was elected to the Society of Sigma Xi in 1957.

Dr. Raphael's interest and experience in automatic computation includes work in that field for R.C.A., Moorestown, New Jersey; for Bolt, Beranek and Newman, Inc., Cambridge, Massachusetts; and as a Consultant for the RAND Corporation, Santa Monica, California. He taught at RAND summer institutes for Heuristic Programming (1962) and Simulation of Cognitive Processes (1963), and lectured at UCLA during the summers of 1963 and 1964. During his doctoral studies he worked as a Research Assistant in the Artificial Intelligence Group at the MIT Computation Center. From June 1964 to February 1965, he held joint appointments as Assistant Research Scientist and Acting Assistant Professor of Electrical Engineering at the University of California at Berkeley. Since joining the staff of SRI in February of 1965, he has

served as a part-time Lecturer in Electrical Engineering at Berkeley and in Computer at Stanford University.

Dr. Raphael is a member of the Association for Computing Machinery, the Association for Machine Translation and Computational Linguistics, and the Society of Sigma Xi.

Shapiro, Elmer B. - Senior Research Engineer  
Systems Engineering Laboratory

Mr. Shapiro joined the staff of Stanford Research Institute in 1960. He headed a project concerned with the development of new and advanced techniques for designing and analyzing communication networks. This involved studies of various switching methods (such as circuit switching and store-and-forward switching), network-congestion phenomena, and traffic routing and control doctrines. He also served on a DOD switching committee that studied and evaluated several major military developmental switching systems.

Mr. Shapiro's interests are in the synthesis and analysis of digital information-processing systems and switching systems for communication networks.

Recently, he participated in an SRI command-and-control study of the U.S. European Command, particularly concerned with the data-processing aspects of communication-network management and radio-frequency allocations.

Before joining the Institute, Mr. Shapiro was a member of the Technical Staff at the Bell Telephone Laboratories from 1953 to 1955 and from 1957 to 1960. He supervised a group responsible for the planning and development of data trunks, including signaling and supervision facilities. He was also responsible for the system planning of maintenance and error control for a developmental, solid-state data processor. During his early years at BTL, Mr. Shapiro participated in the logical design of the Tradic Computer (an airborne digital machine) and the design of high-output transistor pulse-regenerative amplifiers.

From 1955 to 1957, Mr. Shapiro was on active duty in the U.S. Army at the Computing Laboratory of the Ballistic Research Laboratories (BRL), Aberdeen Proving Grounds. There, he served as an electronic engineer on the engineering staff of the Ordvac computer, concerned with the operation and maintenance of the system. He was also responsible for the logical and circuit design (a mixture of solid-state and vacuum-tube design) of control equipment necessitated by the installation of an enlarged core memory. Also, during 1957, he served as a full-time licensed engineer of the commercial AM station, WAMD, in Aberdeen, Maryland.

Mr. Shapiro received a B.S. degree from the Illinois Institute of Technology in 1952 and an M.S. degree from Stanford University in 1953, both in Electrical Engineering. He completed the BTL Communications Development Training Program in 1958.

Mr. Shapiro is a member of the Association for Computing Machinery, the Institute of Electrical and Electronics Engineers, and the IEEE Groups on Computers and Communication Technology.

Wahlstrom, Sven E. - Senior Research Engineer  
Computer Techniques Laboratory

Mr. Wahlstrom received an Electronics Engineer degree from Hogre Tekniska, Laroverket, Orebro, Sweden in 1947 and an M.S. degree from Chalmers Institute of Technology in Gothenburg in 1952. From June 1952 until January 1954, when he joined the staff of the Swedish Board for Computing Machinery, he worked on design of sounders and transistor circuits for hydroacoustic equipment.

In 1954 he developed paper tape equipment, similar to the Flexowriter, and a card-to-paper-tape converter. In 1955 he was responsible for advanced development work in the use of transistor circuits for core memories; he was also responsible for the BESK Computer Center.

