Quarterly Progress Report

Division 2

Data Systems

15 November 1964

Prepared under Electronic Systems Division Contract AF 19(628)-500 by

Lincoln Laboratory
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Lexington, Massachusetts

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INTRODUCTION

This report reviews progress during the period 1 August through 31 October 1964 for the General Research Program of Division 2. Separate progress reports on the Ballistic Missile Re-entry Systems, Project Apollo, and Project PRESS describe other work in the Division during the period. All the work of Groups 21 and 22 and some of the work of Group 28 is therefore reported separately.

Detailed reports of research will continue to be available in the form of Technical Reports, Group Reports, and Journal Articles. A list of the reports issued during the present reporting period is included here.

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Associate Head

31 October 1964

Accepted for the Air Force
Stanley J. Wisniewski
Lt Colonel, USAF
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UNCLASSIFIED REPORTS BY AUTHORS IN DIVISION 2

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PUBLISHED REPORTS

Technical Report

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306	The Baseball Program: An Automatic Question-Answerer, Vol. II. Flow Charts	A.K. Wolf C.S. Chomsky B.F. Green, Jr.	11 April 1963	DDC 446579

Group Reports

No.				
1964-6	Random Noise Considerations in the Design of Magnetic Film Sense Amplifiers	H. Blatt	17 August 1964	DDC 605323 H-602
1964-36	Exploratory Preparation of Foils Strongly Colored in the 1-6μ Region of the Infrared	E.W. Pike	30 July 1964	DDC 604009 H-599
1964-51	The Software Problem	D.B. Yntema	4 September 1964	DDC 605824 H-605

Journal Articles*

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2134	Infinite Dimensional Control Problems. I. On the Closure of the Set of Attainable States for Linear Systems	P.L. Falb	J. Math. Anal. Appl. 9, 12 (1964)
2195	Detection of the Peak of an Arbitrary Spectrum	L. Kleinrock	Trans. IEEE, PTGIT IT-10, 215 (1964)
2310	The Relation of the Initial Costate to the Cost Surface in Optimal Systems	H.K. Knudsen M. Athans	Trans. IEEE, PTGAC AC-9, 315 (1964)
2345	Searching for Novel Targets	U. Neisser R. Lazar†	Percept. and Motor Skills 19, 427 (1964)

* Reprints available.

† Author not at Lincoln Laboratory.

Published Journal Articles (Continued)

JA No.			
2362	On the Angular Resolution of Multiple Targets	J.R. Sklar F.C. Schweppe	Proc. IEEE (Correspondence) 52, 1044 (1964)
MS-770	Fuel-Optimal Control of a Double-Integral Plant with Response Time Constraints	M. Athans	Trans. IEEE, Appl. and Indust. 83, 240, (1964)

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UNPUBLISHED REPORTS

Journal Article

JA No.			
2369	Radar Frequency Modulations for Accelerating Targets Under a Bandwidth Constraint	F.C. Schweppe	Accepted by Trans. IEEE, PTGMIL

Meeting Speeches*

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920A	Machine Perceptions of Three-Dimensional Solids	L.G. Roberts	Symposium on Optical and Electro-Optical Information Processing Technology, Boston, 9-10 November 1964
1059	Optimization of Signals	F.C. Schweppe	International Conference on Microwaves, Circuit Theory and Information Theory, Tokyo, 7-11 September 1964
1126	Separation of Gyromagnetic from Gyroelectric Optical Effects in Ferromagnets	D.O. Smith	International Congress on Magnetism, Nottingham, England, 7-11 September 1964
1128	Static and Dynamic Theory of Magnetic Fine Structure in Thin Films	K.J. Harte	
1135	Immediate Recall of Digits Presented at Very High Speeds	D.B. Yntema F.T. Wozencraft L. Klem	Psychometric-Psychonomic Meeting, Niagara Falls, Ontario, 8-10 October 1964
1169	A Decision Model for Uni-dimensional Similarities	W.P. Harris R.A. Wiesen	

* Titles of Meeting Speeches are listed for information only. No copies are available for distribution.

