OBJECTIVES

To disseminate to RCA engineers technical information of professional value.

•

To publish in an appropriate manner important technical developments at RCA, and the role of the engineer.

•

To serve as a medium of interchange of technical information between various engineering groups at RCA.

•

To create a community of engineering interest within the company by stressing the interrelated nature of all technical contributions.

•

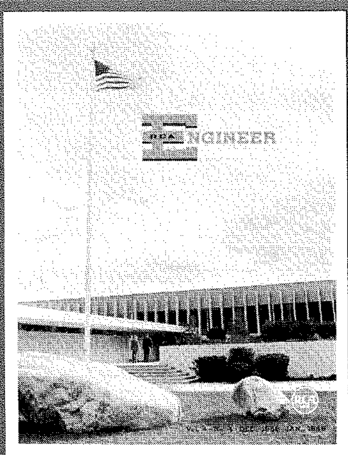
To help publicize engineering achievements in a manner that will promote the interests and reputation of RCA in the engineering field.

•

To provide a convenient means by which the RCA engineer may review his professional work before associates and engineering management.

•

To announce outstanding and unusual achievements of RCA engineers in a manner most likely to enhance their prestige and professional status.



OUR COVER

Our cover this issue shows the main entrance to the new building constructed to house DEP's Missile Electronics and Controls Department at Burlington, Massachusetts. The first major RCA facility in New England, the 135,000 square foot building provides research, engineering and manufacturing facilities for more than 500 scientists, engineers, and supporting employees.

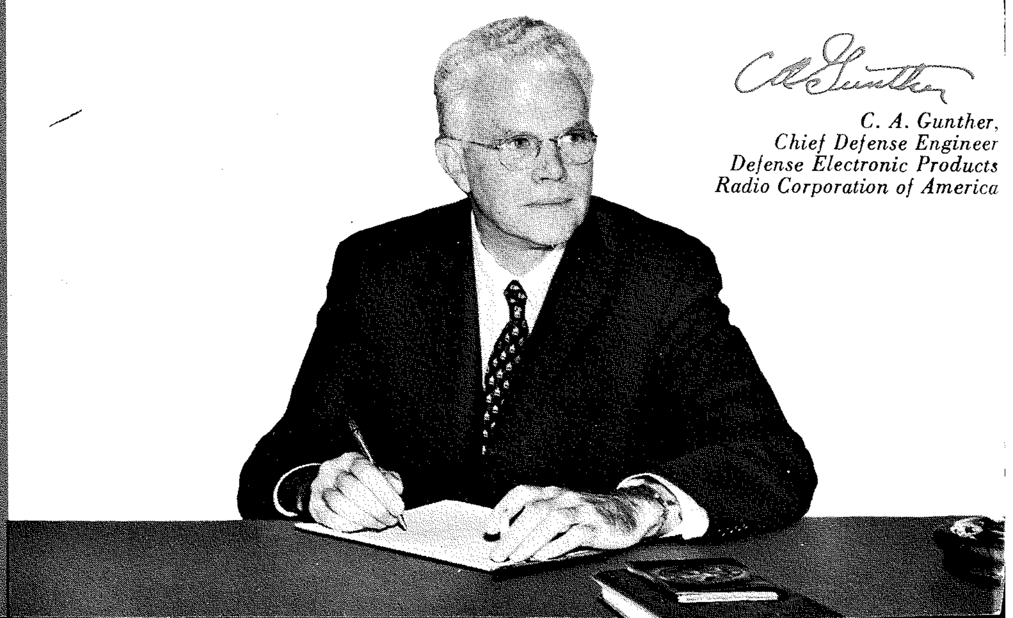
COORDINATION THROUGH COMMUNICATION

There is little to argue against the fact that RCA is well equipped in electronic engineering skills and abilities that contribute to a wide variety of products . . . ranging from simple black boxes to complicated weapon systems. Our progress in electronics, our salient growth in this dynamic field, and our many years of experience in military electronics is sufficient testimony to our intense interest in engineering. But a good reputation is not built on these factors alone. More importantly, it is earned through the efficient *coordination* of all our skills and experience into a unified effort, resulting in new standards of performance and value.

In accomplishing these objectives we must utilize the engineering experience and facilities of all the RCA technical groups at numerous distant locations. We cannot afford to rediscover or reinvent since the rapid application of "know how" is requisite in meeting our deadlines. To overcome these geographical and technical barriers and to be always "on schedule" requires efficient *coordination through communication.*

This, then, is a vital key in earning the position as leader in electronics. This responsibility for spreading "know how" rests with engineering supervision—who must not only create the proper environment, but must budget the time and money for adequate communications when planning product development. In Defense work, as in any other field, a skill or technique that is developed but not made known to our engineering community is lost to the common goal. But, by the mere expedient of telling it to a fellow worker, the sources of reference to this skill or technique are doubled! The telling process is only one form of communication, however. If the skill or technique were written in the form of an engineering memorandum, or published in a technical journal it becomes generally known — available for all who are in need of it.

The better part of the coordination problem can be solved by good communication—by the free exchange of ideas, skills and techniques between all those working toward a common goal. Good communication must be well-planned and well-directed to be effective. But conscientiously undertaken, with each engineer contributing to another's understanding, RCA's aggregate skills and experience will be advanced well beyond the technology of the industry. And everytime RCA advances a little, so do the opportunities for its employees.



C. A. Gunther,
Chief Defense Engineer
Defense Electronic Products
Radio Corporation of America

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RCA ENGINEER

A TECHNICAL JOURNAL PUBLISHED BY **RADIO CORPORATION OF AMERICA**, PRODUCT ENGINEERING, CAMDEN, N.J.
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DEP'S FUTURE PLANNING

THE ELECTRONICS INDUSTRY is bright with future. From the laboratories and the minds of our engineers and scientists will come discoveries and applications to add richness to our already high standards of living; new electronic techniques will uncover the mysteries of space, and in the area of defense electronics our creativeness and ingenuity will do much to determine whether man will live in a free or totalitarian world.

There can be no doubt that the electronics industry is among the most dynamic of the growth industries and that the possibilities for development and applications of research are almost limitless. Yet in this environment, rich with opportunity and potential, some companies will flourish while others wither and disappear. As I see it, the difference will lie in the extent and quality of their planning. No one will quarrel with the necessity for planning as a concept in business management. Few are aware, however, of the scope and detail of planning required in all phases of management in a large, complex operation.

This is understandable since all but a handful of employees in a large corporation work within a circumscribed area and do not have the opportunity to become aware of the planning which must take place with regard to all aspects of the business. Because of difficulties in communication, and also because for competitive reasons much of the planning must remain on a confidential basis, planning activities are like an iceberg with only a small segment visible. Our careers and well being are so vitally affected, however, by planning that I am pleased to have the opportunity to review with you our business prospects and goals and the manner in which we intend to achieve them.

DEFENSE SPENDING TO GROW

In the exciting field of electronics, defense electronics is perhaps the area of greatest growth and potential. Our volume, for example, in 1958 will be approximately double our sales in 1953. During this period we have, of course, grown proportionately in manpower; we have increased tremendously in our capabilities in new product areas and our facilities have been enlarged. I foresee a continuing high rate of growth

by
ARTHUR L. MALCARNEY
Executive Vice President
Defense Electronic Products
Camden, N. J.

provided that we plan carefully. Certainly, the market has sufficient potential to justify an optimistic approach in our planning. In 1958, total expenditures of the Department of Defense will approximate 39 billion dollars. We estimate that the total defense budget in 1963 will be at least 53 billions—an increase of slightly more than 35%. Electronics expenditures in 1958 will be approximately 3.8 billions, and our estimate for 1963 is 6 billions—an increase of roughly 58%. See Fig. 1 Charts.

It can be seen that not only is our national defense expenditure increasing, but electronics will constitute a larger percentage of defense dollars. While statistics are difficult to personalize, I believe that these data have a message for our professional engineers and managerial people. If we are alert and can keep pace with the growth in defense electronics, opportunities for personal advancement will be unbounded. I am aware that aspirations differ and my statement is made with this knowledge. The individual who is eager for the challenge of new technical frontiers and the creative stimulation of new products will, I believe, find them in abundance in DEP. Similarly, opportunities for progression on the managerial ladder will be present and our major problem will be to develop qualified candidates who will be ready when they are needed.

Planning, by definition, involves projection of current activity into the future. Growth, except in unusual circumstances, does not "just happen." It is a result of careful preparation and involves assuring the timely availability of all elements necessary to the conduct of the business. This, in the case of DEP means engineers, managers, products, orders, facilities, support activities, suppliers, and funds — among other considerations.

PLANNING INVOLVES RISKS

Making ready for the future involves risk-taking. While business plans must be realistic, they cannot be based upon orders in the house. Rather they must be developed from intelligent and painstaking appraisal of the market as it will most likely develop from the standpoint of defense needs at various dates in the future.

I have stated that plans must be realistic. I believe there is as much danger in underestimating the market as in overenthusiastic blue-sky planning. Failure to evaluate future needs adequately will not only stultify growth but will automatically concede the market to others who will be ready.

FIVE YEAR PLAN

Each of our product departments annually prepares a five-year plan embracing a forecast of anticipated bookings, billings and product lines, as well as requirements for manpower and facilities. In addition, central staff functions develop plans for programs which lie outside the charters of existing departments. The central staff groups coordinate the individual plans for operation of the various departments into an overall program for DEP. It is obvious, of course, that plans for year one of a five-year program are more likely to be more factual than those for year five. However, year five will become year four of next year's five-year plan and with each ensuing year our projections can be firmed up.

Such advance planning is essential in providing us with the necessary lead time in our programming. For example, as our planning indicates the need for

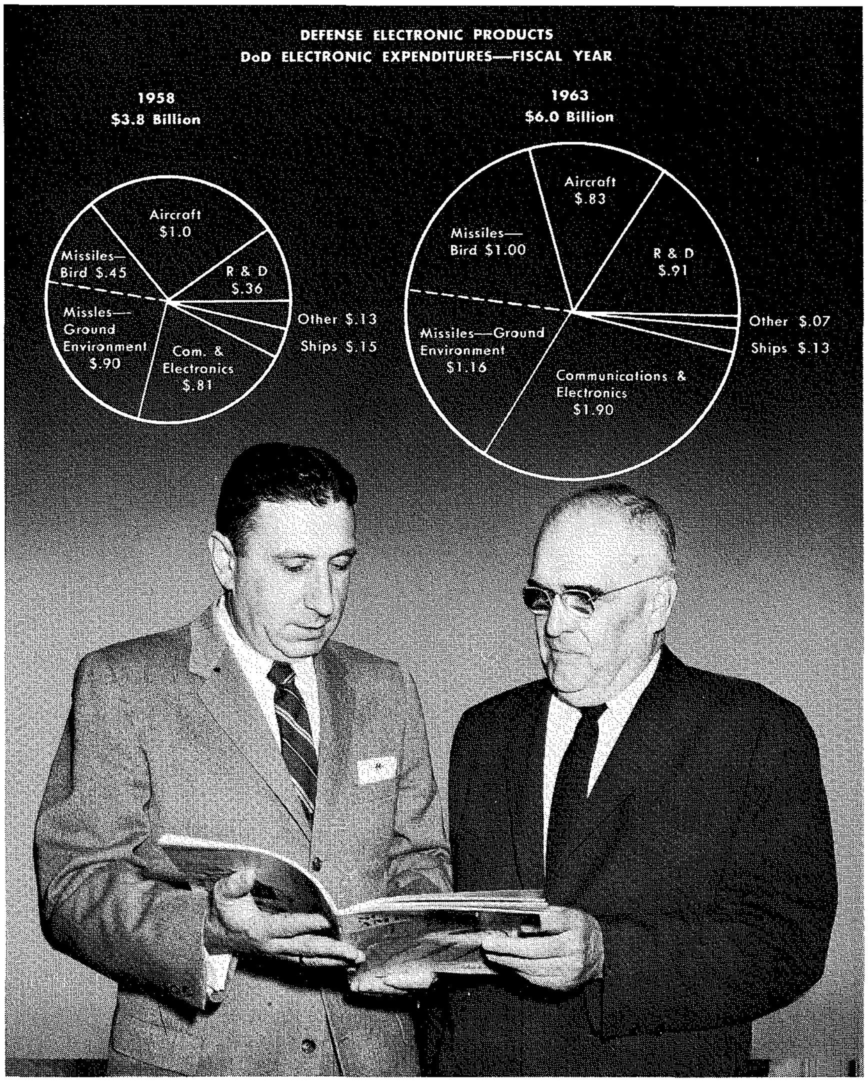


Fig. 1—"Dollar Volume" Pie Charts showing the Department of Defense expenditures for 1958—and the predicted totals for 1963.

The author, A. L. Malcarney, and Dr. C. B. Jolliffe (right), Vice President and Technical Director, RCA, discuss DEP's future plans for military products.

more engineers and other personnel to support anticipated volume, we must determine the point at which existing facilities will become inadequate. Selection and procurement of site, development of architect's plans, obtaining of corporate approval, financing, construction and facilitation must be fitted into the time sequence and coordinated with the recruiting program if we are to be ready on time.

PHILOSOPHY OF OPERATION

Underlying our pattern for future growth is a philosophy of operation which has been tested and found effective. I should like to discuss with you some of the major premises of our growth approach.

1. *Small Central Staff*

   It is our belief that operations should be decentralized and that we should be so organized as to permit the addition of such new operating units as are needed. This may result from possession of a unique capability, the advantage of geographical location, or the necessity for providing parallel production or services where additional load in an existing facility cannot be accommodated efficiently. However, we do not subscribe to complete decentralization since it is necessary, in my opinion, to monitor the activities and the performance of the operating departments. Accordingly, as you will note in the Fig. 2 chart, Organizational Structure of Defense Electronic Products, we have a small central staff responsible for coordinating activities common to all operating departments, measuring their performance, providing functional guidance and planning on a consolidated basis for DEP.

2. *Autonomy of Operation*

   It is our belief that growth will be more rapid and operating performance more gratifying in an atmosphere of responsibility. Our operating departments, therefore, are set up to be autonomous, self-sustaining with regard to possession of staff services, and responsible for profit and return on investment. In a very real sense operating departments function as a team whose success or failure will be a reflection of the contributions of engineering, marketing and other departments. Indeed, a major purpose of decentralization is to provide a sense of identity as well as to permit measurement of contributing functions.

3. *Definition of Product Areas*

   In DEP we refer to the product area assigned to a department as a charter. Although charter areas are broadly defined they are not necessarily mutually exclusive, and several departments may develop products and capability in the same area. This is not only because such skills may be required in different geographical locations, but also because the volume of available work may require duplicate facilities. In addition to the establishment of a charter area, successful operation demands adequate facilities and competent managerial personnel. It is to be noted that obtaining adequate facilities is a function of the department's own planning. Requirements for space and facilitation are plotted as part of its five-year plan by each department, and in sufficient time to permit timely acquisition.

   Similarly, the competence of managerial personnel is the responsibility of the operating department manager who is held to account for overall performance and must mold his own team which includes, in addition to managers, the engineering force and other personnel.

   Before leaving the area of charter, I should like to comment upon the relationship of the individual engineer to the development of the product. I have stressed with each of our operating managers my belief that charter definitions should not be proprietary and exclusive. Rather it is my strong contention that the product area will be determined by the technical competence of the engineers and the developments they are able to create. I have no doubt but that if two departments were started with the same charter and capabilities, product developments at the end of five years would be totally dissimilar and would reflect the strength of management and the creativity of the engineering staff.

4. *Pre-eminence in Selected Areas*

   Defense electronics represents a constantly broadening field, and

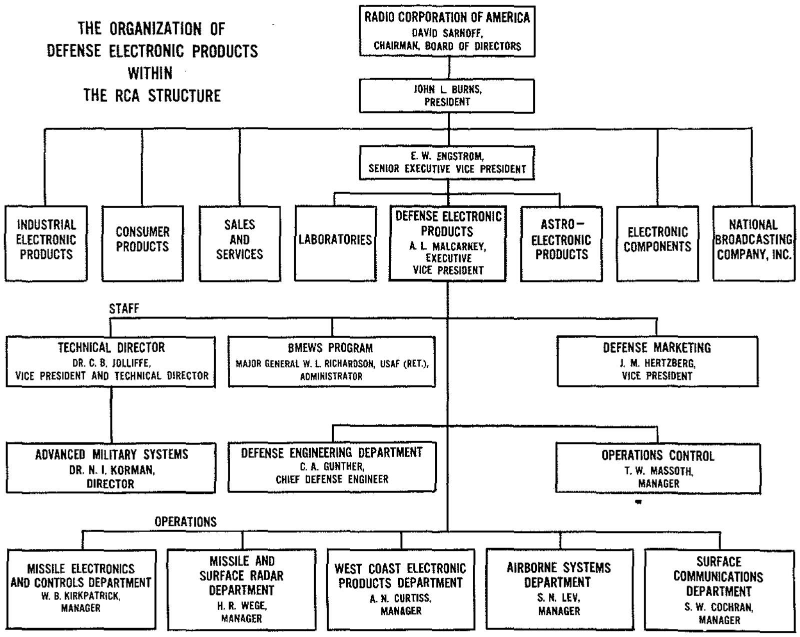


Fig. 2—Box chart showing the organizational structure (within RCA) of DEP which is comprised of five separate decentralized departments.

it is our policy to develop pre-eminence in selected technical areas as opposed to broad diffused capability. Our G. E. & D. funds are utilized carefully in the direction of furthering our knowledge in areas showing potential. Our marketing activities similarly are directed toward obtaining business which will not only be currently rewarding, but which may be the springboard for future activity.

The Fig. 3 chart, Missile and Surface Radar Product Line Growth, demonstrates the validity of this policy and planning approach. Each of our operating departments is inbued with this philosophy and establishes as planning goals technical areas within its charter in which it will develop pre-eminent positions.

5. *"Seeding" for Future Growth*

Planning for expansion carries the obligation of providing favorable growth environment. Freedom to grow involves a complex of factors including opportunity to expand under a charter, the establishment of attainable accomplishment goals, proper facilitation, competent management, qualified engineers, and establishment of a sense of direction.

Our experience indicates that a small operation grows more easily than larger units. Many reasons may be advanced for this such as closer personal identification with the operation by engineers and managers, greater manageability of the smaller operations, and more intense interest in business of small dollar potential. Further, individuals develop competence as they grow with the business. Recognizing this, our plans for future growth involve, in addition to maximizing potential in existing departments, the planting of "seeds." By establishing new departments in environments conductive to healthy growth, we hope to accelerate our overall rate of development and to achieve our ambitious billing goals.

An excellent example of this is the establishment of our Missile Electronics and Controls Department featured on the front cover of this issue. This was originally established as the Airborne Systems Laboratory which was an extension of the engineering function of the Airborne Systems Department. The laboratory was established at Waltham, Massachusetts in 1955. A new facility was built for the laboratory at Burlington, Massachusetts and in June of 1958 operations were transferred from Waltham to Burlington. As of September 1, 1958, a new department, the Missile Electronics and Controls Department, was established based upon the existing systems laboratory which will be expanded into a fully integrated operating department. We hope to follow similar patterns in establishing future departments which will be necessary based upon our current business projections.

6. *Creativity and Capability*

The building block which is the integer of our growth is the engineer and his creativity. In defense electronics, as in no other operating business, we sell the products of the experience and imagination of our engineers. Engineering functions in DEP constitute roughly 50% of our total manpower and engineers represent about half of the total of the engineering population. Engineering is thus a line function with us and in our planning we are aware of the importance of establishing the proper atmosphere for effective engineering.