In 1956 he joined the group that formed Facit Electronics, where his first task was to develop the Carousel Random Access Memory. After significant contributions to the design of other products, such as core memories and electromechanical devices, he was given the full responsibility for the design of the Facit EDB 3 computer system. This computer, which was completed in early 1962, has a unique system of combining large core memories with the central processor, carousel memories, punch card equipment, line printers, etc., permitting a very effective input and output of data. For example, up to 5 peripheral units could transfer data simultaneously.

Mr. Wahlstrom was Section Manager and later Head of the Development Department; as such he was responsible for the development of all commercial products of Facit Electronics. In February 1963 he joined Ampex Corporation, where he held positions as Manager, Tape Transports Development, and Manager of Systems. His work at Ampex was mainly devoted to digital equipment; he was also project leader for the development of a special-purpose digital computer.

In May 1965 he joined the staff of Stanford Research Institute, where he has made contribution to the realization of cellular logic. He has also assisted in the design of digital equipment for evaluation of oblique ionosphere sounder data.

Wensley, John H. - Senior Research Engineer  
Systems Engineering Laboratory

Mr. Wensley joined the staff of Stanford Research Institute in July 1962 and worked until early 1964 on the Augmented Human Intellect program. In particular, he was project leader on the first stages of RECAP, a research project aimed at the augmentation of a programmer's effectiveness by on-line use of a computer.

He has been concerned with the problems of new computer system designs, and in particular with the problems of using such new computers. In this work he was the principal investigator on an SRI-sponsored project to investigate a prototype design for a highly parallel computer system.

In addition, he has worked on problems of the reduction of graphical data from the OGO series of satellites. Recently he has been carrying out research on intelligent automata, and particularly on the design of heuristics and their simulation on a computer.

In 1950 he joined the staff of the Research Laboratories of the General Electric Company (of Great Britain) in their Line Communications Laboratory. His first work was concerned with research into new methods of designing networks and feedback systems. In 1954 he started the computing service of the company, being responsible for all phases of its activity including programming, operating, and scheduling. This service was centered around a digital computer.

In 1956 he became a founder member of a new company, jointly sponsored by the GEC and International Computers and Tabulators, Ltd. This company planned and designed computers and associated systems. He was responsible for the logical design and programming for the 1301 computer (a medium-size business data processor). He held the position of Head of the Methods Division and during 1961 was appointed as Manager of the Project Planning Department of International Computers and Tabulators.

He has been active in the field of automatic coding since 1956 and was a member of the European working committee which defined ALGOL 60. He led a team which implemented COBOL 60 and "ICT Rapidwrite" and was responsible for the definition of an early automatic coding language "CODEL" which was aimed at use by both scientific computers and business data processors.

Mr. Wensley received his B.A. honours degree in Mathematics at Cambridge University, England in 1950.

He has been author or coauthor of the following papers: "The Solution of Electrical Field Problems Using a Digital Computer" (coauthor), Electrical Energy, Vol. 1, pp. 12-16 (September 1956);

"The 1301 Data Processing System" (coauthor), G.E.C. Journal, Vol. 27, No. 2, pp. 77-85 (Spring 1960); "A Class of Non-Analytical Iterative Processes," The Computer Journal, Vol. 1, No. 4, pp. 163-167 (January 1959).

Yarborough, John M. Jr. - Research Engineer  
Computer Techniques Laboratory

Mr. Yarborough received an M.S. degree in Electrical Engineering from Stanford University in June 1959. While attending Stanford he was employed at Stanford Research Institute during the summer, working on the design of transistor drivers for ferrite-core circuits.

Upon graduation, Mr. Yarborough was commissioned as an Ensign in the United States Navy and was assigned to the Naval Research Laboratory, Washington, D.C., as an Electronic Scientist in the Sound Division, from 1959 until June 1962. His work there included design of digital timing systems, data-retrieval systems, and analog-to-digital converters.

In July 1962 Mr. Yarborough joined the staff of Stanford Research Institute, where he has been responsible for a major portion of the logical and circuit design of a special-purpose parallel-search computer. He has also done logic and circuit design on the PIONEER Space Probe and on the investigation of man-computer interface schemes on the CDC special-purpose digital subsystems, including a laser pulse code identification device and a teletype-line to digital-tape-recorder interface.