Unpublished Meeting Speeches (Continued)

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1155	Detectability of the Deletion of a Tone from a Tone-Plus-Noise Background	A.I. Schulman R.R. Mitchell	Acoustical Society of America, Austin, Texas, 21-24 October 1964
1190	Military Operations Research: A Review and Some Comments About the Future	J.L. Vernon	Operations Research Society of America, Honolulu, 14-18 September 1964
1198	Digital Computer Technology	F.C. Frick	Electrical Industries Association Symposium, Bedford, Massachusetts, 23 September 1964
1212	A Planar Germanium 3 Gc Ultra-fast Switching Transistor	D.S. Granberry* R.S. Lewis*	Texas Instruments, Inc., Seminar, San Francisco, 29 October 1964
1218	Large Capacity Magnetic Film Memory Techniques	J.I. Raffel A.H. Anderson	IEEE, Electronic Computers Group, M.I.T., 2 November 1964.

* Author not at Lincoln Laboratory.

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DIGITAL COMPUTERS
GROUP 23

I. COMPUTER SYSTEMS

A. Curve-Drawing Scope

The curve-drawing CRT display unit is now on-line and test results indicate that the stability of the system is good. Three more CRT units are planned.

B. Optical Input

All defects in the ITT Industrial Laboratories image dissector system have been the result of poor circuit design rather than fundamental shortcomings in the technique. Most of these defects have been corrected, but a serious error remains in the design of the deflection driver. A dynamic focus correction system has yet to be specified and designed. Further tests to determine basic tube performance are being continued as time permits.

C. Multiuser Consoles

Two keyboard-outputwriter consoles have been completed, with the exception of the logic for the outputwriters. Keyboards and typewriters have been received, and the power supply chassis and tables have been completed. Keyboard logic has been built and checked out. Two additional keyboards have been ordered to be used, without typewriters, in the present console-display area.

D. Symbolic Page-Address Transformation

Coaxial cable wiring for SPAT has been completed. The remainder of the open wiring and terminating resistors is being installed. The power control has been assembled, tested, and installed in frame 8, rack A of the TX-2 computer. The power supplies, blowers, and margin check supply have also been installed and are being tested.

II. CIRCUIT DEVELOPMENT

A. Integrated Circuits

Several hundred commercial integrated circuit elements from one manufacturer were given extensive tests; eight manufacturer specified DC quantities were measured. In general, the specifications were met; however, 6 percent of the elements failed to meet the "available current" specification. Additional tests uncovered a number of units which met all the published specifications, but showed evidence of pinholes that resulted in high-resistance leakage paths to the substrate. The stability of the pinholes is not known. Visual inspection confirmed the presence of the pinholes and uncovered several instances of poor metalization.

Integrated circuit decoder and driver preamplifier cards have been designed for use in the large-capacity memory tester. The cards use both General Micro-electronics low-level

RTL and Fairchild high-level RTL elements. Prototypes have been tested and have operated satisfactorily.

B. UHF Switching Transistors

1. Germanium Planar Switch

The frequency response of the last ten sample UHF germanium switching transistors provided by Texas Instruments is much improved. The average f_t at V_{cb} = 1 volt and I_c = 20 ma is 3 G_c. These units are about equal in performance to the best 3-stripe mesa units supplied a year ago and are much more practical to produce in quantity. With the exception of minority carrier storage, the objectives have largely been met. For best performance, the unit as it now exists must be used as a nonsaturated switch. It is anticipated that pilot-line samples will be made available and that further work on carrier storage will be performed.

2. High-Speed Silicon Microcircuits

The first sample units of ultra-miniature silicon-integrated circuits have been delivered from Philco. Individual 2 G_c silicon planar transistors, which form the basis for the microcircuit, have also been delivered. All devices are operable but possess many of the problems of the early stages of development. It is expected that the next group of units will exhibit a major improvement in base resistance, which will also provide other significant benefits.

3. Measurements

Our f_t measurement has been made automatic to the extent that it is now possible to sweep out curves for f_t vs I_c as a function of voltage on an x-y recorder. The time required to obtain one curve is now a few seconds compared to several minutes to obtain the data manually and several more to plot it. The accuracy remains the same.