An interesting and challenging transformation has taken place in

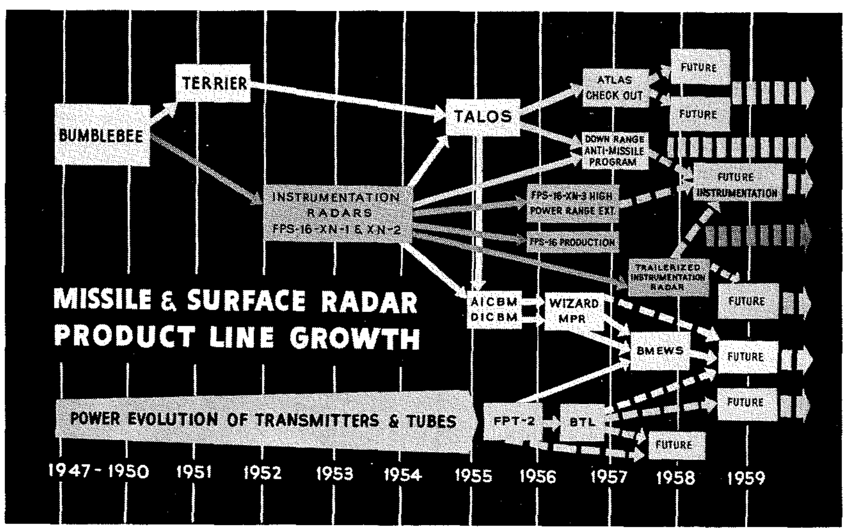


Fig. 3—This chart of the Missile and Surface Radar Product line growth depicts a typical evolution and the realization of the "planning approach."

defense electronic products. In the Korean War period, and immediately following, our billings were largely for "black box" apparatus. Thus we had heavy production runs, and were primarily concerned with selling apparatus. Our national defense needs, however, have changed drastically and our effort and sales are changing to reflect this. In 1953, for example, expenditures for R&D support constituted 8.5% of total Department of Defense expenditures. It is estimated that this will increase to 37.2% for 1959. DoD expenditures include ships, tanks, and ammunition which have a relatively small part of R&D. In our judgment approximately 60% of expenditures for electronic equipment procurement will be in the R&D and support areas.

This is a direct reflection of changing defense needs of our Country. Prototypes and limited production items are required instead of volume production. The pace in development is so rapid that missile and communication equipment may be obsolete in concept before it is even produced, and the race both from the standpoint of our national economy and individual companies is to the creatively swift.

7. *Weapons System Concept*

A further change which is to be noted is the development of the weapons systems concept of defense. The supersonic character of missiles, the far-flung nature of our defense establishment, and the need for rapid evaluation of enemy threat and defense against enemy weapons requires an overall systems approach by the military and by individual contractors. More and more of the contracts awarded to DEP are in the area of large weapons systems. This places a tremendous burden upon both management and the individual engineer. Management is, of course, aware of its responsibility for developing organizations capable of handling large weapons systems projects with the implicit need for the various disciplines involved in the conception and development of overall systems. However, establishing such organization imposes tremendous problems of communications of which we are aware and which we have only partially solved. The individual engineer is likewise faced with problems. From a personal standpoint, it is necessary for him to become a much broader individual, since he will be thrown into contact with diverse elements of weapons systems organization. The individual engineer must become broader and more flexible and above all must recognize his responsibility for upward communication.

8. *Need for Improved Utilization*

There is one final point which I should like to impress upon each of our engineers. I have mentioned that the electronics budget will increase by approximately 58% in 1963. It is our hope that billings in DEP will double in the same period. We are planning, however, for an increase of only 75% in our engineering staff for several reasons: (1) because of the limited availability of qualified engineers and (2) because we are hoping and planning for an increase in individual productivity. This is essential not only to achieve the goals of our operating departments and DEP, but also because of its significance in cost to the government and the increased technical output which we will realize from improved utilization.

In summary, I have attempted to demonstrate that a period of tremendous growth is planned for DEP. The growth will be in the area of R&D effort and large weapons systems approaches. The key to our growth will be our ability to attract and inspire creative effort by engineers who together with their support personnel will make up better than half of our population. Demands on the individual engineer will be greater since it will be necessary for him to be flexible and familiar with a wide variety of disciplines. The state of the art will change with increasing rapidity and our engineers will be required to learn more and more about more and more. It is possible for management to plan for facilities, product areas, billings and personnel recruitment programs. Creativity, however, must flow from the interest and application of dedicated individuals. It is my belief that our engineers will in the future—as in the past—meet and beat the obligations imposed by our plans and commitments to the Department of Defense.

ARTHUR L. MALCARNEY'S progress since joining the Company in 1933 as a mechanical inspector is both interesting and inspiring. Between 1936 and 1940 he was successively assistant foreman, foreman and superintendent in various maufacturing areas. Serving as Manager of the Parts Fabrication Department from 1942, Mr. Malcarney was named Manager of Production two years later.

In 1946, he was appointed Parts Plant Manager and advanced to General Plant Manager of the Engineering Products Division in the following year. Art remained in this position until 1953 when he became Manager and Vice-President of Commercial Electronics Products, beginning in October of 1955.

The years of 1957 and 1958 were notable for Arthur L. Malcarney. On June 7, 1957 he was elected Executive Vice President, Defense Electronic Products; in 1958 he received a twenty-five year service pin from the Company.

Mr. Malcarney served with the Army Air Corps from 1930 to 1933, acquiring an interest in radio and communications. He is a graduate of the Advanced Management Course at the Harvard School of Business Administration.

An ex-athlete and still an avid outdoor sportsman, Art enjoys vicarious satisfaction from the exploits of his three sons.

THE ENGINEER'S RESPONSIBILITY IN FULFILLING THE DEFENSE CONTRACT

by **M. C. BATSEL**
Chief Technical Administrator
Defense Electronic Products
Camden, N. J.

IT SEEMS TO ME that the most important single factor in a bargain, in a purchase or in a contract is that all parties involved must be in complete agreement. Such a meeting of the minds results only when the purchaser needs and wants the product, approves the quality, and is satisfied that the price is right. The supplier, on the other hand, must be convinced that he can furnish a commodity that will provide a reasonable profit and satisfy the purchaser in all respects. When this product satisfies the purchaser over a sufficient period of time, whether it be a familiar consumer article or a complex military equipment, it is said to be reliable. Thus, the supplier earns the reputation of producing a product of high quality and dependability.

In an oversimplified example, it is easy to visualize how this works when one goes to the clothier to purchase a suit. The careful buyer makes sure that he is satisfied with what he is purchasing. The reputable, dependable clothier invests the time and effort to see that his good customer gets exactly what he wants. When this same buyer becomes more and more discriminating and increases his specific demands, complete agreement becomes more difficult to reach. This complexity could keep mounting until it would require a detailed description of just exactly the type of material, costs, and how the suit should be tailored. Now, when these two parties become the Government Defense Department and RCA evaluating the requirements of a proposed electronic system, the complexity in reaching complete agreement and satisfaction may pyramid beyond perception.

In this paper, I am going to define some of the underlying problems and then suggest how they may be overcome. The problems involved, as might be expected, are divided between the military departments and the equipment manufacturer or contractor. Although major responsibility rests with the contractor, engineers on both sides have a definite challenge in assuring successful fulfillment of the contract.

USER PROBLEMS FOR THE MILITARY

First, let's consider some of the user's problems since he is the one we must satisfy. Dr. Barnard, Deputy Assistant Secretary of Defense for R & E, has this to say about the importance of user satisfaction: "A selection of one weapon over its competitor's is more often being decided by our ability to operate it reliably and to maintain it effectively within our means. We look for this trend to continue but to receive much more emphasis in the decision-making processes."

That problems do exist for the militory is borne out by the appearance of published papers and speeches by Defense Department officers stressing (1) the need for shorter development and design cycles, (2) greater ease in operation and maintenance of equipment, and (3) greater system and equipment reliability. Other areas requiring improvement are the contractor's lack of familiarity and detailed knowledge of the environment, capability of operating personnel, maintenance plans and capabilities of maintenance personnel. Other needs are to overcome communication problems in portraying the salient "field use" factors, permissible limits, and deviations in Government specifications for the contractor. The old procedures of preparing detailed Government specifications by military department engineering personnel are no longer sufficient assurance of meeting all requirements.

CONTRACTOR'S PROBLEMS

Electronic equipment manufacturers pretty much agree that Government contracts do provide numerous opportunities for capable contractors to employ all the engineering creativity at their command. Today, there is a much greater direct responsibility on the contractor's engineers to make decisions that will assure maximum value of equipment in the field. Both the contractors and the military agencies agree that the day has passed when it is feasible to attempt to build equipment according to fixed specifications alone.

Other factors requiring consideration are the overemphasis on research and development resulting in too little stress on practical equipment design, and the utilization in some cases of semi or non-technical personnel in interpreting contracts for the bidders engineers.

The contractor is also challenged to obtain more adequate data on military requirements, environments, materials and parts, and on recommended functional circuits. There has also been a need for complete agreement between the agency and the contractor on specific contractual requirements that stipulate the degree of reliability and maintainability.

HOW TO SOLVE THE CONTRACT PROBLEMS

To know how to overcome some of the foregoing obstacles described, perhaps we should return to the simple example of the man buying a suit from the clothier. Just as the dependable clothier satisfies his buyer, RCA must assume the responsibility of selling the Government agencies and keeping them satisfied. This requires detailed study of the user's requirements *for him and with him!* When this is done it will be up to the electronic equipment supplier to go even further to determine or envision actual field use, perhaps beyond the contracting agencies' present knowledge. This will lead to the establishment of approximate performance limits, reliability figures and maintenance requirements. Now the Government agency can say "Build a model that you think will satisfy our needs, then demonstrate it to our satisfaction." Formal specifications, reliability figures, and performance limits can then be established. This kind of thorough analysis overcomes most of the problems previously described.

DESIGN RESPONSIBILITIES IN FULFILLING THE CONTRACT

Of course, there are many things the engineer must do in the course of assuming his proper responsibility in fulfilling the defense contract. Some of them are reviewed here in a general way that may be helpful.

First of all, it is our duty to challenge any portion of a requirement or specification where change will result in a better equipment, simpler more reliable operation, and cheaper cost over the life of the equipment. To do this effectively, we must put ourselves in the role of the people using the equipment—then make sure that the "spec" and the design reflect this viewpoint.

The military contracting agency, on the other hand, should give the engineer as much knowledge as possible through briefings—and through visits to operating units. This knowledge should permit mature engineers to provide the best possible solution to the problem in their design plans. They should also understand the design needs in terms of shipping and storage hazards. Since it is necessary to work to schedules and within allowable cost, and since it is necessary to reduce the time required to produce new designs, the possession of this kind of information is essential. Time can be saved over present procedures where several successive models must be made and tested in the field before the actual problems are understood.

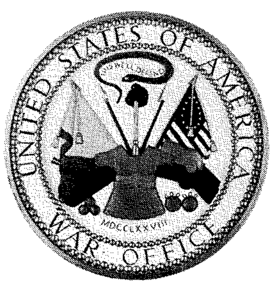
The following is a *check list of points to be considered by the designer* in fulfilling the design contract:

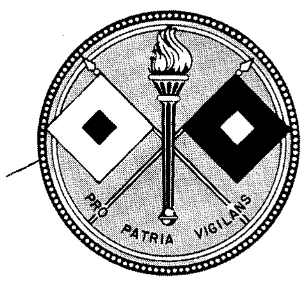
a) A knowledge of the user's needs and situation.
b) An understanding of the reliability and maintenance requirements.
c) An analysis of parts and material requirements to meet the reliability and maintenance requirement.
d) Consideration of assembly problems, design to minimize errors or effects of variations that are experienced in production processes.
e) Standards of workmanship required must be specified and assurance of compliance during manufacture must be established through adequate tests.
f) Test procedures necessary to determine the controls needed to insure the required degree of uniformity in production must be developed.
g) Preparation of more suitable maintenance manuals. (The information needed for their preparation should be accumulated during the design planning process.)
h) Consideration must be given to installation problems.
i) Adequate information and plans should be prepared for the use of the installers.

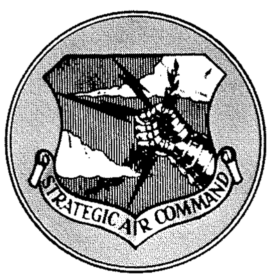
The proposed circuitry to perform the required functions should be analyzed to determine critical areas and the tolerance to variations in parameters of component parts. Functional units of systems must be compatible in the system. There should be agreement with the customer on maintenance procedures, an understanding of the type of maintenance to be performed in various areas and echelons. Based on this information, decisions can be made in regard to the needs for special checkout equipment or the possibility of utilizing the existing testing equipment possessed by the using agency.

DESIGN REVIEWS

Design reviews have been found to be extremely valuable, whereby a review of the proposed circuitry and mechanical design by the most experienced engineers in the organization is made to insure that the knowledge and experience accumulated by all engineers in the design function is utilized during the planning stages. These design reviews are also valuable as a training process for the younger engineers. Re-design is not attempted during the review. All factors relating to *serviceability* and *cost* are discussed and areas needing correction are referred to the designers for action. The responsibility rests with the designer







but creativeness and ingenuity are encouraged. Preparing for a review of his design, the engineer has learned that he should question every part. He is aware of the necessity to secure adequate information to enable him to specify completely all requirements for purchase specifications. The design review procedure reduces the number of drawing changes required during production, and when equipment has later been evaluated in field test. This saves money, time, and confusion on the part of the production people and increases confidence in the equipment.

HANDBOOK DATA

Experienced design engineers must accumulate data and information regarding materials and parts that can be printed in handbook form. The establishment of standardized functional circuits will save time and give assurance of known performance. These can be used to perform specific functions with a known reliability and performance capability.

Designers should make use of available data to guide them in the application of parts and the reliability that will result from the use of standard JAN or MIL parts in various environments. Typical data of this nature are shown in an RCA report reprinted by the Bureau of Ships, Navy Department. This can be obtained from the Office of Technical Services, Department of Commerce, Washington 25, D.C. The title is "Reliability Stress Analysis of Electronic Equipment," Report No. TR-1100. This information is a useful *guide* for the purpose of determining the magnitude of the problem of procuring parts that will enable the equipment to meet the specified requirements. It does not relieve the designer, however, of the responsibility for the required purchasing specifications for the parts that will fulfill the need in terms of reliability and suitability for the environment.

The Electronic Industries Association published a booklet entitled, "Suggestions for Improving the Maintainability of Military Electronic Equipment for the Designer, Installer, User, and Maintainer." This booklet, prepared by the Military Equipment Panel, contains many valuable suggestions for the designers of electronic equipment. Designers should make use of the suggestions in this booklet.

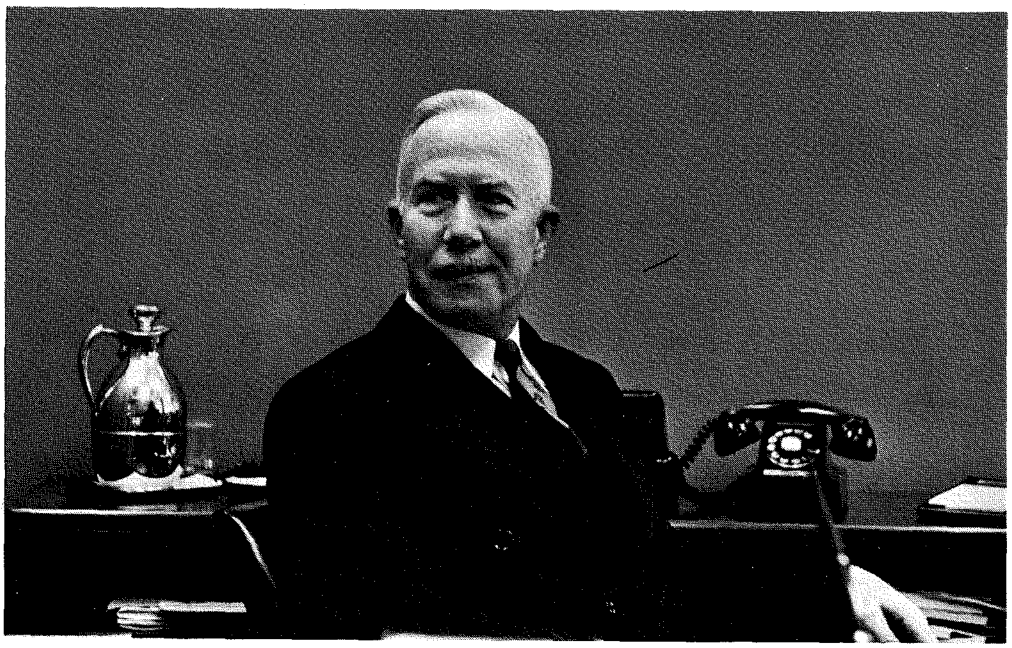
CONTRACTUAL RELIABILITY PROCEDURE

There is a growing trend toward a contractual requirement and definite agreement between the military agency and the contractor, that a certain minimum reliability will be attained and that maintainability in terms of down-time will be agreed upon. The reliability is stated in a quantitative manner such as mean-time-between-failures, probability of operating without failures for a specified time, or other measurable stipulation. These specifications are arrived at on the basis of providing an environment for the parts that will permit the required reliability to be obtained. The design must, therefore, take into account such factors as operating temperatures, electrical and mechanical stresses to which the parts will be subjected, and the effect of variations in parameters on the performance of the equipment.

CONCLUSION

The engineer and engineering management alike must assume the responsibility for selling as well as fulfilling the Government contract, and not leave the solution of practical problems to those who do not understand the technical phases.

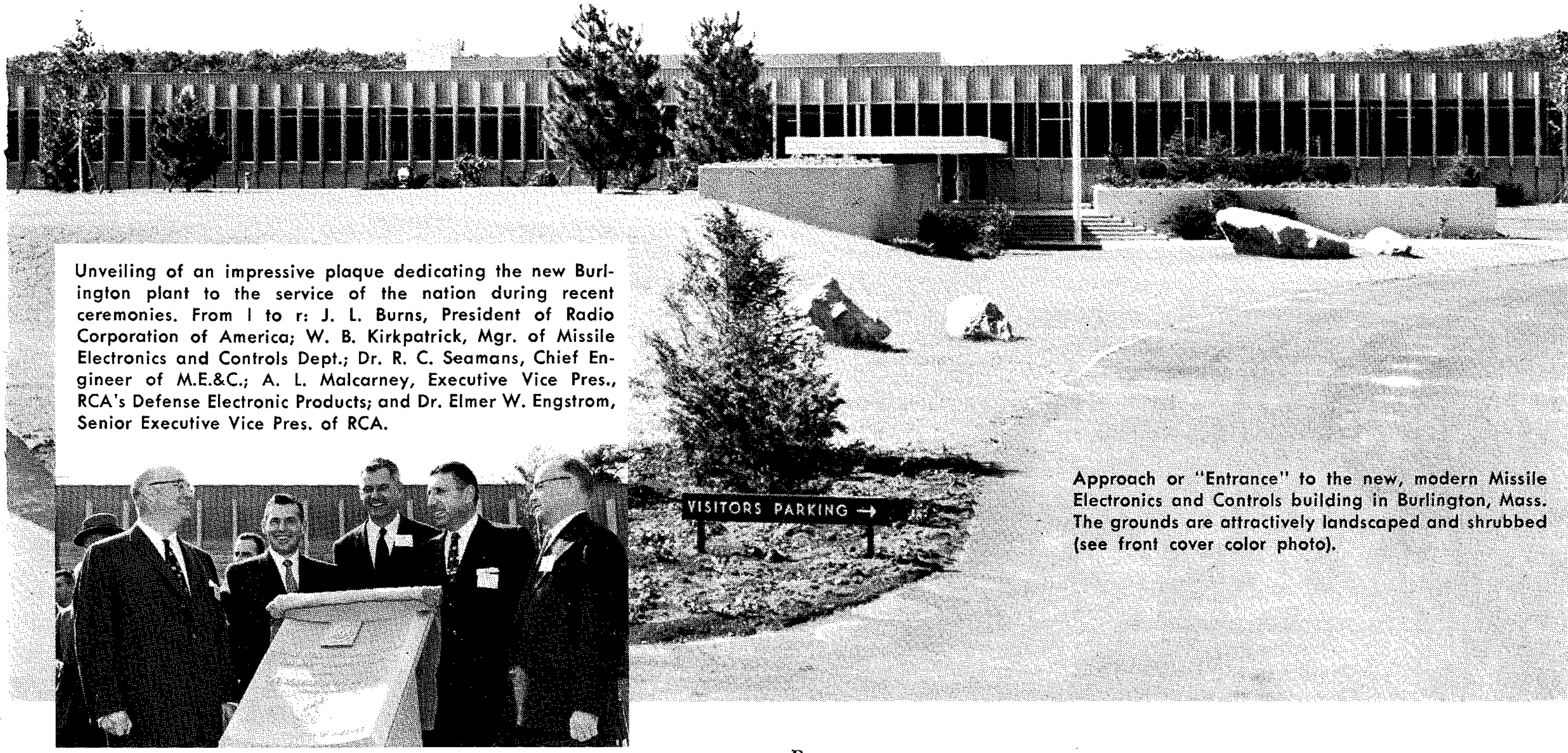
We must become thoroughly educated to the customer's requirements and, at the same time, help educate him to realize the value of having the contractor's engineers make recommendations without respect to previously established procedure. This will help us insure the customer's ultimate satisfaction in obtaining a system he needs and wants—and one that meets contractual reliability and maintainability figures.