Mr. Yarborough's most recent responsibilities have included the design of portions of a high-speed video signal processor for use in an intelligent automaton. The video processor abstracts important features from scenes scanned by a television camera mounted on the automaton.

Mr. Yarborough is a member of Tau Beta Pi and Phi Beta Kappa.

COST BREAKDOWN  
Preferred Level of Effort

Personnel Costs	\$Rate/Hr.	Study & Invest.		Status Reports		Tech. Reports		TOTAL
		ITEM 1 (Phase 2f & Phase 3)	ITEM 2 (Added Effort)	ITEM 3 (Added Effort)	ITEM 3 (Added Effort)	ITEM 3 (Added Effort)	ITEM 3 (Added Effort)	
		Hrs.*	\$Amount	Hrs.*	\$Amount	Hrs.*	\$Amount	
Supervisory	[REDACTED]	675	[REDACTED]	---	---	---	---	[REDACTED]
Sr. Professional	[REDACTED]	1,015	[REDACTED]	---	---	100	[REDACTED]	[REDACTED]
Professional	[REDACTED]	8,290	[REDACTED]	70	[REDACTED]	100	[REDACTED]	[REDACTED]
Technician	[REDACTED]	1,530	[REDACTED]	---	---	---	---	[REDACTED]
Clerical Services	[REDACTED]	500	[REDACTED]	70	[REDACTED]	100	[REDACTED]	[REDACTED]
Total labor		12,010	\$ [REDACTED]	140	\$ [REDACTED]	300	\$ [REDACTED]	\$ [REDACTED]
Payroll Burden @ 19%**			[REDACTED]		[REDACTED]		[REDACTED]	[REDACTED]
Total Salaries & Wages			\$ [REDACTED]		\$ [REDACTED]		[REDACTED]	\$ [REDACTED]
Overhead @ 90%			[REDACTED]		[REDACTED]		[REDACTED]	[REDACTED]
Total Personnel Costs			\$ [REDACTED]		[REDACTED]		[REDACTED]	\$ [REDACTED]
Direct Costs								
Travel:								
Air/Rail Fare, 2 trips			\$ [REDACTED]					\$ [REDACTED]
to RADC @ [REDACTED]/trip			[REDACTED]					[REDACTED]
Subsistence, 6 days @ [REDACTED]/day			[REDACTED]					[REDACTED]
Local Transportation			[REDACTED]					[REDACTED]
Materials and Supplies			[REDACTED]					[REDACTED]
Equipment Purchases			[REDACTED]					[REDACTED]
Computer Time, SDS 940			[REDACTED]					[REDACTED]
Communication and Shipping			[REDACTED]					[REDACTED]
Report Production			---					[REDACTED]
Total Direct Costs			[REDACTED]		\$ [REDACTED]		[REDACTED]	\$ [REDACTED]
Total Estimated Costs			[REDACTED]		\$ [REDACTED]		[REDACTED]	\$ [REDACTED]
Fixed Fee			[REDACTED]		[REDACTED]		[REDACTED]	\$ [REDACTED]
TOTAL ESTIMATED COST + FIXED FEE			[REDACTED]		[REDACTED]		[REDACTED]	\$ [REDACTED]

\* 169 Hours/Man-Month.  
\*\* Included in payroll burden are such costs as vacation and sick leave pay, social security taxes, and contributions to employee benefit plans.

Proposal for Research  
SRI No. ESU 67-48

12 October 1967

#### EQUIPMENT PURCHASES

Radio link for communication between  
vehicle and computer interface

\$ [REDACTED]

Second TV camera and attachments for  
enhanced recognition capabilities

[REDACTED]

Additions to present TV preprocessor  
for enhanced recognition capability

[REDACTED]

High-Speed Memory	\$ [REDACTED]
Logic Modules	[REDACTED]
Power Supplies	[REDACTED]
Cabinet and Cages	[REDACTED]

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TOTAL COSTS FOR EQUIPMENT PURCHASES

[REDACTED]