The equipment necessary to make complex h_{rb} measurements is almost operational. This will lead to better r'_b measurements and hopefully a better understanding of the results.

C. Transistor Flip-Flop Memory

All 1800 flip-flop subassemblies have been tested and assembled in memory plane plug-in units. Approximately 8 percent did not meet specifications and were repaired by replacing a diode or transistor. All plug-in units have been assembled and tested in a mockup of the system. Only one flip-flop was found that would not work correctly. The back-panel wiring and associated logic for the two memory systems have been completed. An in-out unit has been built for the FX-1 computer that will permit it to supply input levels to the memory and check output levels. A program for the FX-1 has been written that will write and check several patterns in the memory.

Memory access time of approximately 50 nsec was measured in the system mockup that is used to test plug-in units. The access time in the completed system should not be much greater.

III. MAGNETIC FILM ENGINEERING

A. Clean Room

Preparation and equipping of the clean room for the precision cleaning and processing of glass memory substrates are nearing completion. Two ultra-clean work stations have been installed; one for photoetching, the other for substrate cleaning. It is expected that the facility will become operational during the next reporting period.

B. Pattern Scribing

Scribing of precision fine-line patterns on the modified Haag-Streit Coordinatograph layout machine has been quite successful. Diamond ruling tools have been procured which will scribe lines ranging in width from 0.0001 to 0.001 inch in 1-mil increments and from 0.001 to 0.004 inch in 2-mil increments. Ruling has been done mostly in silver chemically deposited on glass, but has also been done in Eastman Kodak Special Plate Type 033-01 and in dyed Kodak Photo Resist. Insufficient opacity of the latter material has prevented effective photocopying of the scribed patterns.

It has been found possible to scribe not only lines but also the pad patterns at the ends. A program of machine improvement is in progress which has as its goal the complete automation of some functions of the machine.

C. Magnetic Film Characteristics

Two techniques for making films with improved magnetic properties are being investigated. When an evaporated Permalloy film having an over-layer of copper is annealed at 300°C for about 15 minutes, an effective diffusion depth of about 50 Å (as measured by loss of saturation flux) results. This causes the wall coercive force to increase beyond H_k, while the latter remains unchanged. The corresponding increase in the required digit current due to increased angular dispersion is much less than the increase in H_c for such films, unlike inverted films prepared by other techniques.

These results have suggested a second approach which is to deposit two-layer films from alloys having widely different coercive forces (e.g., CoNiFe and NiFe). The result due to exchange coupling appears to be a composite film whose magnetic properties are a weighted average of the two layers taken separately.

D. Content-Addressed Memory

An extensive series of depositions has been carried out to find proper techniques for making films with good switching and magnetoresistive characteristics. Adequate films may now be made as indicated by looper data and by sampling bit positions. Plane testers are being constructed which will be used to gather tolerance data preparatory to building a memory.

E. Large-Capacity Memory Tester

The positioning device for pulse testing single-word and digit-substrate pairs is finished. Precise checkout of the mechanism and construction of required electronics remain to be completed.

Equipment has been assembled for testing the drivers which have been designed for the LCM tester. This equipment will also be used for further work on tester sense amplifiers. Digital logic and other electronics are being assembled for the tester.

F. Circuit Design

A series word driver and switch has been developed for the large-capacity memory, which will supply a maximum of 800 ma with 30-nsec switching times.

G. Page-Address Memory

The redesigned sense amplifiers using input step-up transformers have been installed. Memory margins are good and checkout is essentially complete. Substitution of SPAT logic circuits for existing FX-1 logic is under way.

IV. SYSTEM PROGRAMMING AND APPLICATIONS

A. Class-Oriented Ring Associative Language

CORAL is now in use in VITAL as well as in two editing programs which use the vector scope for alphanumeric display and the keyboard for control. One program is designed for editing at the syllable level, the other at the character level. The present form of CORAL includes diagnostic printouts to help the user apply the system efficiently and to find his errors quickly.