MAX C. BATSEL brought over 30 years of engineering experience to his present post, Chief Technical Administrator, Defense Electronic Products. As a part of his defense engineering duties, Mr. Batsel serves as Chief Administrator of RCA's Reliability Program.

After his graduation with a BME degree from the University of Kentucky in 1915, Mr. Batsel worked with Western Electric Company and Westinghouse. He came to RCA's Photophone Division as Chief Engineer in 1929. In 1932, Mr. Batsel became Manager of Sound for RCA's Engineering Division. From 1941 until his appointment in 1945 as Chief Engineer of Engineering Products, he served as Chief Engineer on Special Equipment of RCA's Indianapolis plant. Mr. Batsel is a member of Tau Beta Pi, a Fellow of IRE, a Fellow of SMPTE, a member of the American Society of Naval Engineers and of Radio Pioneers. He has received the Modern Pioneers Award of the National Association of Manufacturers.

INTRODUCING THE MISSILE ELECTRONICS AND CONTROLS DEPARTMENT



Approach or "Entrance" to the new, modern Missile Electronics and Controls building in Burlington, Mass. The grounds are attractively landscaped and shrubbed (see front cover color photo).

Unveiling of an impressive plaque dedicating the new Burlington plant to the service of the nation during recent ceremonies. From l to r: J. L. Burns, President of Radio Corporation of America; W. B. Kirkpatrick, Mgr. of Missile Electronics and Controls Dept.; Dr. R. C. Seamans, Chief Engineer of M.E.&C.; A. L. Malcarney, Executive Vice Pres., RCA's Defense Electronic Products; and Dr. Elmer W. Engstrom, Senior Executive Vice Pres. of RCA.

By
W. B. KIRKPATRICK, Mgr.
Missile Electronics and Controls Dept.
Defense Electronic Products
Burlington, Mass.

The formation of the new Department and the Burlington facility within Defense Electronics Products was based upon the stated Plans and Objectives for Defense Electronics Products as described by Mr. A. L. Malcarney. To assist Defense Electronics Products in attaining its long term objectives, the new organization was established in September 1958 to concentrate in the missile electronics and controls field with the immediate objective to have it become a separate financial entity on January 1, 1959.

ADVANTAGE OF LOCATING IN THE BOSTON AREA

The key factor in the Defense Electronics Products growth pattern is our ability to attract and hold outstanding engineers and scientists. It is recognized, of course, that growth cannot take place unless new business is attracted, but our new business must flow from the products and concepts conceived by our engineers. While it is, of course, possible to attract engineers through existing or traditional locations, the possibilities of successful recruiting are enhanced if facilities are located in areas where engineers abound numerically. Generally speaking, there are four major areas in which electronics producers are clustered. These are the Middle Atlantic and Mid-West Regions, California and New England. Defense Electronics Products facilities already exist in the Middle Atlantic Region (Camden and Moorestown) and in California (Los Angeles).

The Burlington location gives Defense Electronics Products representation in a major electronics producing area with access to a substantial force of trained electronics engineers and close proximity to Massachusetts Institute of Technology, Harvard and many research laboratories and technical laboratories and technical and industrial schools.

The New England area is not noted for volume consumer items such as radios and television and lags behind the other major areas in dollar volume of sales. However, it has become a center for companies engaged in research and development and the production of prototype and highly specialized equipment plus precision components and sub-assemblies.

Research expenditures of electronics companies in Massachusetts rose by 45.7% from 1955 to 1957 while total sales increased from 182 to 232 million dollars in the same period, a gain of 27.3%.

Many new and beautiful electronics plants have been built on Massachusetts Route Number 128 which was designated as the "Electronics Highway" in a recent issue of *Time* magazine. The new Defense Electronics Products Burlington facility is located on this road.

DISCUSSION OF PLAN FOR ESTABLISHMENT OF BURLINGTON DEPARTMENT

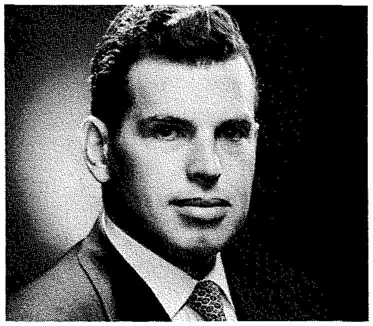
In January of 1955 the Airborne Systems Laboratory was established at Waltham, Massachusetts as an extension of the engineering function of the Airborne Systems Department. The first major Radio Corporation of America activity to be located in the

New England area, the Airborne Systems Laboratory was organized to provide the capability for analysis, preliminary design and development of advanced airborne weapon systems. The Facility was specifically designed for advanced research purposes and attracted an outstanding group of engineers and scientists. (See article by Dr. R. C. Seamans)

In June 1958 operations were transferred from Waltham to the new Burlington facility which contains a modern machine and fabrication shop, a gyro engineering laboratory, large-scale analog and digital computers, a flight simulation laboratory and other equipment essential to the development of complex electronics systems.

From the standpoint of engineering capabilities and organization, physical facilities and location, the Burlington Department has a firm foundation for expansion in the area of systems, radar, infra-red, digital computers and electro-mechanical fields. The potential in these areas is great and, with proper planning and direction, it is felt that the billing goals desired are realistic and attainable.

Editor's Note: The editors are pleased to have the opportunity of paying tribute to the newly formed Missile Electronics and Controls Department—and particularly to its engineers and scientists dedicated to the defense of our country. From this issue of your engineering journal, we hope you will gain some idea of the tremendous opportunities and challenges that lie ahead for RCA in military electronics. Fields of interest range from the development and production of prototype and specialized equipment, to military airborne components, radar devices, guided missiles, and instrumentation and development work for the Atomic Energy Commission. Our President, Mr. John L. Burns in an address at the dedication of the Burlington facility stated: "Electronics will become New England's largest industry during the next decade, growing to more than 3 billion dollars in volume and giving the area a leading role in the Space Age."



WILLIAM B. KIRKPATRICK graduated from University of Pennsylvania in 1942 with a B.S. degree in Electrical Engineering, and also studied at Ohio State University. During World War II, Mr. Kirkpatrick served with the U. S. Air Force at Wright Field, where he worked with Governmental and Commercial Laboratories and Manufacturers in developing and testing airborne radar equipment for the Air Force. He was released from active duty in 1946 with the rank of Major.

Mr. Kirkpatrick joined RCA in 1947, and during the next ten years served in such capacities as Manager of Air Force Contracts, of Government Contracting, of Government Custom Equipment, and Airborne Systems Marketing. In 1957, Mr. Kirkpatrick was named as Manager of the Airborne Systems Department, and just recently was made Manager of DEP's new Missile Electronics and Controls Department in Burlington, Mass.

While the facilities established at Burlington are adequate for our immediate growth effort, it will be necessary to plan for further building expansion in the very near future to provide required engineering and production space.

The critical area of manpower will require continuing attention. While a splendid nucleus exists for an engineering department, which will achieve the eminence necessary to establish Burlington as an outstanding supplier to the Armed Forces, it will be necessary to recruit managers and other personnel for marketing, manufacturing and other support departments. This will be accomplished in part by the transfers of key supervisory personnel from other departments in Defense Electronics Products as well as from outside sources.

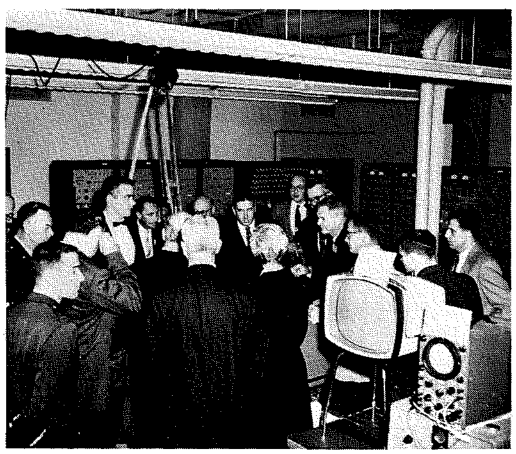
In establishing the Burlington Department it is not planned to enter into production immediately. Until late 1959 or early 1960, the facility will primarily provide engineering service, although a strong marketing organization will be required quickly in order to develop the bookings essential to meeting our billing objectives. While the facility will possess a full roster of support activities such as finance, personnel and purchasing, it is not anticipated that production will be undertaken on a significant scale until perhaps 1960.

Current planning calls for the establishment of a model shop which will possibly expand in 1960 to a job shop occupying space to be allocated to manufacturing. By 1962 it is anticipated that the job shop will develop into a complete manufacturing facility.

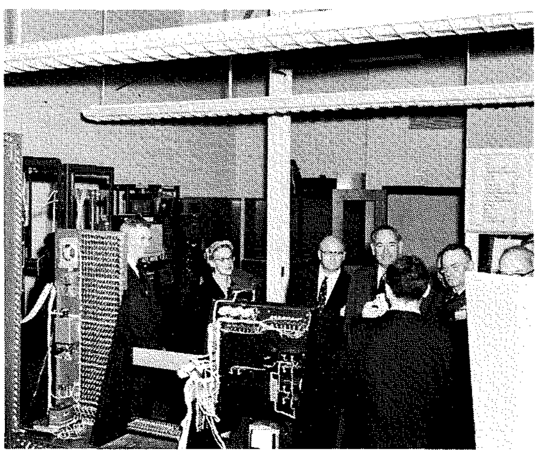
ORGANIZATION

The organization to manage the new Department will follow the normal pattern established for the proper operation of an independent operating department. The implementation of the Missile Electronics & Controls organization at this time is as shown in the organization diagram.

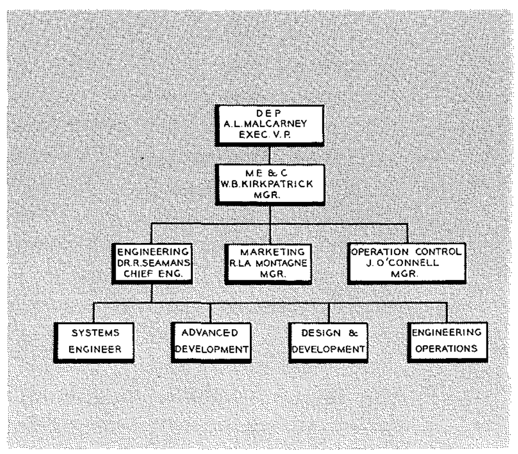
The establishment of the Burlington Engineering Plant as an integrated department and the realization of its goals are integral elements of Defense Electronics Products growth and are indispensable to aid in the achievement of Defense Electronics Products plans for the years ahead.



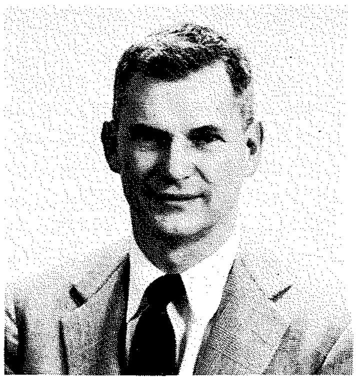
Scene during a laboratory inspection visit. Note the RCA vidicon TV camera positioned near ceiling to pick up the action.



Visiting dignitaries including Governor Furcolo of Massachusetts and Charles L. Shea, Chairman of Burlington Board of Selectmen get opportunity to see one of the laboratories.

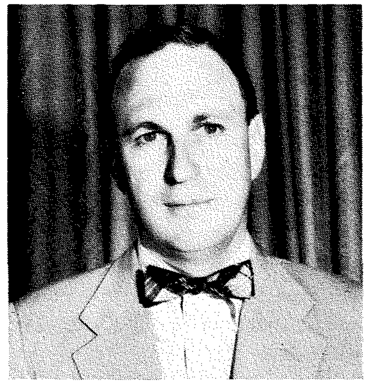


Organization Diagram showing the major activities of the Missile Electronics and Controls Department.



DR. R. C. SEAMANS, JR. received a B.S. in Engineering Science from Harvard in 1939 and an M.S. in Aeronautical Engineering from M.I.T. in 1942. He was Instructor, Assistant Professor and Associate Professor in Aeronautical Engineering at M.I.T. from 1941 to 1955. His doctorate degree in Instrumentation was granted in 1951, and in 1953 he was made Director of the Flight Control Laboratory, M.I.T. Dr. Seamans came to RCA in 1955 as Manager of Airborne Systems Laboratory, DEP. He is now Chief Engineer of the Missile Electronics and Controls Dep't. Dr. Seamans is a consultant to the Weapon Guidance and Control Panel of the Scientific Advisory Board, USAF, and has been a member of the Subcommittee on Automatic Stabilization and Control of the National Advisory Committee for Aeronautics which has been superseded by the National Aeronautics and Space Administration.

HENRY W. PICKFORD received his B.S. degree in Aeronautical Engineering from M.I.T. in 1946. Following two years with the Structures Department of Chance Vought Aircraft Company, he returned to M.I.T. as a Staff Member concerned with operational evaluation of guided missile systems. Four of his years there were spent in the development of an experimental guided missile—during the last two of which he was in charge of a system development group effort. He was awarded his Master's Degree in Aeronautical Engineering from M.I.T. in 1955. Mr. Pickford joined the Airborne Systems Laboratory of RCA in 1955, and is presently a member of the engineering staff reporting to Dr. Seamans in the Missile Electronics and Controls Department.



ROBERT W. JEVON received his B.S. degree in Aeronautical Engineering from the Massachusetts Institute of Technology in 1946 and his M.S. degree in Aeronautical Engineering from the same institution in 1951. He was an instructor in the U.S. Air Force from 1944 to 1945, and from 1946 to 1950 he was employed by Grumman Aircraft Corp. in aerodynamics, flight test, and missile design. From 1951 to 1956 he performed scientific liaison for Government Defense Agencies. Mr. Jevon joined RCA in May, 1956 as a Staff Engineer with the Airborne Systems Laboratory, DEP, at Waltham, Mass., involved in Technical Program and Manpower Planning, Cost Estimation and Space Allocation. He is presently on the staff of Dr. Seamans in the Missile Electronics and Controls Department of Defense Electronic Products.

ENGINEERING ACTIVITIES OF THE NEW MISSILE ELECTRONICS AND CONTROLS DEPARTMENT

by

DR. R. C. SEAMANS, H. W. PICKFORD, and R. W. JEVON

Missile Electronics and Controls Department
Defense Electronic Products
Burlington, Mass.

As of September 1, 1958, the Airborne Systems Laboratory became the nucleus of the new Missile Electronics and Controls Department. The Airborne Systems Laboratory was established in February 1955 to provide concentrated system analysis and development capability for the Airborne Systems Department of Defense Electronic Products. Initially the laboratory studied the interceptor fire control problem and aided in design modifications to the MG-3 interceptor system. Electronic and control systems responsibility for the Canadian CF-105 supersonic interceptor was assigned to the laboratory in the spring of 1956. From July 1956 until November 1957 the laboratory was engaged in advanced system design and development for the electronic and control system of the F-108 long-range interceptor. In conjunction with this program, a design for an advanced air-to-air interceptor missile for use with the F-108 was generated. With the completion of the F-108 interceptor system work at RCA, the laboratory was launched on its present program of advanced aircraft, missile, and rocket systems design.

ENGINEERING FACILITIES AND ORGANIZATION

The Missile Electronics and Controls Department presently employs approximately 500 personnel, of whom approximately half are professional scientists and engineers. This staff recently occupied the new 135,000 square foot facility in Burlington, Massachusetts, shown in Figs. 1 and 2.

Facilities include a four-console analog computer installation (Fig. 3) plus extensive simulators for human engineering and overall system evaluation. While the computer is generating vehicle flight paths and missile trajectories in real time, a human operator can be simultaneously confronted with the corresponding radar, communications, electronic countermeasures, and control displays of the simulated mission as it unfolds. A general-purpose scientific digital computer installation (Fig. 4) designed for direct tie-in to the analog equipment completes a versatile analysis and simulation facility. Specialized inertial instrumentation test equipment (Fig. 5), an extensive model shop (Fig. 6), and equipment assembly and test facilities (Fig. 7) are included in the building.

Experience has shown that theoretical analysis and simulation do not result in an operational system design without the support of a closely related experimental equipment development and design effort. Consequently, the new department has built up strong advanced development and design groups in the areas of airborne inertial

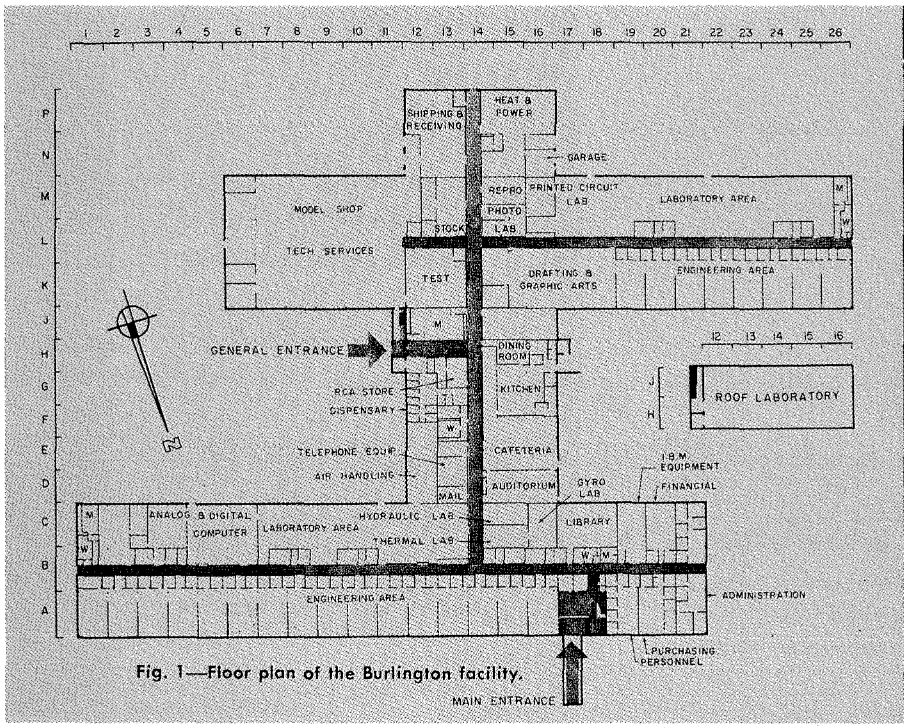
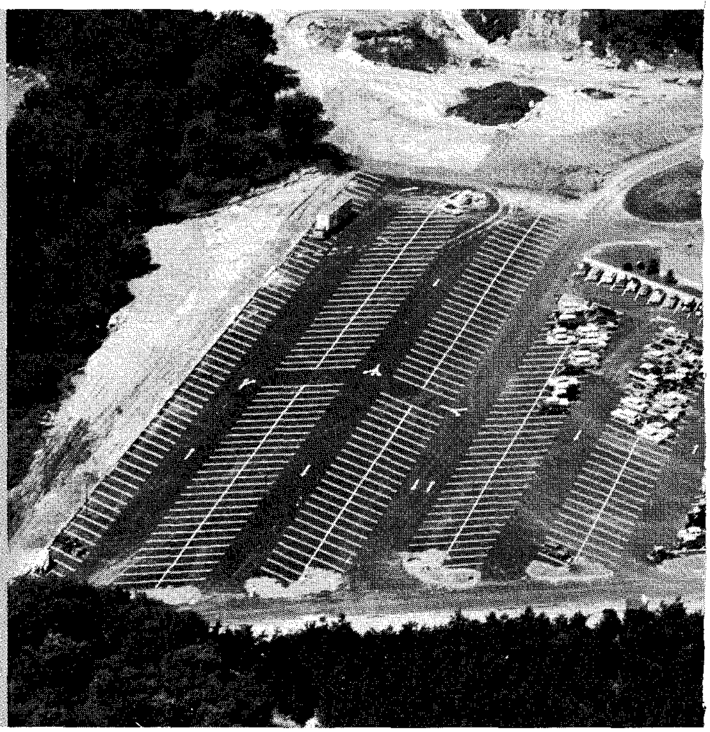


Fig. 1—Floor plan of the Burlington facility.



instrumentation, radar, and digital computation. These specialty groups were first organized around the requirements for manned interceptor systems, but extensions of these specialized techniques are proving essential to the successful development of advanced missiles and orbital vehicles.