B. Variably Initialized Translator for Algorithmic Languages

Progress on VITAL is continuing. The translator, when finished, will be capable of compiling programs for the TX-2 from a wide range of source languages including our present macro assembly language, ALGOL, and CORAL. Presently, a language definition can be accepted and the input text parsed into the appropriate tree form. The final section for compiling machine code from this tree should be finished during the spring of 1965.

COMPUTER COMPONENTS
GROUP 24

I. MAGNETIC FILMS

A. Anisotropy

An important advance has been achieved in understanding the mechanisms of the uniaxial anisotropy field H_k in Permalloy films. A key factor is an experimental method which proceeds as follows: (1) deposition in a magnetic field $H_{||}$ on a substrate at temperature T_s; (2) annealing in either a DC field $H_\perp$ perpendicular to $H_{||}$ or a circular rotating (60 cps) field $H_\odot$ for specified time intervals; (3) quenching by water-cooled coils which are silver-soldered to the substrate holder. Significant aspects of the above procedure are that: (1) annealing is carried out before exposure to air (oxygen); (2) quenching insures well-defined annealing times; (3) each experiment involves freshly-deposited samples which are in a well-defined and reproducible physical state.

Such experiments have made it possible to identify five contributions to H_k having well-defined and separated activation energies. One of the most striking results is the demonstration that, before exposure to oxygen, a low activation process ($\lesssim 0.2$ ev) is present which becomes locked after oxygen exposure. This result is qualitatively explained by assuming anisotropic clusters of lattice vacancies that can become filled with oxygen.

B. Magneto-optics

The gyromagnetic parameter p in the optical μ tensor has recently been measured in iron by Krinchik and Nurmukhamedov* and checked by us in Permalloy to be $|p| \sim 10^{-4}$. This is too small to make possible the high-efficiency light switch discussed in the last quarterly progress report. Progress in this direction will require the development of transparent magnetic films from materials such as ferrites or garnets.

C. Ternary Alloys

Ternary alloy films of NiFeCu have been made by the simultaneous vacuum deposition of NiFe and copper from two separate sources. The resulting films exhibited the expected decrease in magnetization, but the anisotropy dispersion simultaneously increased drastically. The ternary alloy NiFeCu is thus unsuitable for the study of the dependence of anisotropy on magnetization† and has been abandoned in favor of NiFeSi and NiFeAl. The magnetization of NiFe shows a rapid decrease as silicon or aluminum is added to it in the bulk; it is therefore hoped that these alloys will be more suitable for the present investigation.

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*G. S. Krinchik and G. M. Nurmukhamedov, Zhur. Eksp. i Teoret. Fiz. 47, 778 (1964).

†M. S. Cohen, J. Appl. Phys. 35, 834 (1964).

II. ELECTRON TRANSPORT

A. Al-Al_2O_3 Diodes and Triodes

1. Photoelectric Effect in Diodes

An Al-Al_2O_3-Al diode was made by vacuum depositing a thick aluminum film, plasma anodizing, and then depositing a thin (~ 100 Å) aluminum film. With light incident from the thin aluminum side, a photovoltage was observed. By varying the photon $h\nu$ and the bias across the diode, the barrier heights at the thick and thin aluminum interfaces have been determined. The results are 1.5 and 2.2 ev, respectively.

In addition to providing a method for detailed barrier studies, this experiment demonstrates collection of electrons through the conduction band of a thin Al_2O_3 film. Such collection is, of course, crucial to the operation of a triode.

2. Hot-Electron Collection in a Triode

Following the demonstration of collection of photoelectrons in an Al-Al_2O_3 diode, collection in an Al-Al_2O_3 triode has been observed. For the first time the energies of the tunnel-injected electrons were known to be great enough to enter the conduction band of the collector barrier. This condition was just barely satisfied, however, and the collection efficiency was quite low (~ 1 percent). Due to the very high collection impedance ($\geq 10^6$ ohms), it is quite possible that power gain was achieved. Changes in fabrication are in progress which should improve the collection efficiency.

B. Contact Potential During Al_2O_3 Growth

An electron-gun evaporation source has been installed which greatly facilitates multiple evaporations of aluminum in order to check contact-potential reproducibility. Although the clean-surface, gold-aluminum contact potential is still not reproducible from run to run, improved reproducibility in the change of work function of aluminum due to oxygen exposure has been achieved.

Much information has been gained by comparing resistance monitor changes with the contact-potential changes during oxygen exposure. When the pressure is increased to the low 10^{-8} torr region, a rapid increase of resistance occurs which may be due to the first two monolayers which Eley and Wilkinson* report are very rapidly chemisorbed even at low pressures. During this time the work function is lowered only 0.02 to 0.10 volt. A comparatively large decrease of the work function of 0.80 to 1.00 volt occurs when the pressure is raised to the 10^{-5} torr region, and the resistance monitor changes comparatively little during this period. The rate of decrease of the work function during the higher-pressure exposure is much greater if the pump is on during exposure. This raises the question of a gas supply impurity effect or an effect due to the ion pump itself which will have to be investigated.

* D. D. Eley and P. R. Wilkinson, Proc. Roy. Soc. (London) A254, 327 (1960).

III. FILM-MEMORY SENSE AMPLIFIERS

The modified sense amplifiers for the 1000-word FX-1 film memory have been built, tested, and are operational. A modified version of this type of amplifier is ready to try in the high-density memory plane tester. It has a strobe section that is compatible with tester logic and gives three output states (1, 0, and error) instead of two.

The technique of cross feedback on the strobe stage was used to increase the sensitivity from 300 to 100 mv in the strobe stages of the above-mentioned amplifiers. Apparently, values of 25 mv may be obtained by using more feedback. The circuit then becomes a strobed multivibrator whose strobe width is a fraction of its natural period of oscillation.

PSYCHOLOGY
GROUP 25

I. AUTOMATIC PROCEDURE EXECUTOR

APEX is the executive program that is intended to time-share TX-2 among several on-line users, providing easy and efficient access to a library of precompiled subroutines. A considerable fraction of this reporting period was spent in explaining the design to potential users and in making slight modifications to meet their requirements, particularly in the area of input and output. Detailed specifications of the bulk of the program are now established, and the portions that have been specified are progressing through various stages of flow-charting, coding, and debugging. The current status of the five major parts of APEX is as follows:

The Secretary, which handles interrupts and input-output transfers, is well along in coding and debugging. Basic routines for the Xerox, photoelectric tape reader, and IBM tape are operating. The keyboard-typewriter routines are important in a time-shared system and were the subject of considerable discussion with programmers who intend to use the system. These routines are being revised, and the new versions should be ready soon. Work is just starting on a routine for the paper-tape punch. The integration into APEX of existing display routines has yet to begin.

The Maestro determines which user, interrupt, or alarm is to be handled next. During this reporting period a primitive version of the Maestro has been exercised with the routines for the keyboard-typewriter, photoelectric tape reader, and IBM tape. This primitive version has served its purpose and will now be abandoned. Current work involves completing the final version, combining it with the Secretary routines that have been checked out, and making them into a temporary APEX that will allow as much of the system as may be available at any one time to be tested as a working unit.

The Csar (core storage allocation routine) does the bookkeeping needed in sharing time, space, and programs. It also keeps track, to any depth, of the state to which the programmer wants the computer returned when one of his routines has ended. The Csar is the largest of the five major parts of APEX; it is about 90 percent flow-charted, 35 percent coded, and 25 percent debugged.

The Mover transfers information from and to the auxiliary file memory. The basic routines have been written to operate with the existing MK4 operating system. These routines have been briefly tested, but day-to-day operating experience is not yet possible since the Fastrand drum has not been made available for regular use by programmers. Further work on the Mover will be deferred until the arrival of the page-address and memory-snatch hardware.

The Librarian has not been mentioned before, but it has acquired the conceptual status of a fifth major part of the program. It maintains a directory of the user's files and other entities to which he has given names. It does not appear to be a large program, but it has proven to be the subject of intense negotiation. Final agreement on specifications has not quite been reached.