The organization of the engineering activity follows roughly the phases of the development process, beginning with system requirements studies, proceeding through system analysis, synthesis, development, product design, and resulting in a tested operationally suitable development model or pre-production prototype. The floor plan of the new building (Fig. 1) shows the location of theoretical analysis, advanced equipment development, product design, and systems project activities required to develop pre-production models, designed and fabricated under the same roof. Plans call for expansion in development and design and the addition of manufacturing facilities.

TYPICAL DEPARTMENT ACTIVITIES

The original laboratory effort in the area of electronic and control system developments for Air Defense has led to the present active missile system studies. One of these is centered around investigation of the problems of integrating a long range Naval fleet air defense missile with launching aircraft, AEW&C aircraft, and the fleet battle control center. Multiple launchings against mass enemy attacks require extensive data processing and electronic countermeasures capability.

Other aspects of the air defense problem which have been the subjects of study include early warning systems (both airborne and ground-based); warning, surveillance and tracking systems for use against manned bombers in the remote defense zones; and the new class of warning, tracking and attrition systems required to counter intercontinental ballistic missiles. The AICBM problem is under intensive study beginning with a broad research program to understand better the physical phenomena which will permit early warning, detection, identification, discrimination and tracking of enemy ICBM's before they re-enter our atmosphere. These studies will lead to advanced instrumentation and defense systems. In addition to air defense activities, the laboratory has carried on a study of submarine-to-submarine detection and attrition systems.

Effort has also been expended in the study of systems for use with the strategic air arm. These studies encompass inertial reference systems for ICBM's and satellite vehicles; guidance systems for ICBM's; reconnaissance, instrumentation and control systems for high-altitude, boost-glide, global rocket bombing vehicles and anti-satellite, reconnaissance, and weapon systems. Supporting these system studies are specific subsystem study programs as, for example, in the areas of radar mapping, navigation, and control of space vehicles.

FUTURE TECHNIQUE DEVELOPMENT

Through all these systems, the common functional requirements of navigation, communication, detection, identification, tracking, computation, guidance, and control occur again and again. Chronic technical problem areas point up the need for radically improved techniques for radiation transmission and detection, gravitational field and inertial motion sensing, data processing, energy control, and utilization of the human operator. Already system analysis has shown a remarkable similarity between the needs for improving present-day systems and for implementing missile and space systems. Building on experience with existing complex systems, the department will have to place increasing emphasis on the solution of the *critical* unsolved technique problems which grow out of the rapidly expanding arena of man's activities in the earth's atmosphere and beyond. Work in these areas is cooperative with that of RCA Astro-Electronic Products Division.

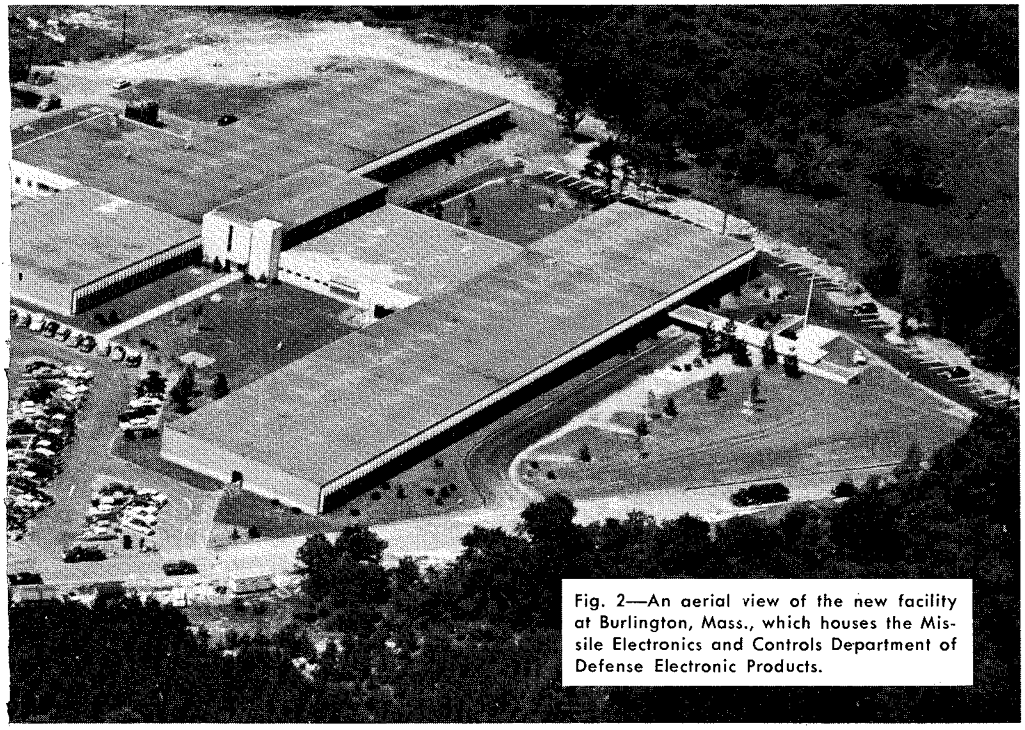


Fig. 2—An aerial view of the new facility at Burlington, Mass., which houses the Missile Electronics and Controls Department of Defense Electronic Products.

FACTORS LIMITING PRESENT TECHNIQUES

Investigations of the physical limitations imposed by our universe go hand-in-hand with our efforts to extend man's control of his environment. Physical phenomena place the bounds on the growth of future systems. The environment for future systems varies from earth's sea level atmosphere to a near vacuum without a ready gravity reference and with exposure to new radiation phenomena. Vehicle velocities will make heating, and ionization of the flight medium major problems, and necessitate short decision and control times. Energy requirements for both propulsion and auxiliary power will be more stringent and place a great premium on weight. System complexity will increase computational, communication, and reliability requirements. Hence, familiar airborne system functions of detection and tracking, navigation, communication, computation, display, and control will be performed by new equipments employing new techniques in new environments. Unlike present-day systems which resulted from the ability to integrate complexes of existing techniques and equipments, the success of the space age systems will hinge on these new techniques.

AREAS OF POSSIBLE IMPROVEMENTS

In coming up against the stops of present "state of the art" in the system functions required, engineers and scientists have already begun to concentrate on particular component and technique developments which may lead to the necessary improvements in system performance:

Improved Radar and Communication Techniques—Detection, tracking, and communications improvements must be aimed at providing increased operational detection ranges at minimum power. There will be continuing need for target range and range rate information for prediction. Increased range will come from higher average power, narrow beams, and improved noise figures. When ECM or other noise limit active radars, IR, optical, or passive electromagnetic systems must be investigated. The antenna problem will be particularly acute aboard advanced vehicles where ion sheaths and ionized trail effects must be considered, and large effective apertures are required.

Attitude and Field Sensing Devices—ICBM's and space vehicles impose successively more stringent requirements on existing radio and inertial techniques for determining a vehicle's relative attitude, position, and velocity. Gyros and accelerometers, or their successors, must show major advances if unaided navigation beyond the earth's gravitational field is to be undertaken. Measuring vehicle position relative to a known planet in terms of the planet's gravitational field gradient requires "accelerometers" of greatly increased accuracy. Optical trackers in space and horizon scanners for attitude sensing during re-entry are possible aids to inertial systems. Electromagnetic and electrostatic fields mapped in space could prove usable for navigation and attitude sensing.

Versatile Storage and Computation—The multiple flight regimes of future systems calling for multiple modes of sensing and control will increase the complexity and versatility of vehicle-borne storage, data processing, and computing. Already the storage requirements for enhanced ground mapping radar displays are calling for extensive digital memory systems. Further advances will be required to program and control a satellite or space flight particularly in the absence of a human pilot. In the interim, airborne digital computers are being placed in increasing numbers in missile and air defense systems.

New Control Devices — Advanced vehicles will continue to require control over vehicle attitude, vehicle velocity, and subsystem functions such as celestial tracking. Attitude control of a vehicle in the outer atmosphere must be provided by unconventional means since there is essentially no fluid medium for applying moments.

Reaction devices utilized differentially might be considered to have the disadvantage that energy is expended. Moving mass elements within the vehicle can be used which theoretically conserve the energy in the vehicle. Other devices are available which conserve energy but provide very low levels of torque. For example, shutters might be used to develop differential pressure from the sun's light. It remains to be shown whether such low-torque devices have practical application.

During rapid ascent and descent through the earth's atmosphere, control problems arise from the relatively high acceleration and deceleration as well as the rapidly varying characteristics of the vehicle. The designer is faced with the necessity of programming a large number of control parameters unless improvements are made in the general state of the control art. Work now in progress on adaptive and nonlinear techniques may provide the necessary background for new unconventional controls which will accommodate simply gross variations in vehicle response. In this connection, digital elements can be expected to generate the nonlinear functions and provide command which will be accepted by new types of digital control actuators.

The Human Operator—In many instances, the complexity of future systems can be drastically reduced by the proper use of human operators. For manned vehicles this requires new techniques for human survival. In short flights the acceleration, pressure, and temperature environments are paramount. For long flights a closed biological cycle must be provided to sustain the pilot. Whether the vehicle involved is manned or unmanned, future weapon system complexes will have central control panels where the human operator can accept diverse information inputs. New displays—visual, auditory, and tactile—are being studied to enhance man's capability to perceive flight, tactical, and strategic conditions on which to base decisions and immediate action.

Power—Propulsion and Auxiliary—Perhaps the greatest physical limitation on man's effort towards flight beyond the earth's atmosphere is the

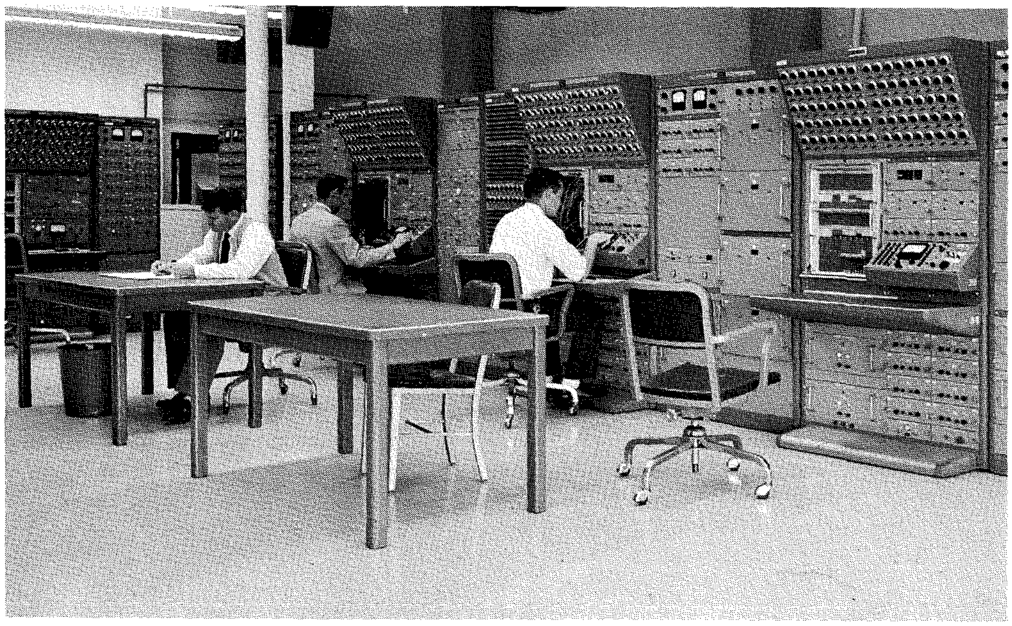


Fig. 3—One of the major laboratory facilities at Burlington is the four-console analog computer installation used in theoretical analysis of airborne systems problems.

Fig. 4—Facilities include a general-purpose scientific digital computer for tie-in with the analog equipment. Shown is the computer console, power supply, and card handling equipment.

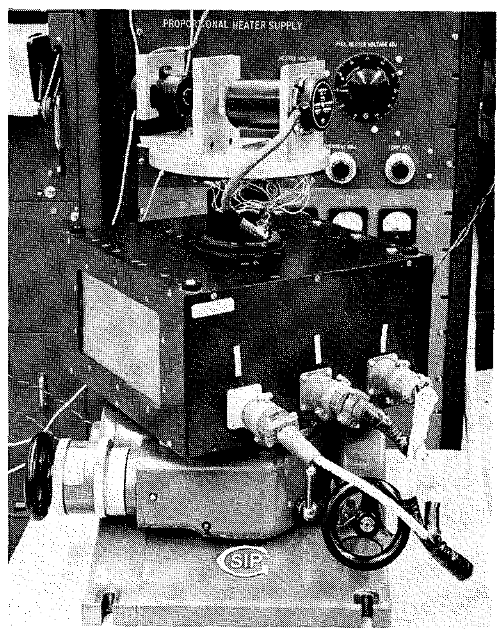


Fig. 5—An inertial gyroscope test table is one of the specialized equipments included in the laboratory complement.

Fig. 6 — An extensive model shop is fully equipped to meet departmental needs.

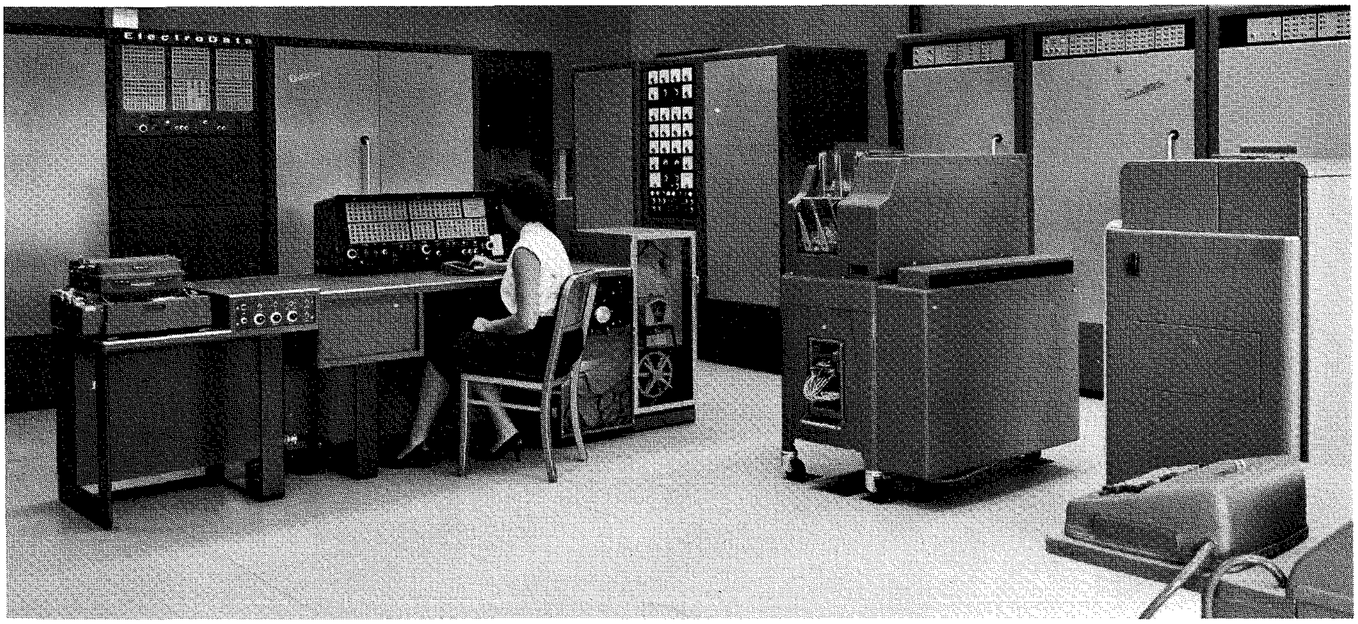
Fig. 7—An equipment assembly and test area in the Burlington facility.

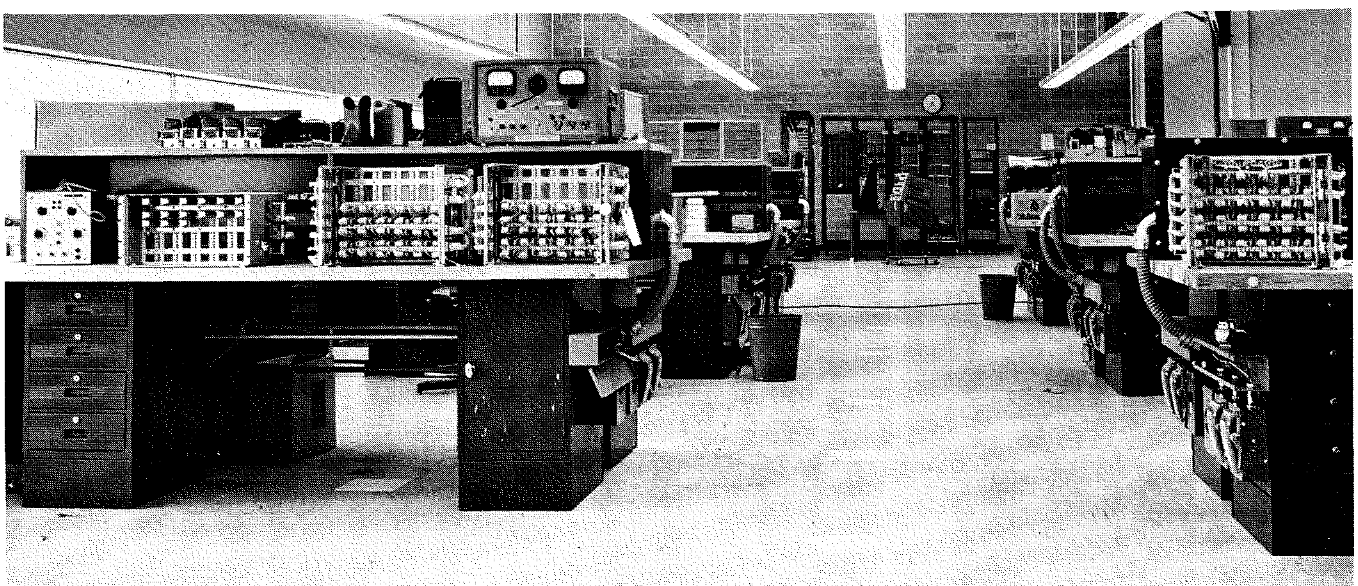
low energy to weight ratio available in existing power sources. If specific impulses of rocket fuels were increased an order of magnitude, many of the stringent weight and power restrictions on advanced flight vehicles would be removed. Prospects for achieving major increases in specific impulses hinge on tremendous exhaust velocities. Hence, nuclear and ion propulsion are under active investigation. However, as long as chemical fuels provide the basic propulsive power, tremendous take-off weight savings can be made by reduction of required payload weight. One area in which the required payload weight can be reduced is through the use of auxiliary power generating equipment which derives its prime energy from the medium through which the vehicle moves as, for instance, by means of air turbines with ram air drives. For orbital and interplanetary vehicles solar energy may be used as the prime source.

Utilization of New Materials—The RCA Laboratories and the Semiconductor and Materials Division are pursuing basic studies to develop new materials for passive circuit elements or solid state devices for energy sources, amplification, switching, and storage. The Missile Electronics and Controls Department is taking advantage of these materials for devices working at minute power levels in configurations or circuits which will most nearly meet advanced systems requirements. Heat dissipation, weight, volume, and reliability specifications can be realistically generated by obtaining data from the specialists in dielectrics, semiconductors, magnetics, and metallurgy who are producing new microminiature components in packages that can live in hyperenvironments.

SUMMARY

The future success of a missile electronics research activity will depend on the extension of present automatic control theory to take advantage of the major technique advances which are key to the feasibility of advanced aircraft, missile and rocket systems. At the same time the department must be committed to development effort which recognizes the economic constraints of the cold war. The military must be supplied with reliable operational equipment at reasonable cost, and in time to be useful.