II. HUMAN INFORMATION PROCESSES

A. Recognitive Behavior

Development of a choice-strategy analysis of human recognitive behavior continues. Shipley* has provided data on the detection and recognition of tones in noise. In one condition, the subject

* E. F. Shipley, "Detection and Recognition with Uncertainty: An Experiment and a Revised Model," Memorandum MP-12, University of Pennsylvania, Department of Psychology (undated).

judged which of two frequencies occurred during a given time interval, and in another condition, which of two intervals contained a tone of known frequency. In other conditions, both interval and frequency were uncertain. Two kinds of instruction were given to the subject: detection (Is it there or not?), and recognition (Which frequency was present or, in which interval did the tone occur?). Different instructions and stimulus conditions were combined into twelve experiments on each of three subjects. These data have now been analyzed from the point of view that has been developing. A major effort was involved in simulation of the decision process on the TX-2 computer to analyze the data obtained under one of the most complex conditions.

Because of the precision of Shipley's data (about 30,000 trials per subject), the analysis yielded several clear results: (1) In eleven of the conditions, one strategy of choice fits the data from all three subjects well. In the twelfth condition, one of the subjects deviated from the group in his selection of a strategy. (2) The values of both of the stimulus parameters were constant for a given subject under all conditions. (3) Choice parameters varied quantitatively over conditions and subjects. These results provide strong evidence for the validity of a choice-strategy analysis of recognitive behavior.

B. Unidimensional Similarity

Analysis of the data from the experiments on unidimensional triads has been completed. The results show that the Thurstonian model yields a better description of the subjects' behavior than does a model based upon Luce's choice axiom. Since this is one of the few situations in which the two theoretical positions make strikingly different predictions, the results of these experiments are important for assessing the adequacy of the two approaches to choice behavior.*

C. Signal Detection

Analysis of trial-to-trial performance in yes-no and in two-alternative forced-choice experiments on detection of tones uncovered interesting sequential dependencies and led to the formulation of a model to account for them. In yes-no experiments, detectability was found to be the same on trials following a hit, a false-alarm, and a correct rejection; however, detectability was depressed on trials following a missed signal. Similarly, in forced-choice experiments, detectability was found to be depressed only on trials following the incorrect selection of the first interval as the signal interval. The model that simulates these phenomena assumes that the listener is mistuned on some fraction of all trials and that mistuning, having arisen, tends to continue.

Another model was formulated to account for the changes in slope of the operating characteristic that occur in yes-no experiments when the a priori signal probability is varied. This model, which assumes that the listener is daydreaming on a fraction of the trials, generates not only the slope difference but also the criterion shifts that attend variation in signal probability.

D. Perceptibility and Memorability

A relation between ease of perception and short-term retention has finally been demonstrated. The stimuli were meaningless, garbled speech sounds produced by the TX-2 computer. Two

* W. P. Harris and R. A. Wiesen, paper read to the Psychometric Society, October 1964.

garbles were sounded about $1\frac{1}{2}$ seconds apart, and the subject was to state whether they were the same or different. The responses were correct more often when a random noise was added to the second garble than when the same noise was added to the first. The conclusion was that the memory-trace of a sound that had been perceived clearly was retained better than the trace of a sound to which noise had been added.

Four previous experiments on short-term retention of words and digits had failed to show any relation between perceptibility and retention when memory was tested by recall. Taken together, the two results are interpreted as showing that the subject of an experiment on immediate recall does not store a faithful recording of the sounds that he has heard; he is able to recode the stimuli almost instantly into a condensed, symbolic form that is more easily retained.

CONTROL RESEARCH
GROUP 28

I. ON-LINE DATA STORAGE, RETRIEVAL, AND EDITING

One of the principal objectives of the work on data storage and retrieval described in the previous quarterly progress report was to design a system which could be easily extended in capability. During this quarter we have demonstrated such an extension. The initial system has been extended to include the capability for adding data fields to existing files, inputting entries from the console, filing and retrieving message texts, and deleting fields, entries, and whole files. Although new routines had to be written to provide the additional capability, none of the old routines had to be rewritten.

The status of the system can be seen from the number and types of commands in the system. Five general classes of commands allow the user to:

(a) Create a new file, obtain information about the files already existing, or delete a file.