THE ROLE OF SYSTEMS ANALYSIS IN A RESEARCH AND DEVELOPMENT PROGRAM*

by

DAVID WELLINGER

Missile Electronics and Controls Dep't.
Defense Electronic Products
Burlington, Mass.

DAVID WELLINGER received the AB degree in Mathematics and the MA degree in Mathematical Physics and Statistics from Boston University in 1945. From 1945 to 1952 he continued graduate study at Harvard and Columbia while teaching at several Universities in the East. During this time he conducted research in Mathematical Models in the Psychology of Learning at the Laboratory for Social Relations at Harvard.

From 1952 to 1955 he worked in the field of Guided Missiles and Guidance and Control at MIT, coming to RCA's Airborne Systems Laboratory in 1955 in Systems and Weapons Analysis.

Mr. Wellinger is a member of the American Mathematical Society.

EXTENSIVE RESEARCH and development programs are a normal prerequisite to the production of communications systems, fire control systems, and guidance and control systems for water, air, or space vehicles. The purpose of this paper is to examine the role of systems analysis in such programs.

RESEARCH AND DEVELOPMENT PROGRAMS

As shown in Fig. 1, it is convenient to think of a systems research and development program as being subdivided into three major areas: systems engineering, component and sub-system development, and systems test. The work in each of these areas may be briefly delineated as follows:

1. The job of systems engineering is
   a. to establish system and sub-system requirements
   b. to integrate the various sub-systems into a complete workable system
   c. to appraise the effectiveness of the system.
2. The component and subsystem development task consists of
   a. establishing components requirements
   b. designing, developing, and testing components
   c. designing, developing, and testing subsystems.
3. The work in the systems test category includes
   a. conducting functional system tests to determine the compatibility of the sub-systems with each other
   b. conducting tests to establish whether or not the system meets the established requirements.

Some overlap exists between these areas and they are interdependent; therefore, close coordination and a continuous channeling of information between groups assigned to each area is required.

SYSTEM ENGINEERING AND SYSTEMS ANALYSIS

To systems analysis, a subdivision of systems engineering, falls the task of analyzing the system to establish overall system requirements, system configuration, and subsystem requirements. In all cases, the requirements must be realistic, so that frequent checks must be made with the development engineers to assess the state of the art in various equipments.

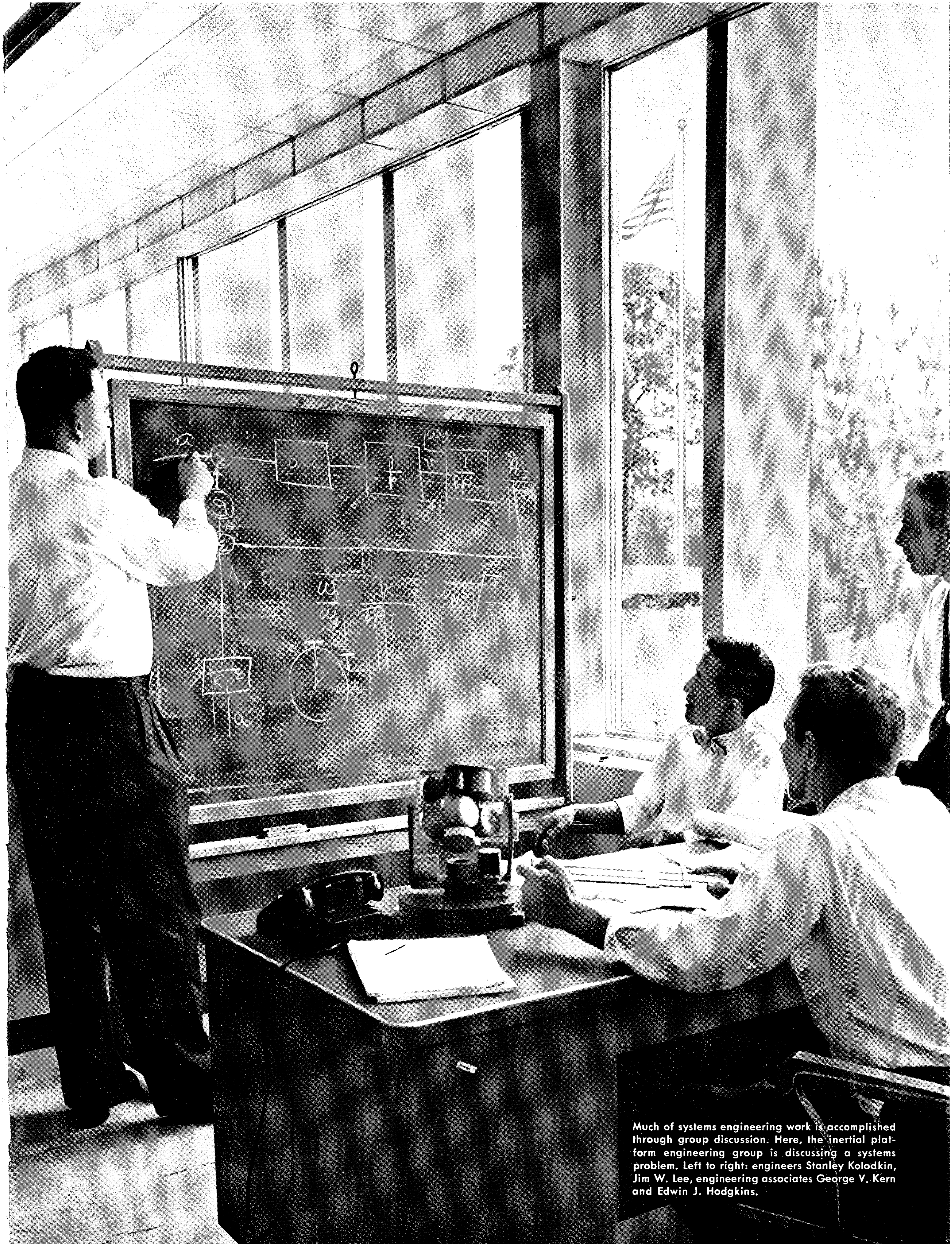
As shown in Fig. 1, the systems analysis group may be considered to be composed of two subgroups: operational and requirements analysis, and dynamic and error analysis.

OPERATIONAL ANALYSIS

The engineers engaged in operational analysis give careful consideration to the question "What job must the system do?" For example, in conducting an operational analysis for an airborne interceptor fire control system, consideration must be given to:

1. The characteristics and capabilities of the enemy airborne threat in the period for which the system will be in use. (i.e., numbers and types of bombers, their radar cross-sections, their aerodynamic properties, their counter-measures equipment, etc.)
2. The aerodynamic capabilities and physical properties of the interceptor in which the fire control system will be employed.
3. The main features and capabilities of the supporting ground environment radar and communications network.
4. The capabilities and operational

*This paper is based upon a talk delivered by the author to engineering students employed by RCA during the summer of 1957.



Much of systems engineering work is accomplished through group discussion. Here, the inertial platform engineering group is discussing a systems problem. Left to right: engineers Stanley Kolodkin, Jim W. Lee, engineering associates George V. Kern and Edwin J. Hodgkins.

characteristics of the air-to-air weapons that will be available for the use by the interceptor system in the era under consideration.

5. Airborne interceptor radar characteristics.

6. Human operator limitations and capabilities.

Based upon these factors, it is possible to establish interceptor tactics and possible mission profiles (from take-off, through climb to altitude, navigation and vectoring, target acquisition and attack, and return-to-base). Then, knowing the use that is desired of the entire interceptor weapons system, the operational analysis engineer can establish overall requirements on the performance of the fire control system and can conduct a preliminary evaluation of the effectiveness of the interceptor weapons system and the contribution of the fire control system. Finally, as the details of the system and the subsystem are made known, the operational analysis engineers devise and determine optimum tactical usage of the system to meet requirements under various conditions.

The techniques and skills employed in operational analysis are many. In the analysis of the fire control system, the following areas of knowledge apply: aerodynamics, vector analysis, dynamics, differential equations, probability and statistics. In studies of other systems (as well as fire control systems) knowledge is also required in astro-physics, game theory, and atomic physics. Digital or analog computer simulation is frequently employed in addition to the paper analysis.

SYSTEM CONFIGURATION

Following the establishment of requirements by the operational analysis group, formulation of the system configuration is undertaken jointly by engineers from each of the system engineering subgroups. Information on achievable hardware and on its complexity, size, weight, reliability, cost, and maintainability is obtained from the development and test groups and, coupled with system requirements, is used in determining the system configuration. The preliminary configuration must be checked carefully to insure that no unusual system integration difficulties will be encountered.

DYNAMIC AND ERROR ANALYSIS

It is then necessary to arrive at specifications for the major system parameters (i.e., values and tolerances of system gains and system lags) and subsystem requirements. This work is accomplished by engineers engaged in systems dynamic and error analysis. Uusually, the system cannot be designed to operate optimally under all anticipated conditions. Instead, the goal in establishing subsystem requirements is to achieve a system that will operate very well in the majority of cases or under the most likely circumstances, and will operate satisfactorily under nearly all anticipated conditions. Paper analysis of the system (involving techniques and knowledge of servomechanisms theory and transients in linear systems) is followed by analog computer simulation of the system. The paper analysis discloses major problem areas and yields preliminary results. Simulation serves as a back-up to the paper analysis and is a means for exploring problems not easily solved by paper analysis, such as the effects of equipment non-linearities or (where applicable) the effect of a human operator in the loop.

AN EXAMPLE: INTERCEPTOR FIRE CONTROL SYSTEM

As an example, consider an interceptor fire control system during the attack phase of the mission. The system may be represented functionally as shown in Fig. 2. The motions of the target or bomber aircraft and the interceptor aircraft may be combined through three-dimensional geometry to give the actual range from interceptor to target and the angular velocity of the line of sight. A radar tracking subsystem is employed to measure the geometric quantities. Since the radar base is subjected to interceptor motions (indicated by the dotted line in Fig. 2), a tight-loop subsystem is required for stabilization. The measured quantities are then processed by a computer to produce quantities indicating the angular deviation of the interceptor from the desired course. (Here, the desired course is that which will allow the interceptor to fire its weapon so that

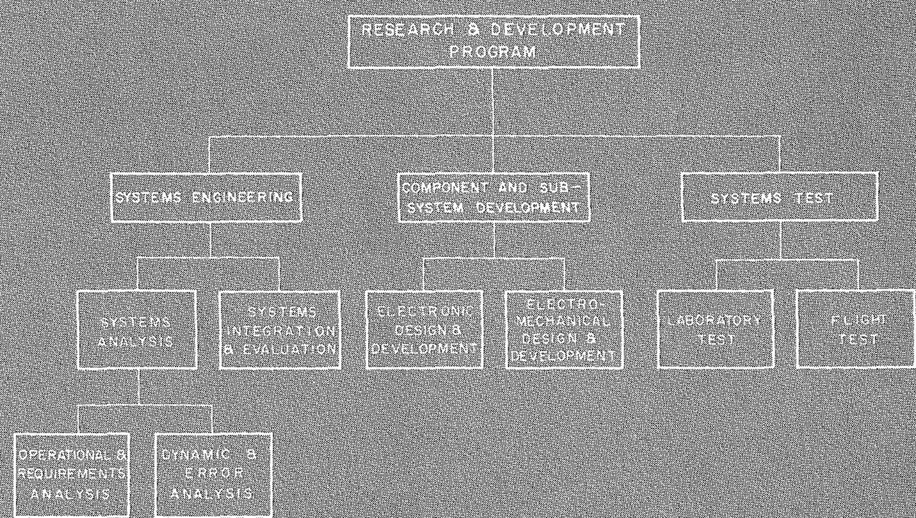


Fig. 1—Schematic representation of organization for a systems research and development program.

the weapon may hit the target). An adequate set of equations must be devised for the computer to solve, with due consideration being given to the sometimes conflicting goals of accuracy and simplicity. The off-course error may then be either

1. displayed to the pilot who gives appropriate acceleration commands using the control stick in the interceptor cockpit (manual mode of operation), or

2. sent to a coupler that processes the information automatically to produce the correct acceleration commands (automatic mode of operation).

In either case, the autopilot-aircraft combination produces appropriate interceptor aircraft responses to these commands, thereby completing the loop. The entire system must take into account the three-dimensional nature of the interception, cross-coupling problems, acceleration command limiting (to avoid exceeding interceptor aircraft limitations), and radar noise.

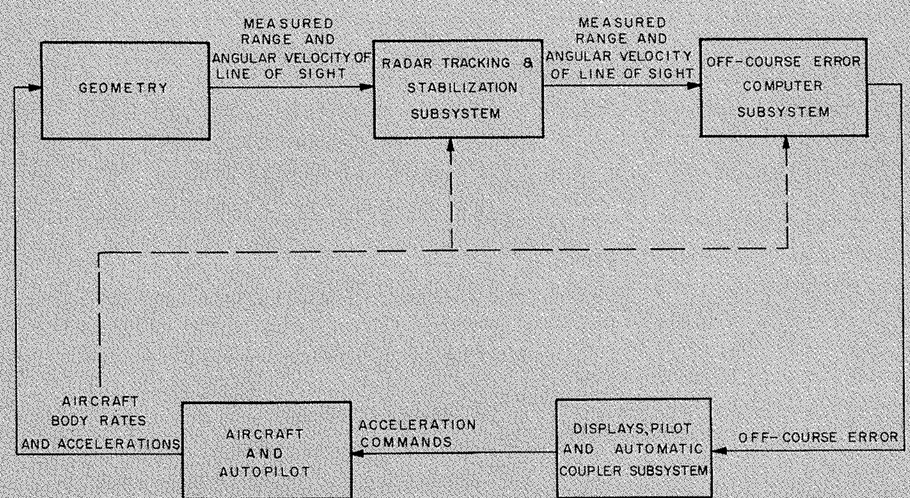


Fig. 2—Simplified functional diagram of airborne interceptor fire control system.

DESIGN SPECIFICATION CRITERIA

For any guidance and control system, specifications for the critical system parameter values and their tolerances as well as subsystem requirements are determined by consideration of four criteria;

1. stability
2. accuracy
3. speed of response
4. noise reduction

In general, specifications determined by optimization based on any one of these criteria will differ from the specifications determined on the basis of any other of these criteria. Therefore, a compromise is necessary. For example, in an interceptor fire control system, the system noise level must be kept sufficiently low to avoid excessive aircraft control surface motion and to make the ride comfortable to the interceptor pilot or crew. This means that some degree of filtering (lag network) must be provided. On the other hand, the system must respond rapidly to wipe out initial off-course errors or to cope with target maneuvers. Filtering is detrimental in this case, so that a compromise must be effected.

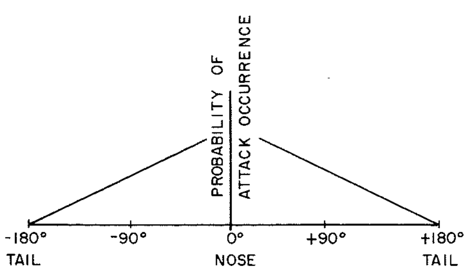
SUB-SYSTEMS DEVELOPMENT AND SYSTEMS TEST

The subsystem specifications determined by the dynamic and error analysis group serve as a guide for the design, development and test work of the component and subsystem development engineers. However, in setting up the mathematical model of the system for purposes of analysis and simulation, simplifications are often made in the representation of the system's elements based upon past experience. During the course of subsystem development or system testing, it may be discovered that the actual equipment possesses unanticipated properties or that it exhibits unusual properties. Therefore, new problems may necessitate a re-examination of the parameter values and subsystem specifications.

Planning for system field test is usually a joint effort of the systems engineering and systems test groups. The objectives of the field tests and predictions of system performance in the field tests may be based upon the results of the systems analysis (including simulation). For the interceptor fire control system, the flight tests may be planned toward making a comparison between simulator runs and actual flight runs. Good comparison allows for interpolation (and some extrapolation) of existing data in evaluating system effectiveness. Discrepancies require further examination and can lead to product improvement.

SUMMARY

While the work in the systems analysis area is mainly analytical in nature, an appreciation of the problems and accomplishments in the development, integration, test and evaluation areas is also necessary if the engineer is to do a good systems analysis. Indeed, systems analysis engineering affords the engineer contact with all phases of a research and development program, thereby providing the engineer with a comprehensive view of the entire program as well as an opportunity to examine challenging problem areas throughout the progress of the program.



NOTE: THIS FIGURE SHOWS THE PROBABILTY THAT AN ATTACK WILL BE INITIATED FROM A GIVEN ASPECT ANGLE.

Fig. 1—Probability of attack distribution

ANALYTICAL APPROACHES TO THE ECM PROBLEM

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EVALUATION OF PERFORMANCE of a weapon system is usually expressed in terms of mission success probability and involves a study of the inter-relationship between the weapon system and its support equipment (the ground environment, control centers, and communications). In the absence of enemy counter-measures (ECM) the analyses are fairly straightforward inasmuch as the required input data for the automatic system is available in a form to allow "normal" performance. A figure for overall mission success probability, P_{MS}, under these circumstances is readily established and is the product of the several individual success probabilities for each phase of the mission:

$$P_{MS} = P_S \, P_V \, P_D \, P_C \, P_K \, P_R \quad (1)$$

where P_S = Probability of scramble
P_V = Probability of vectoring
P_D = Probability of airborne detection
P_C = Probability of conversion
P_K = Probability of weapon kill
P_R = Overall system reliability

When ECM are employed, the picture changes rapidly. The enemy's purpose in using ECM is to deny certain types of information or to introduce false data into the weapons system. There exist many methods and techniques by which this can be done and if no action is taken to nullify these effects they can be extremely damaging to the weapons system performance. The endeavor to incorporate features into the weapons system for purposes of counteracting the effect of ECM is known as counter-counter-measures (CCM).

The ECM or CCM student will conclude very quickly that in spite of the intense popularity of these subjects, very little quantitative information is at hand to describe what ECM does to radar systems or how radars, through CCM, handle ECM. The reasons are, obviously, that we are usually dealing with *enemy* countermeasures which we cannot specify and that the human element (on both sides) enters into the picture somewhere. Not so obvious are the facts that the number of possible countermeasures is astronomic, and that the ECM question is not independent of other non-electronic factors such as altitude, closing rates, maneuver capability, and so forth. But, the engineer demands a number to describe ECM or CCM capability. Therefore some methods by which success probability under certain of these ECM conditions may be obtained are dealt with here.

In this paper, it is desired to find a quantitative measure of an electronic system's capability against specific ECM threats. We choose to call this measure "the probability of success against ECM". It is merely the probability of what our system can do against jamming compared with what it can do in a clear or non-ECM environment. We require this number since it is a factor in the overall success probability equation along with the other independent probability factors as indicated in equation 1.

THE MODEL

Before we can make an analysis, we must select a model. For purposes of illustration, a simple model is chosen. Parenthetically, we mention that the selection of an appropriate model is one of the difficult hurdles in ECM analyses and the one that precipitates the most argument. We will be concerned with an Interceptor Weapons System during the attack phase of a mission against a single bomber target at high altitude.

We may specify the threat as a non-maneuvering subsonic bomber with typical radar reflective area. The operating altitude will be high enough to be out of the ground clutter and atmospheric problems. The bomber target is capable of continuously dropping chaff throughout an interceptor attack and carries noise (barrage) jammers with around-the-clock radiation capability.

The interceptor considered is a supersonic aircraft equipped with unguided missile type of armament. The interceptor radar is assumed to have a pure collision home-on-jam mode and an anti-chaff circuit.

It is assumed that the interceptor is vectored by the ground environment to the target via a pure collision course. After detection and lock-on, the interceptor normally attempts to attack on a lead collision course.[1]

APPROACH TO THE STUDY

In this study we will consider the influence of ECM only upon those probabilities in Equation 1, which are concerned directly with the interceptor system at the initiation of the airborne detection or attack phase. These probabilities are those of detection (P_D) and conversion (P_C). From the effects of the assumed countermeasures upon these probabilities we will develop the probability of success against ECM.

[1]Against a non-maneuvering target, the interceptor's collision course is a straight line ending in a collision with the target. A lead collision course is also a straight line ending when the missile—launched at a predetermined point, and continuing on the same straight line—collides with the target.

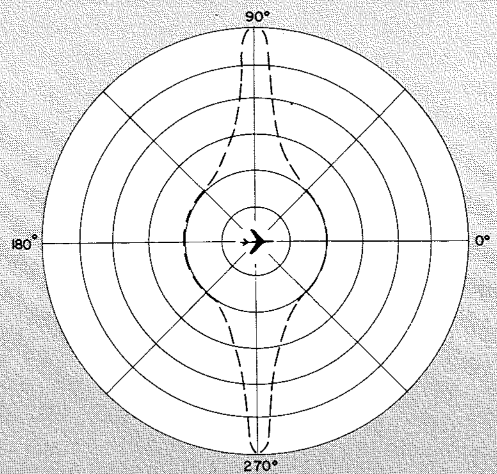


Fig. 2—Assumed target radar cross-section

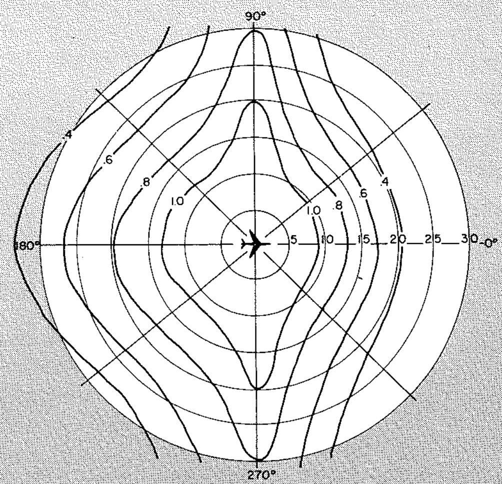


Fig. 3—Cumulative probability of radar detection in target space

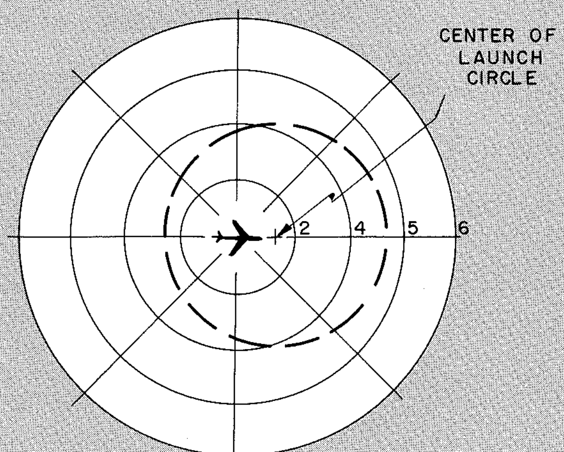


Fig. 4—Missile launch range in target space

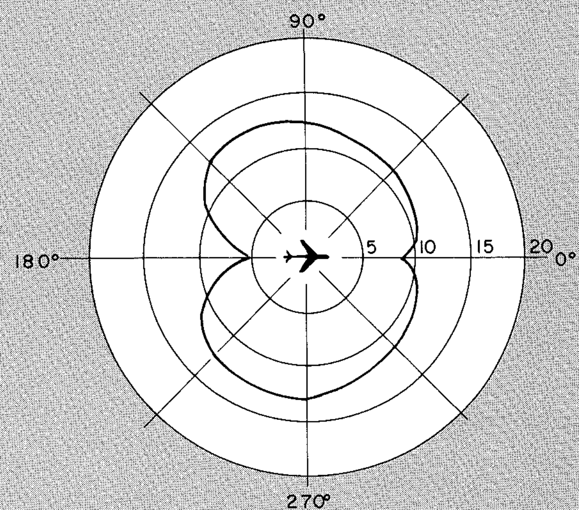


Fig. 5—Kinematic conversion barrier in target space (drawn to same scale as Fig. 3 & 6)

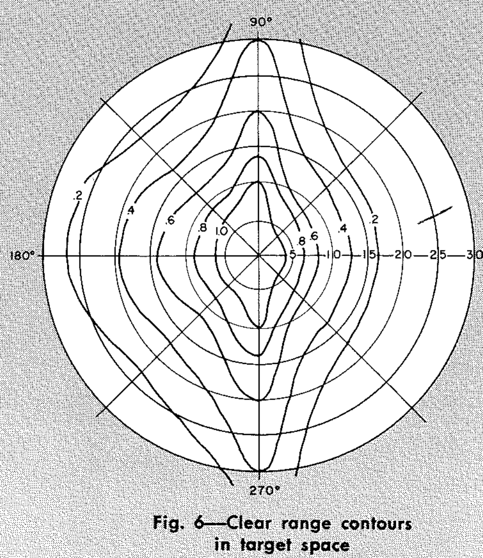


Fig. 6—Clear range contours in target space

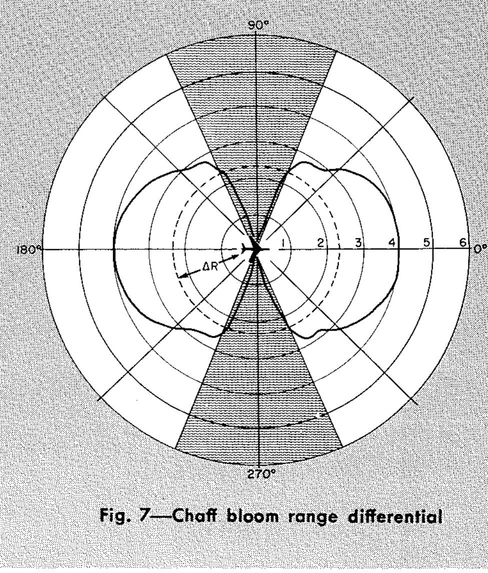


Fig. 7—Chaff bloom range differential

To calculate the probability of success against this bomber threat, we must go through the following steps:

1. Establish the probability of attack from each aspect angle.[2]
2. Derive kinematic limitations to the interceptor system.
3. Establish the interceptor radar's "in the clear" capability.
4. Determine the inherent capability of the radar system vs chaff.
5. Determine the inherent capability of the radar system vs noise jamming.
6. Combine the above information to give an "average" probability of success-against-ECM number.

ATTACK DISTRIBUTION

To start the analysis, we must first determine from what aspects attacks will be launched — that is from what aspects does the interceptor approach the target. It is a good tactic for the interceptor to attack the bomber as soon as possible and therefore it will take up a collision course with the target immediatey after take-off. If our ground radars provide warning of a raid early and if the interceptor is based near the target's projected route, the target will be intercepted from head-on aspects most of the time. We will take a linear probability distribution as indicated in Fig. 1.

DETECTION IN THE NON-ECM ENVIRONMENT

We have assumed that the interceptor is on a pure collision course with the target as a result of ground vectoring. At some point the interceptor radar will detect the target. The range at which the interceptor radar can detect the bomber can be ascertained by using the radar range equation. For typical airborne radars, the detection range of our target (Fig. 2) varies around the clock as shown in Fig. 3. Because operator factors and random noise enter into the range calculations, the contours are presented in terms of probability of detection. When the interceptor penetrates into the detection range, the radar yields the target's range and bearing. Target heading and speed are then computed and the interceptor acquires the required lead collision course. This must be accomplished before the missile is launched, so we need to know the range from which the armament is launched at each aspect. A typical unguided missile launch range contour is shown in Fig. 4. The launch range is greatest at nose-on aspects, where the closing rates are high, and least at tail-on aspects where the closing rates are low.

THE KINEMATIC BARRIER

Let us next consider the interceptor kinematic conversion problem. We can work backward from the launch range and find the point at which the interceptor must begin its maximum turn (typically a few g's) from a pure collision course in order that it will be on a lead collision course by the time it reaches the missile launch range. If we do this around the clock we generate a kinematic conversion barrier which represents the penetration along a collision course beyond which the interceptor can never satisfy the armament launching requirements. To be more realistic we must back off a bit from this boundary to account for the fact that it takes a few seconds for the radar operator to achieve lock-on, for the airborne computers to solve equations, to ready the armament, etc. We may approximate these effects by allowing a time T for all this action and merely add T times the closing rate (closing rate varies around the clock, and for given target and interceptor speeds, is a function of the cosine of the look angle[3] and the cosine of the aspect angle for collision courses) to the above barrier and hence arrive at the more realistic kinematic conversion barrier shown on Fig. 5.

CAPABILITY IN THE NON-ECM ENVIRONMENT

At this point we can ascertain the probability of detection and conversion in a non-ECM environment for the interceptor. It is necessary only to overlay the detection contours of Fig. 3 on the conversion barrier of Fig. 5. For each aspect of interest, the success probability equals the value of the detection probability contour which intersects the conversion barrier at the aspect in question. We can do this around the clock and add up all the success probabilities, after weighting each by its probability of occurrence from Fig. 1, to give us the total probability of conversion and detection in the clear.

CAPABILITY AGAINST BARRAGE JAMMING

Let us now bring ECM into the picture by first considering the probability of success against barrage jamming. This type of jamming involves an attempt by the enemy to mask the target by broadcasting noise in the radar's frequency band. Its effects are similar to thermal noise, but its level is usually several orders higher in intensity.

It is necessary here to develop con-

[2]Aspect angle is defined as the angle from the target path to the line-of-sight between target and interceptor.

[3]Look angle is the angle between the line of sight and the interceptor velocity vector.

A group of the authors of some of the articles herein are shown around the plotting table in the analog computer room. From left to right are Werner Sievers, Earle Blanchard, John Daelhousen (Systems Manager), and David Wellinger.

tours similar to Fig. 3 which will represent the "clear radar range", R_c, in the barrage jamming environment. This is the range at which the jamming signal equals the radar echo at the radar receiver. Within the clear range, the radar echo is stronger than the jamming signal so that the radar can "read" the target through the jamming and obtain the required range information. There is always a clear range (provided the radar has a greater power than the jammer) since the radar signal varies as the inverse of range to the fourth power while the one way jamming signal varies as the inverse of range squared. Utilizing the radar range equation and the one way jammer range equation, we can solve for the range, R_c, where the two signals are equal and get the result:

$$R_c = \sqrt{\frac{P_R\, G_R\, \sigma}{4\pi P_J\, G_J\, K}} \qquad (2)$$

where P_R = radar transmitted power

G_R = Radar antenna gain

σ = target reflective area

K = a factor accounting for the radar's ability to reject a jamming signal

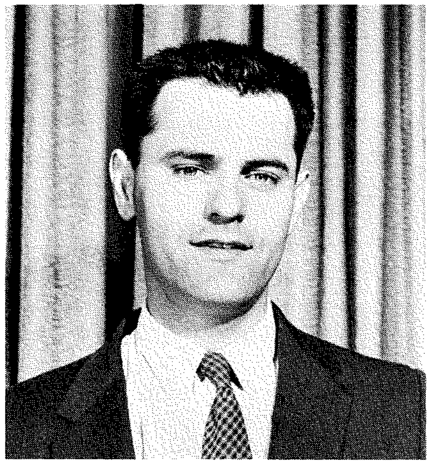
P_J = jammer transmitted power (within the radar's bandwidth)

G_J = jammer antenna gain

The factor, K, is again a statistical measure since it involves operator performance and probabilities of various occurrences such as parallel or crossed polarizations between jammer and radar along with other uncertainties.

With the solution of the above equation, we can develop a family of clear range contours for various probability levels as shown in Fig. 6. Inherent in the curves is again the uncertainty connected with the factor, K.

We can use the same procedure for determining the probability of success against barrage jamming we used in the non-ECM case. We overlay the clear range contours, Fig. 6, and the



EARLE P. BLANCHARD received the B.S. in Electrical Engineering in 1942 from Northeastern University, and studied graduate programs in Servomechanisms and Advanced Mathematics at M.I.T. and Adelphi College. After four years in the Signal Corps he was employed at M.I.T. in 1946, working in Systems, including electronic equipment and components. For the six years from 1950 Mr. Blanchard was employed by the American Bosch-Arma Corporation in the design and development of sub-systems in a fire control system. After one year with ARDE Associates as a consultant to the G.E. Company on Guided Missile Guidance and Control, he came to RCA in 1956 to the Airborne Systems Laboratory, where he has been active in various navigation systems problems.

WERNER E. SIEVERS attended M.I.T. from 1948 to 1953, receiving the B.S. and M.S. in Electrical Engineering. He continued his graduate study in Transients and Circuit Analysis at M.I.T. from 1956-57. From 1953 to 1956 he was employed by Sanders Associates in the field of guided missiles and electronic components. Coming to RCA Airborne Systems Laboratory in 1956, he has been working on Electronic Counter-Countermeasures, Airborne Radar Systems and ECM Simulation. Mr. Sievers is a member of the IRE, Eta Kappa Nu, Tau Beta Pi, and Sigma Xi.

Cockpit simulators have been built by RCA to permit the analysis of complicated fire control systems problems in which a human operator performs a part of the mission. Left to right are technicians R. J. Geehan (in cockpit), Kevin Ronan, and Courtland Baird.

kinematic barrier contour, Fig. 5, and read off the probabilities of the clear range achieved at the kinematic boundary for various approach aspects. The probabilities are highest at beam and tail-on aspects which suggests that a beam approach or a tail chase is the best tactic against noise jamming targets. We then weigh these probabilities according to the attack distribution of Fig. 1 and sum them to get the probability of success in a noise jamming environment. The figure will be reduced from that for the clear environment because of the shorter ranges at which target range information is obtained.

If the ground environment becomes unable to vector the interceptor because of ECM or other reasons, it is possible for the interceptor to achieve its own pure collision course by "homing" on the jammer's radiation in cases where the AI radar is jammed. This is accomplished by nulling the angular rate of the radar antenna while it is tracking (in bearing only) the jammer's radiation. This homing course is continued until the interceptor penetrates the clear range and obtains complete target information.

CAPABILITY AGAINST CHAFF

We can now direct our attention to the effectiveness of our system in the chaff ECM environment. Chaff is employed in an attempt to decoy the radar away from the target or to confuse the radar by cluttering up the target area with spurious returns. Against chaff we will assume that, as an anti-chaff measure, our radar will narrow its range gate to a minimum. The chaff being dumped out of the target has a delay associated with it before the chaff "blooms" to a size large enough to compete with the target. The bloom distance is assumed to be a fixed distance behind the target. By employing high range resolution we have a means of rejecting the chaff echo while receiving the target echo. But the radar range gate is sensitive to range only along the radar line of sight and the range difference between target and chaff along this line of sight varies as the cosine of the aspect angle. In addition the "effective" bloom size of the chaff varies with aspect angle because of the varying radar cross-section of the target. Thus we can say that the apparent range differential between target and the point where chaff blooms to a level competitive with the target is approximated by

$$R_D = \Delta D \frac{\sigma}{\sigma_o} (\cos A_T) \quad (3)$$

where ΔD is the fixed chaff bloom distance behind the target, σ is the target cross-section at the aspect of interest, and σ_o is the nose-on (0° aspect) cross section. The minimum radar range gate will allow discrimination between targets whose range differs by ΔR (the range gate's cell of resolution). The chaff, therefore, can have no ill effects on the radar at aspects where it blooms to competitive size at range differentials greater than ΔR. Fig. 7 is a polar plot of the effective bloom range differential and shows that only in a cone abeam of the target does chaff enter the radar's cell of range resolution.

Within this cone abeam of the target the radar will lose lock-on and outside the cone lock-on is not affected. Also if lock-on is lost the attack cannot be completed; conversely, the attack is successful if lock is not broken. Thus, contrary to the noise jamming case, the interceptor should avoid beam approaches when attacking a chaff dispensing target. To establish our probability of success against this model it is merely necessary to obtain the probabilities of successful attacks, where lock is not broken, and weigh these probabilities in accord with the occurrence probabilities of Fig. 1.

CAPABILITY AGAINST THE COMBINED ECM THREAT

If we now assign a probability of occurrence to each of the various types of jamming (noise or chaff in our case) we can develop a single number which will reflect our system capability against the overall potential ECM threat. If the enemy is believed to employ chaff and noise jamming simultaneously with close to unity probability, then the probability of detection and conversion for each aspect in an ECM environment is the product of the success probabilities against noise jamming and chaff. Weighting (according to Fig. 1) and summing these probabilities around the clock gives us the total probability of success in the postulated ECM environment.

Now we cannot attribute all the decrease, from unity, in the probability of detection and conversion on ECM alone, since even in the clear the interceptor may not be able to convert. If we break up the overall probability of conversion and detection into two factors and let one be the probability of detection and conversion in the clear, the second will be a factor which accounts for the effects of ECM and only ECM. Thus this latter factor can be called the probability of success against jamming (P_J) and is equal to:

$$P_J = \frac{\textit{Probability of success under ECM}}{\textit{Probability of success in the clear}} \quad (4)$$

CONCLUSION

For our model we have found that ECM can appreciably reduce the weapon systems effectiveness. The above analysis suggests that system performance can be improved by altering the interception tactic from the intital collision course to a tail chase in order to place the interceptor at high success probability aspects. Such a tactic requires a definite speed advantage of the interceptor over the target.

There are many countermeasures and counter-countermeasures in the picture today. As more and more new ideas are generated in the field, the problem of determining capability becomes more difficult.

Additional aspects of the interception problem can also be treated in a more comprehensive study of this type. The methods are basically the same, but would be extended to include detrimental effects such as the ground environment vectoring inaccuracies and the ECM effectiveness in this area, the difficulties confronting guided missile armament during the terminal phase of the attack against ECM, and the effects of mass bomber raids upon all areas of the interception operation. Also, the study would include beneficial factors such as interceptor reattack capability, the effects of alternative tactics such as pure pursuit or other modified courses, and the advantages of a predetermined preferred attack aspect. All types of anticipated ECM and CCM activity plus the human crew potential for interpretation of the environments can be reflected in the study to enable prediction of the system's overall probability of mission success.

ADJOINT TECHNIQUES IN SYSTEM DESIGN

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PART I—THE APPLICATION OF ADJOINT TECHNIQUES

WHEN A STUDY IS made of a complex control system, the first step is to specify the equations governing the behavior of the system. The equations may be solved on a digital computer when only a few solutions of high accuracy are desired. The more usual case requires a study of the system under a wide variety of conditions. The analog computer is the natural choice when a large spectrum of conditions is to be studied.

This paper deals with an advanced technique involving the application of the mathematical theory of adjoint systems to analog computers. This technique affords considerable savings in time and money in comparison with conventional analog computer methods, and permits a much more thorough system design investigation and evaluation than is possible with conventional techniques. While the mathematical details of the adjoint transformation and the justification of its application are somewhat involved (the foundations are presented in Part II of this paper), the formal method of application to analog computers is simple and readily accomplished.

SYSTEM DESIGN PROBLEMS AND OBJECTIVES

In the design of guided missile, bombing, or fire control systems, the payoff is the miss distance measured at the time the missile passes by the target or at the time the projectiles are released. An extremely elaborate or complicated system means nothing if the miss distance exceeds the specification as determined by the size of the weapon warhead. In the case of an interceptor fire control system, we are interested in the response of one particular variable, the miss distance, at one particular time, the firing time. Interceptor radar lock-on to the target can occur at any time prior to firing, with initial off-course or heading errors. Unbalances, proportional and bias errors can exist throughout the fire control run and affect the miss. In addition, target maneuvers and radar scintillation and receiver noise can contribute to the overall miss. Similar disturbances and problems arise in the cases of guided missile or bombing systems.

The objective in system design is to consider all the factors or system disturbances that may affect the miss, and arrive at a system configuration and system parameters that minimize the miss due to the combination of the various disturbances.

CONVENTIONAL ANALOG COMPUTER TECHNIQUES

The conventional analog computer technique for conducting such system design studies is as follows: the computer elements (i.e. summing and integrating amplifiers, resolvers, multipliers and potentiometers) are connected so that the equations that describe the electrical analog set-up are the same as those that describe the physical system being studied. The initial conditions are set corresponding to some particular time of application of a particular disturbance. The analog computer is allowed to run and the response is observed; i.e., the miss distance is plotted as a function of elapsed time following the application of the particular disturbance. This procedure is repeated for each new time of application and for each disturbance separately. In a typical system design program conducted in the conventional manner, at least several hundred runs are required.