(b) Define new relations between files, obtain information about relations already defined, search files on an existing relation, or delete a relation.

(c) Add a new data field to a file, update a particular field, or delete a data field.

(d) Exercise general control over system operations such as starting and transferring control from one sequence of operations to another.

(e) Read a tape of prestored data into an existing file and write a tape containing files on which some processing has been completed.

II. HYBRID COMPUTER DEVELOPMENT

Program support for the hybrid computation facilities has included the continued development of automatic mapping and scaling algorithms, the development of a set of floating point arithmetic and special function routines for the LINC, and the development of programs for stereo viewing of functions of two variables. Automatic mapping requires the generation (by a general-purpose computer) of an interconnection of integrators from an original set of differential equations. A map should use a minimal number of integrators and also satisfy interconnection constraints imposed by the design of the DDA. An algorithm has been developed in which the problem statement is used first to generate a map using a minimal number of integrators; further integrators are then added as necessary to satisfy the constraints due to limited interconnection capability. The combination of this mapping algorithm and the existing scaling algorithm is the basis for a complete automatic setup of the DDA.

Construction of the DDA is progressing as anticipated. An important network in the DDA forms the value $\sum_{i=1}^{16} a_i y_i$; $a_i = 0, 1$; $y_i = \pm 1$. The speed of this network has a substantial effect on the rate at which integrators can be incremented. We have designed this network using a decomposition based on the symmetric functions; the resulting network as constructed appears to have rise and fall times of about 200 nsec which is well within our tolerances.

A new flip-flop, which has a high packing density and suitable speed for buffer registers, is now being tested and appears satisfactory.

Checkout of the designs of logic cards for the DDA is continuing, and delivery of the magnetic core memory is expected in about three months. The extra delay in delivery resulted from a redesign by the manufacturer which will increase the operating speed of the DDA. The iteration time per integrator has been redueed from 2.5 to 1.5 μsec.

In addition to eontinued investigation of data-processing algorithms which can be studied on a hybrid computer (spectral analysis and parameter estimation), the use of the DDA (when connected to a large general-purpose computer) for the simulation of trajectories is being investigated. The DDA would be useful in simulation problems where an appreciable amount of computer time is spent in integrating the equations of motion for a number of trajectories, e.g., in intercept studies and attaek games.

III. ESTIMATION AND CONTROL THEORY

A book by Athans and Falb on the subject of optimal control will be published in the fall of 1965.* This work contains the basic theoretical concepts such as vector differential equations, the state variable representation of systems, and modern variational principles required for the formulation and understanding of optimization problems. In addition, the book contains extensive applications of the theory in the design of optimum engineering properties.

Past reports described investigations into the basic structure and properties of difference equation algorithms for nonlinear parameter estimation. The results of this previous research have been used to design explieit algorithms for estimating the position, velocity, and variations in the weight-to-drag ratio of a re-entry body from range, azimuth, elevation, and Doppler radar measurements. These algorithms ean operate in real time and are applicable either to a real-time computer-radar complex or to post-flight analysis. The potential of an on-line hybrid implementation of these methods is being investigated.

Signal design studies that use differential equation models and the calculus of variations have progressed. Interesting properties of the optimum set of bandwidth and energy limited signals for a white Gaussian communication channel were uncovered. Earlier work on optimum frequency modulations has been documented.†

*M. Athans and P. L. Falb, Optimal Control: An Introduction to the Theory and its Applications, Lincoln Laboratory Publications (McGraw Hill, New York) (to be published).

†F. C. Schweppe, "Radar Frequency Modulations for Accelerating Targets Under a Bandwidth Constraint," accepted by Trans. IEEE, PTGMIL.

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13. ABSTRACT

This report reviews progress during the period 1 August through 31 October 1964 for the General Research Program of Division 2. Separate progress reports on the Ballistic Missile Re-entry Systems, Project Appollo, and Project PRESS describe other work in the Division during the period. All the work of Groups 21 and 22 and some of the work of Group 28 is therefore reported separately. Detailed reports of research will continue to be available in the form of Technical Reports, Group Reports, and Journal Articles. A list of the reports issued during the present reporting period is included here.

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