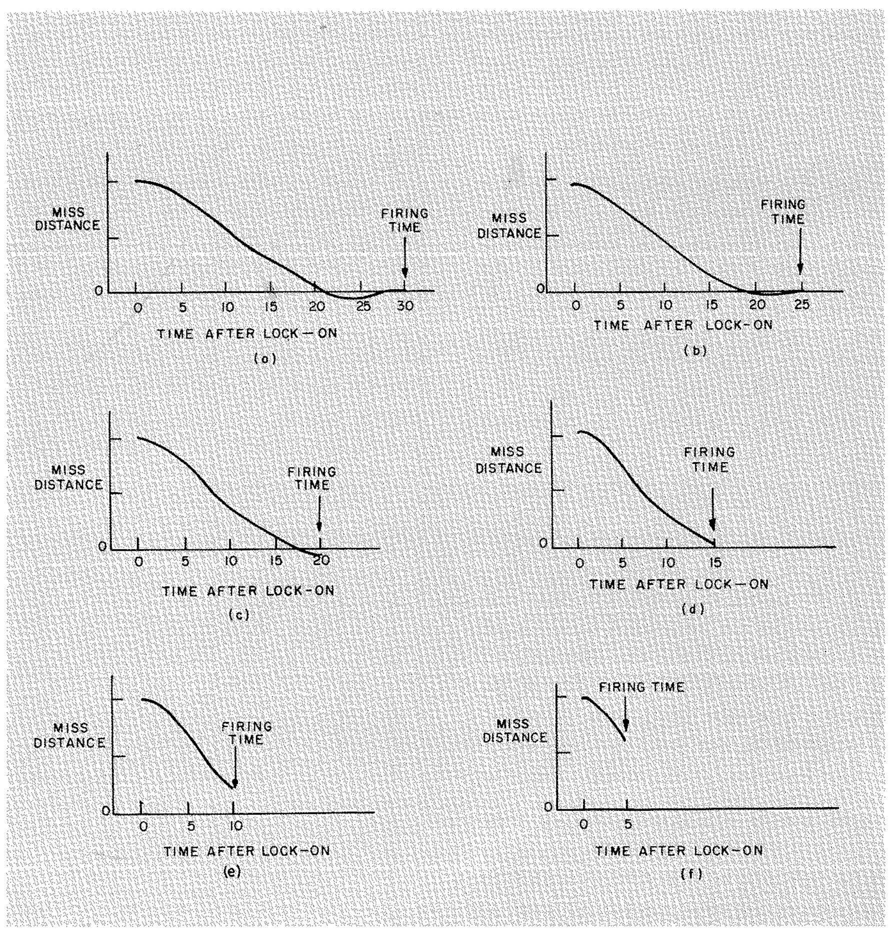


Fig. 1—Analog computer responses to an initial off-course error corresponding to six different initial lock-on times

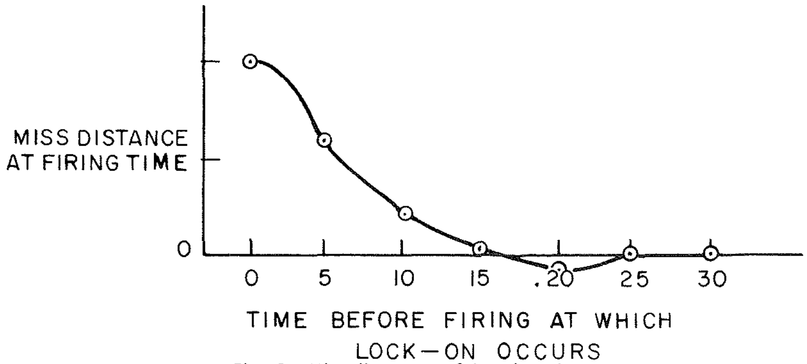


Fig. 2—Miss distance at firing time due to initial off-course error at lock-on

AN EXAMPLE

Fig. 1 shows as an example six computer runs where miss distance is plotted against time after lock-on in response to an initial off-course error existing at interceptor radar lock-on. Each of the runs corresponds to a different initial time (or initial range from interceptor to target) at which lock-on occurs. In each run, the important quantity is the miss distance at firing time due to the initial off-course error, and thus only one pertinent point is given for each run. These six points are plotted and joined together by a curve as shown in Fig. 2.

Each of the other disturbances (such as target maneuver and drift) requires a separate set of runs. Thus, the number of analog computer runs required is high.

THE ADJOINT TECHNIQUE

Given the analog computer diagram showing the hook-up of computer elements to obtain the conventional simulation of the physical system, the adjoint of the system may be obtained by reversing the direction of signal flow of all the elements in the computer diagram throughout the system, and by starting the computer runs with the time-varying quantities at their conventional final values and running them "backwards" (i.e., in reverse from the original system). The input to the adjoint simulation is at the point at which the miss distance would be measured in the conventional simulation, and the outputs of the adjoint simulation are at the points where the disturbances would be applied in the conventional simulation.

COMPARISON OF CONVENTIONAL AND ADJOINT METHODS

If the adjoint of the set of equations describing the fire control system is formed, the outputs of a single adjoint simulation run are curves similar to that shown in Fig. 2. That is, not only is the curve of Fig. 2 (which required the six conventional runs of Fig. 1) given by the one adjoint run, but other curves similar to Fig. 2 corresponding to the miss due to each of the other disturbances are also given by the same adjoint run. In this way, if the system response to five different disturbances were under examination, conventional analog computer techniques would require 30 runs to accomplish what one adjoint technique analog computer run would yield.

It is not to be inferred that a single simulator solution of the adjoint system provides all the required information. A separate solution is needed for each of the prescribed courses between interceptor and target. These courses change with type of armament employed, course type such as lead pursuit or lead collision, interceptor and target velocities, and approach angles. These changes make the time-varying elements in the simulation change in a different way. Nevertheless, the use of adjoint techniques allows a considerable reduction in the number of simulator runs required and permits a more thorough design evaluation than the conventional approach.

NOISE STUDIES

Another advantage of the adjoint technique is the ability to handle noise (and other quantities of a statistical nature) as one of the disturbances. A conventional simulation requires the use of some form of noise-generating equipment. The calibration of this equipment leaves much to be desired, and one can never be sure that characteristics of the noise generator and filters match those of the physical system under study. Even if one had complete confidence in the calibration process, there is still the problem of processing the data. Each run of the system with a random input results in a different value of miss at firing time. Therefore, many runs must be made so that these miss disturbances can be averaged to obtain the root-mean-squared (rms) values. This same information can be obtained much more economically through the use of the adjoint system. With only one run of the simulator, it is possible to record the mean-squared value of miss due to each of several statistical disturbances. This one run could be the same run which produced all the information concerning miss distances due to initial off-course errors, constant and proportional errors and other disturbances on the system. Moreover, there is no need for using noise-generating equipment with the adjoint system.

SYSTEM DESIGN RESULTS

An example of the design results that may be readily obtained using adjoint techniques is shown in Fig. 3, where the three curves correspond to three adjoint runs. Note that the curve of Fig. 3 corresponding to a system gain equal to two is identical with the curve of Fig. 2. Inspection of Fig. 3 indicates that the optimum

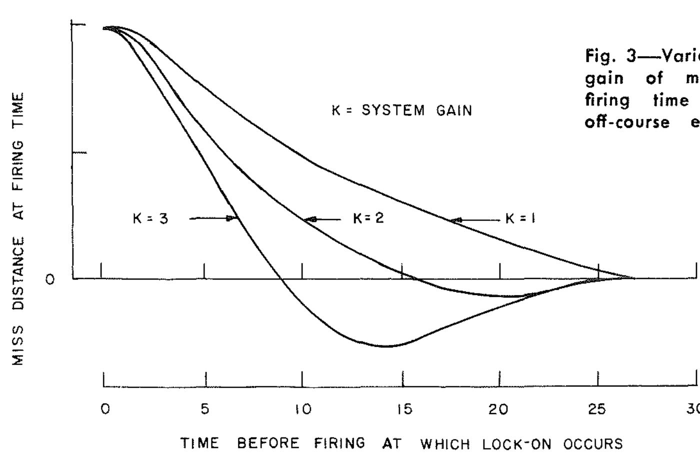


Fig. 3—Variation with system gain of miss distance at firing time due to initial off-course error at lock-on

design value for system gain is approximately two.

Another example that demonstrates the utility of the adjoint technique in system design is the selection of the time constant for the system smoothing filter. Optimization of the computer smoothing time constant requires a compromise between minimizing the miss due to glint noise (glint miss) and minimizing the miss due to steady target turns (turn miss). If there is no smoothing, the system is most effective against a maneuvering target, but is least effective for radar interference. Large smoothing time constants eliminate the problem of glint miss, but make the system extremely sluggish in combatting target maneuvers. Fig. 4 shows root-mean-squared values of miss distances at time of fire due to radar glint interference plotted as a function of the smoothing time constant. Also shown is the miss due to a maneuvering target. The misses due to each of the two types of disturbance are obtained in a single adjoint run for each value of the time constant. The total miss is the sum of the rms miss due to radar noise and the miss due to target maneuvers. The selection of the optimum time constant is then readily accomplished by choosing the value that minimizes the total miss.

CONCLUSIONS

Application of the adjoint technique to analog computer studies in system design investigations is easily achieved and has the following desirable properties:

1. The effect of a disturbance upon system performance as a function of the time of application of the disturbance may be obtained in one run.
2. The effect of each of several input variables to a system may be obtained separately in the same single run.
3. The resultant effect due to noise may be obtained without using a physical noise source.

These properties make the adjoint technique an extremely useful tool in system design and evaluation studies. The cost and time expended is considerably reduced in comparison with requirements for conventional analog computer techniques.

The adjoint method may be applied to linear or nearly linear systems with time-varying parameters. It has been applied most frequently to guided missile problems, and can also be applied to systems containing non-linearities such as control surface restrictions (see reference 5). It is believed that the RCA Burlington Laboratory was the first to apply the adjoint technique to a fire control system design problem. Undoubtedly, application of this technique may be made to many other complex systems.

PART II—FOUNDATIONS OF ADJOINT TECHNIQUES

This part of the paper describes the basis for the construction given in Part I for the simulation of the adjoint system and shows why the application of the adjoint technique to analog computers gives rise to the significant properties illustrated in Part I. Certain salient points concerning analog computer representations of systems of differential equations and the evolution and properties of adjoint transformations are also reviewed. References listed at the end of this paper present additional mathematical detail.

ANALOG REPRESENTATION OF DIFFERENTIAL EQUATIONS

As an example, consider the following differential equation:

$$\frac{d^2y}{dt^2} + t\frac{dy}{dt} + y = f \qquad (1)$$

This equation is typical of those found in systems of equations describing the performance of control systems for aircraft and missiles. To solve this equation on an analog computer, it is rewritten in the following form:

$$\frac{d^2y}{dt^2} = -t\frac{dy}{dt} - y + f \qquad (2)$$

One of the computer elements is an integrator which is capable of putting out a voltage proportional to the (minus) integral of its input. Thus, if the input to the integrator is the right side of equation (2), the output of the integrator will be the (minus) integral of this, or $-dy/dt$. These operations could be described by the portion of the computer hookup diagram shown in Fig. 5 (a). Note that one of the inputs $-t\ dy/dt$ is the same as the output $-dy/dt$ except for a multiplication by t. This signal can be formed by putting both $-dy/dt$ and t into a multiplier as shown in Fig. 5 (b). The remaining signal y is the integral of dy/dt. The loops are completed by integrating dy/dt and running the output back to the input as shown in Fig. 5 (c). The quantity f is the input or forcing function to the system and y is the output or response to this input.

If $y = y_1$ and

$$\frac{dy_1}{dt} = y_2 \qquad (3)$$

equation (2) may be rewritten as

$$\frac{dy_2}{dt} = -ty_2 - y_1 + f \qquad (4)$$

Equation (3) corresponds to integrator B of Fig. 5 (c), and equation (4) corresponds to integrator A.

MATRIX EQUATIONS AND ANALOG COMPUTER REPRESENTATIONS

Equations (3) and (4) which represent the system of Fig. 5 (c) can be written as the following matrix equation:

$$\begin{pmatrix} \frac{dy_1}{dt} \\ \frac{dy_2}{dt} \end{pmatrix} = \begin{pmatrix} 0 & 1 \\ -1 & -t \end{pmatrix} \begin{pmatrix} y_1 \\ y_2 \end{pmatrix} + \begin{pmatrix} 0 \\ f \end{pmatrix} \qquad (5)$$

Equation (5) is of the general form

$$\left(\frac{dy(t)}{dt}\right) = A(t)y(t) + f(t) \qquad (6)$$

where $y(t)$ is the column matrix

$$y(t) = \begin{pmatrix} y_1 \\ y_2 \end{pmatrix} \qquad (7)$$

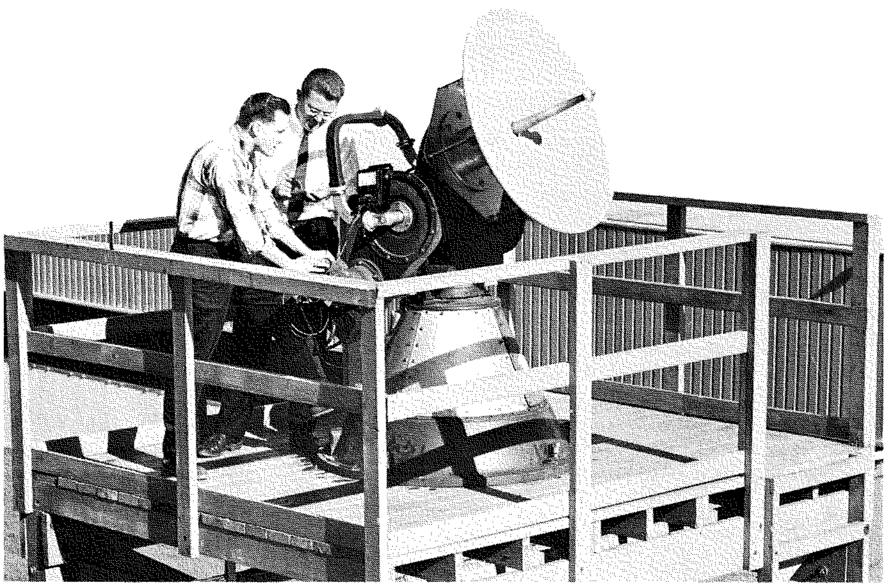
$f(t)$ is another column matrix

$$f(t) = \begin{pmatrix} f_B \\ f_A \end{pmatrix} = \begin{pmatrix} 0 \\ f \end{pmatrix} \qquad (8)$$

and $A(t)$ is the matrix

$$A(t) = \begin{pmatrix} a_{BB} & a_{BA} \\ a_{AB} & a_{AA} \end{pmatrix} = \begin{pmatrix} 0 & 1 \\ -1 & -t \end{pmatrix} \qquad (9)$$

Referred to a computer hookup diagram, the elements of the matrix $A(t)$ represent the connection between the output of one integrator and the input of some other or the same integrator. In an actual computer hookup, not every integrator output need be connected to every other integrator input, in which case the corresponding matrix element would be zero. In the example, the



An automatic tracking radar designed for use against supersonic targets is tested on the roof of the Burlington facility by technician Alden Marshall (left) and engineer Knowlton Miller.

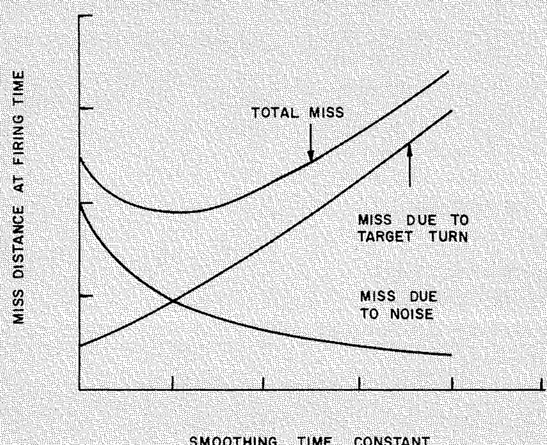


Fig. 4—Miss distance at time of fire due to noise and target maneuver

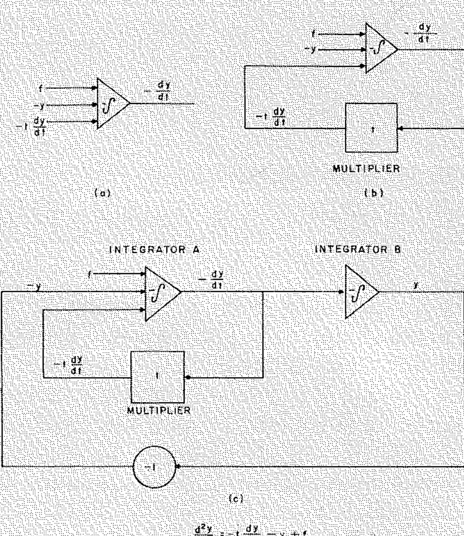


Fig. 5—Formulation of the analog computer representation of a differential equation

output of integrator B does not feed back directly into its own input; so the upper left element of the system matrix of equation (9) is zero. Similarly, integrator B has no input forcing function; so the first element of the input matrix $f(t)$ is zero. These concepts may be extended in a similar manner to a general nth order linear differential system.

SYSTEM WEIGHTING FUNCTIONS

A useful tool in the theory of differential systems is the Green's function or weighting function of the system. Such a function $g(t, T)$ is defined to be the system response to a unit impulse applied at time $t = T$. The reason for applying the name "weighting function" to the Green's function is that the general solution to systems of the form of equation (1) is given by the integral

$$y = \int_{-\alpha}^{t} g(t, T)\ f(T)\ dT \quad (10)$$

The output is thus the integral of the input weighted by the Green's function. The Green's function is a function of the time of application of the input and the time of observation of the response; that is, it is a function of both T and t.

In the general nth order linear differential system, a unit impulse, or a unit initial condition on an integrator, will produce a response at the output of every integrator in the system. There will thus be n Green's functions relating the unit impulse of a given integrator to the output of the n integrators. Similarly, every integrator may have its own unit initial condition, each producing n responses of its own. We are thus led to the concept of a Green's matrix, each element of which is a Green's function. A given element of the matrix is the response at the output of a certain integrator resulting from a unit initial condition on some particular integrator, provided all other initial conditions are zero. The general solution of the differential system of equation (6) is given by

$$y(t) = \int_{-\alpha}^{t} G(t, T)\ f(T)\ dT \quad (11)$$

where $G(t, T)$ is the Green's matrix.

ADJOINT EQUATIONS

If the original system is described by

equation (6), the corresponding adjoint equation is defined as

$$\frac{dx(T-t)}{d(T-t)} = \bar{A}(t)\ x\ (T-t) + h(T-t) \qquad (12)$$

where the matrix $\bar{A}(t)$ is formed by interchanging the rows and columns of the matrix $A(t)$.

The usefulness of the adjoint system comes about as a result of the following property: If $G(t, T)$ is the Green's matrix of the system described by equation (6), then $\bar{G}(T, t)$ is the Green's matrix of the corresponding adjoint system described by equation (12). This theorem is important not only because of the transpose property, but also because the roles of t and T are interchanged. Its proof may be found in Reference 2.

ANALOG REPRESENTATION OF ADJOINT SYSTEMS

Suppose that it is desired to evaluate the system weighting function for a fixed value of time of observation, t, but with a variable time of application of the disturbance, T; that is $G(t, T)$ is desired as a function of T for a fixed value of t. By applying impulses into the adjoint system, the roles of t and T are reversed and corresponding Green's functions are obtained as continuous functions of T. The only difference is that the Green's matrix of the adjoint system is the transpose of the original system matrix. If in the original system, a unit impulse is applied to an integrator, outputs are obtained at every integrator throughout the system. These outputs then form one column of the Green's matrix. In many situations, we are interested in one particular variable, and hence in the output of one particular integrator. Hence, we are interested in a row in the Green's matrix, but each individual input or disturbance produces the functions in a column. It is thus necessary to repeat the disturbances one at a time to each of the individual integrators in a conventional analog computer simulation. With the adjoint system, however, the desired functions are all in a single column and can all be recorded simultaneously with a single run of the computer.

In the original system, the general equation corresponding to the ith integrator is

$$\frac{dy_i}{dt} = \sum_{j=1}^{n} a_{ij} y_j \qquad (13)$$

while in the adjoint system, the general equation corresponding to the jth integrator is

$$\frac{dy_j}{d(T-t)} = \sum_{i=1}^{n} a_{ij} y_i \qquad (14)$$

Hence, while y_j multiplied by a_{ij} is an input to the ith integrator of the original system, y_i multiplied by the same term a_{ij} is an input to the jth integrator in the adjoint system. Thus, to simulate the adjoint system, it is necessary to reverse the direction of signal flow throughout the system. Also, because elements in equation (12) are functions of $(T-t)$, it is necessary to start the simulation with time-varying elements at their final values and drive them in the reverse sense from the original system.

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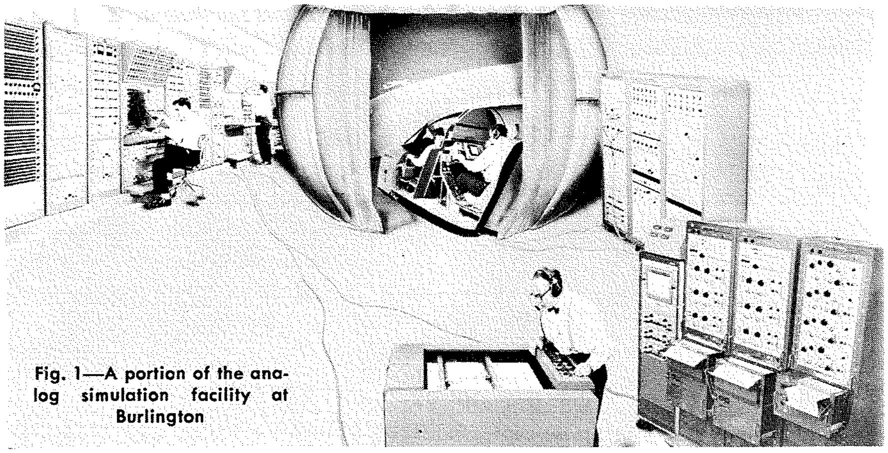

Fig. 1—A portion of the analog simulation facility at Burlington

THE ANALOG COMPUTER IN THE DESIGN OF COMPLEX SYSTEMS

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MACHINE COMPUTATION is often employed in support of system design. The systems may be simple loop servos or complex multi-loop systems. The latter category is considered here with particular emphasis on airborne systems, although the discussion also applies to complex systems of other types, such as a nuclear reactor power supply system or an automatic control system for factory processing.

The computational facility employed may be digital, high-speed analog or real-time analog. Each of these has applications for which it is best suited, depending upon the accuracy and number of solutions required as well as other factors. This paper considers the real-time analog computer facility located at the Missile Electronics and Controls Department laboratories at Burlington.*

* Princeton and Moorestown have smaller but somewhat similar facilities, except for special auxiliary equipment.

ANALOG SIMULATION

In arriving at the design of a system, a mathematical model of the system may be constructed by describing the system with a set of dynamic equations. On an analog computer, the system variables are represented continuously as a function of time by voltages (i.e., the voltages are analogous to the variables of the equations of the mathematical model of the system). Standard equipment for an analog computer includes summing and integrating amplifiers, multipliers, resolvers, potentiometers, attenuators, and function generators. Using these, the analog computer solves systems of both linear and non-linear differential equations. The solutions are represented by voltages that drive pens to trace the solutions on paper.

Fig. 1 depicts a portion of the RCA analog simulation facility at Burlington, one of the largest and most modern in the electronics industry. The standard analog equipment is shown on the left-hand side of the picture, and the recording equipment is located on the right-hand side and to the front. Also pictured is the auxiliary equipment consisting of the two-seat interceptor cockpit mock-up in a shell used for environmental simulation.

DESIGN OF COMPLEX SYSTEMS

This analog simulation facility has proven to be an extremely useful tool in the design of complex systems such as missile guidance and control systems, airplane or space vehicle autopilots, and fire control systems. The facility may be employed several ways to assist in design. The principal uses are:

(1) Preliminary evaluation of the system's operational capabilities.
(2) Verification of paper design analysis.
(3) Investigation of the effects of the human operator upon the system.
(4) Pre-flight dynamic tests of components and sub-systems in a simulated systems environment.
(5) Determination of correlation and/or discrepancies (and the causes thereof) between predicted performance and flight test results.

EVALUATION OF OPERATIONAL CAPABILITIES

In designing a complex system, it is necessary at an early stage to assess the operational capabilities and effectiveness of the proposed system. For example, in designing an air-to-air missile system, it is important to have an early estimate of the launch zones, i.e., the regions in which the missiles may be successfully launched. The re-

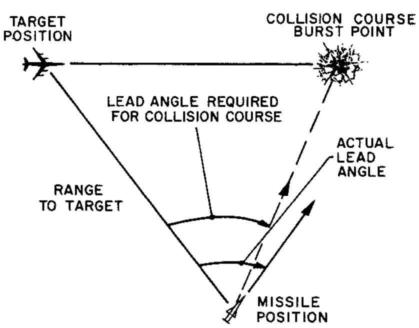

Fig. 2—Missile target kinematics

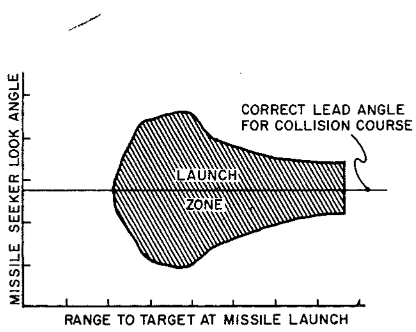

Fig. 3—Admissable missile launch region

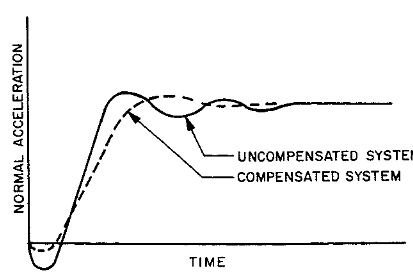

Fig. 4—Effects of amplitude and rate limited servo and compensation on pitch autopilot response

sults are often presented in the form of the allowable angular heading deviations from a collision course with the target versus range to the target at missile launch (see Figs. 2 and 3). While it is possible to set up simplified models for paper analysis to obtain preliminary results, it is difficult to include in these paper analyses the effect of variations in missile velocity and maneuverability, the effect of major lags of the missile electronic system or airframe, or the effects of target maneuvers. An analog simulation allowing for the three-dimensional kinematics and a representation of the missile aerodynamics as well as the guidance and control system with its major lags allows a realistic preliminary determination of the missile system capabilities and the adequacy of overall system design and configuration.

Similarly, it is desirable to make a preliminary evaluation of the conversion capabilities of an interceptor fire control system, including the effectiveness of special tactics or courses that the interceptor may fly. Again, the analog simulation facility affords an expedient means of accomplishing this objective.

DESIGN ANALYSIS

Customarily, a background of component development and paper synthesis and analysis is used to arrive at a suitable system design specification of dynamic properties and error tolerances. This paper analysis is based upon system linearization and little or no kinematics. For example, the dynamics of an airborne or space vehicle can be represented mathematically by six degrees of freedom corresponding to displacements (heave, surge and sway) and rotations (pitch, roll and yaw) in three-dimensions, and equations involving interrelationships between these variables. For purposes of paper analysis, the pitch and roll systems are usually treated separately, ignoring the interrelationships between these two systems to facilitate the analysis. Past experience in system design has shown that this paper treatment of the problem is often justifiable. However, analog computer simulation allows for the necessary examination of the cross-coupling effects between the pitch and roll channels, thereby checking the validity of the simplifying assumptions of the paper analysis. For example, inertia coupling effects in aircraft often require special stability augmentation schemes that are best studied using an analog computer.

Analog computer simulation also permits investigation of other areas not easily covered by paper analysis, such as trigonometric functions, limiters, dead-zones, time-varying coefficients, hysteresis loops, backlash and friction. Such simulation often shows the need for revision of the design established through the paper analysis. For example, Fig. 4 shows that an amplitude and rate-limited servo has an undesirable oscillatory effect upon the response of an aircraft automatic control system. Using the analog computer, a compensation scheme was devised and the comparison is shown in the figure.

Noise, atmospheric turbulence, and other statistical inputs often have a critical effect upon system design. These are also best studied with the aid of an analog computer facility.

HUMAN ENGINEERING

The role of the human in a complex system is always difficult to evaluate because the judgment and decisions of the human are not easily or accurately represented by a set of equations. Furthermore, the human operator's response is conditioned by the environment and manner in which information is given to him. For example, in an interceptor fire control system, it is desirable to investigate the performance of the crew under various conditions utilizing various displays in order that crew effectiveness may be maximized. Experiments of this type have been conducted using the facility shown in Fig. 1. In one experiment, a comparison of two types of displays was made and the results (shown in Fig. 5) indicate better system performance with display A than with display B.

It is also interesting to compare the system performance in the fully automatic mode with that in the manual mode to determine what changes in system parameters or configuration are necessitated by the two different modes of operation. Furthermore, if countermeasures are anticipated against the interceptor weapons system, simulator evaluation of the crew reaction is the only reasonable means of obtaining this information which in turn leads to system design modifications and recommendations of equipment use. Similar remarks would apply to simulation of the human operator's role in a space vehicle, boat, or submarine.

PRE-FLIGHT EQUIPMENT TESTS

Following preliminary design of the system by means of analysis and simulation, breadboard models of the system (or portions thereof) are developed. In addition to the conventional bench testing of the hardware, it is also desirable that there be pre-flight dynamic tests of the equipment in a systems environment. Analog simulation of the kinematics and airframe dynamics permits tie-in of the actual equipment in such a test. The analog computer may be used to simulate the equipment also, so that a direct com-

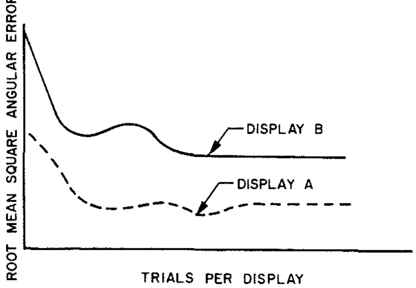

Fig. 5—Results of human engineering study of display effectiveness

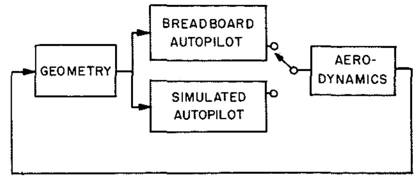

Fig. 6—Schematic representation of tie-in of breadboard model with simulation equipment

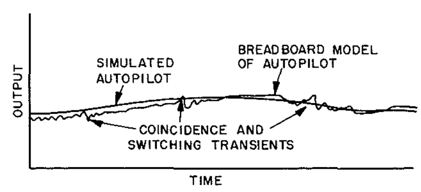

Fig. 7—Results of dynamic systems test of breadboard model of autopilot

parison may be made between the simulator representation and the actual equipment. (Fig. 6 shows a functional diagram of a tie-in scheme.)

Among the advantages of pre-flight systems dynamic testing is that it results in earlier and easier recognition of difficulties. Fig. 7 shows an example where transients due to coincidence and switching circuitry were discovered in the dynamic systems test of a breadboard model of a control system. The geometric conditions leading to these undesirable transients were easily repeatable on the analog computer set-up, whereas setting up specific geometric conditions in flight tests is always a difficult task and seldom achieved on a repeat basis. Furthermore, the analog computer dynamic test of the breadboard allowed for simple and rapid evaluation of the cause of the transients on the spot, in contrast to flight testing where evaluation often occurs a considerable time after completion of the tests. As a result of such tie-ins of actual components and equipment with the analog computer, it is possible to make appropriate changes in circuit design and other modifications and design improvements prior to flight test.

Another example that occurs frequently is the discovery of hunting tendencies in the breadboard model of control systems. These are usually due to discontinuities and may be remedied by redesign or replacement of components. While the necessity of flight testing is not eliminated, these tests of the hardware in a systems environment through use of an analog computer reduce considerably the time and money to be expended on the flight test program.

FLIGHT TEST EVALUATION

Flight testing of the system sometimes reveals a serious difference in performance of the system from that predicted. In this case, further analysis followed by analog computer simulation may prove beneficial. For example, flight tests of a missile may reveal an instability in the guidance system. Upon investigation, it may be discovered that there were certain imperfections in the missile radome. Analysis can show that some of these imperfections created a new loop not taken into account in the original design and analysis. Simulation may then be used to verify that this was the cause of the instability and to determine the means of effecting some suitable compensation. As a further example, often times the hinge moment effects or the aeroelastic (airframe body bending and torsion) effects may have been believed to be negligible and thus not taken into account in the system design, so that their effects are not fully apparent until flight tests. If their influence upon system performance is great (in conflict with original expectations), then additional simulation and redesign are required.

ANALOG EQUIPMENT LIMITATIONS

While the analog computer is no panacea in itself, it is a powerful tool if accompanied by the engineer's ingenuity and care. Even large facilities such as that at the Burlington Laboratories have a limit to the amount of analog equipment available, and therefore the engineer must not oversimulate the system, for if the equations describing the system are too completely detailed, the simulation equipment will not be able to accommodate them. Therefore, the engineer must exercise his judgment in representing the system on the simulator. Furthermore, while analog computer simulation often reveals difficulties that were not anticipated by paper analysis, recognition of the source of these difficulties often requires that the engineer have a "feel" for the physical interpretation and behavior of the system. Also, in evolving the possible causes for discrepancies between actual equipment behavior and simulation, knowledge of all the characteristics of the actual hardware is helpful. For example, an experienced engineer can often readily recognize that either gyro drift or accelerometer misalignment could be the cause of a system inaccuracy. This effect could then be simulated for corroboration or denial of the possible causes.

In all cases, care must be taken to recognize the limitations of the analog equipment. It is ill-advised to attempt to have one analog computer program set-up to solve many different types of problems. Different representations and differing orders of complexity are required, depending upon the engineering objectives. For example, verification of paper analysis system design requires a more detailed representation of system dynamics than does an operational analysis study to assess overall system capabilities. Furthermore, the voltages on the analog computer are limited in their range; consequently, the variables that they represent are also limited. Emphasis in one problem for a system may call for an entirely different range of variables than the examination of another problem concerning the same system.

SUMMARY

Experience has shown that if knowledge of the physical situation represented, the actual system equipment characteristics, and the limitations of the analog computer equipment are combined by the engineer with insight and good judgment, the use of an analog computer facility such as that at the Burlington Laboratories can be an invaluable aid in the design of complex systems. Proper use of an analog computer can reduce considerably the time from initiation of preliminary development model design to completion of final product design as well as lower the cost of the design program and flight testing.

DAVID WELLINGER received the AB degree in Mathematics and the MA degree in Mathematical Physics and Statistics from Boston University in 1945. From 1945 to 1952 he continued graduate study at Harvard and Columbia while teaching at several Universities in the East. During this time he conducted research in Mathematical Models in the Psychology of Learning at the Laboratory for Social Relations at Harvard.

From 1952 to 1955 he worked in the field of Guided Missiles and Guidance and Control at MIT, coming to RCA's Airborne Systems Laboratory in 1955 in Systems and Weapons Analysis.

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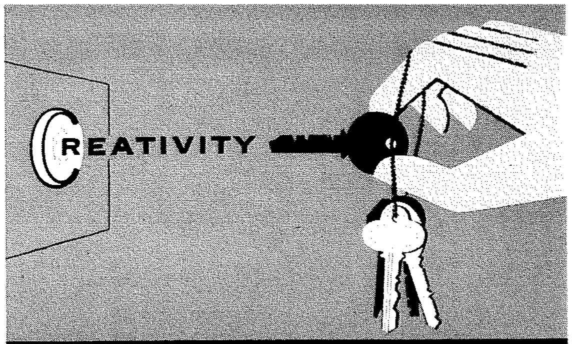

WILL YOUR KEY UNLOCK THIS DOOR?

(Part III of a Series on the Subject of Creativity)

RE-INVENTION BY YOUNG ENGINEERS

By
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A point of great importance to the student or young graduate, is the judgement we pass on the re-creation or re-invention of something already old. If a young man performs this feat, *with no knowledge of the prior work,* it can be as genuine a creation as when it was first done, and it may well be an example of innate ability. All too often, our potential inventors are abashed and actually set back when they discover their ideas have been recorded in prior art. An inhibition arises which may even affect the next creative act. We older (and wiser?) engineers must do our part to counteract this, and recognize the re-creation or re-invention as a sign of merit. The young student or engineer should be made to feel encouraged and confident. At the same time, he will resolve to learn more of his field, so that his future creations will be extensions well beyond present knowledge.

THE INDIVIDUAL—NOT THE GROUP

By
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Recent publicity using the word "Creativity" might lead the casual observer to believe that this is a new subject. Actually, of course, it is as old as mankind. The disturbing part of recent publicity is the tendency to over-emphasize group effort, adjustment to the group, and observation by groups, and de-emphasis of individual thought processes.

The use of group "brainstorming" as a technique to increase "creativity" has had some success. However, this method does not solve problems — giving only ideas or leads. Although the broad experience of the group is valuable, the actual "problem-solving" involves deeper thought processes and longer periods of concentration.

Real "creations" that is, brand new ideas, are the result of individual effort. For a few in the genius category, great strides of thought can be made, practically intuitively. For the larger number of people, a systematic study of all the possible solutions to a given problem is more likely to yield results. In either case, however, the concentration of an individual brain is necessary to achieve genuine "creativity."

"TRY-TRY AGAIN"

By
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According to one of the Editorial Representatives, my patent total is at or near the top in RCA. This may be correct but I have no facts to check it (my present count shows about 300 assigned patents).

However, these did not all come in easy fashion! There were many roadblocks and periods of discouragement. As an example, perhaps my most important formally disclosed invention was the first. It was the indirectly-heated, oxide-coated cathode submitted to GE's Suggestion Dept. about 1919. It was proposed as a means to reduce hum so that the "A" battery used in receivers could be replaced by a-c cathode heating. "Experts," who classed the idea as interesting but impractical, gave me a "pat on the back" for a good try and told me to try again for something better. A few years after the disclosure was abandoned without filing, Westinghouse introduced the indirectly-heated cathode, for the same reasons I had suggested it. It quickly became standard practice. This proved to me that one must not only have the PERSUASIVENESS to get others to use his inventions—but the COURAGE to face, without emotion, the failures and criticisms which often beset inventors.

FACTORS WHICH FAVOR INVENTIONS

By
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Recording and Reproduction
(Retired 1948)

It is a mistake to think of invention in terms of the number of issued patents. I have known many engineers who were prolific in inventions, and others who were equally able and clear thinkers, who were more inclined to follow conventional methods, and whose work, equally valuable in its way, did not result in many new approaches. I doubt whether inventiveness can be taught, but if potentially present, it can be encouraged, and fostered.

Most inventions are made in the course of trying to solve some problem. Therefore to stimulate invention confront an engineer with problems. Make the problems look interesting, either by tying them in with his previous known interests, or by "selling" him on their importance, or their application. Discussions with other engineers, about problems and tentative approaches, are important, and can be very stimulating.

But for profitable discussions, it is of utmost importance that the participants have complete confidence in each other. If engineers are scrupulously conscientious about giving credit to others for ideas or suggestions, the atmosphere will be cleared of the poison of suspicion, and of the fear that the someone else might steal one of our ideas. From that standpoint (confidence in each other), it is better not to be too patent-conscious. Do the job the best way, and then look it over to see whether some novel principles have been employed, that deserve to be covered by patent applications.

The broader one's background, the greater are the chances of his familiarity with some principle which will prove to be a useful and novel method of achieving a result. And keeping abreast of developments in pure research, will help an engineer to be early in utilizing newly discovered phenomena or effects. I have known some scientists who made important inventions by trying to think of applications of each new principle.

Sometimes a sound and useful idea is discarded as unsuccessful, when the fault lay in the crudity of the test. The ability to put refinement into experiments is of great importance, and it is essential to put enough study into them to make sure the principle is tested.

INHERENT MOTIVATION

By
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Creativity is such an inherent trait of man that he is never really satisfied or happy unless he has the opportunity to do some creative work. This satisfaction, which is derived from the work itself rather than the rewards it brings, is often increased when he is engaged in a task that makes severe demands upon him, but is still within his powers.

Being creative is probably within the realm of possibility for every human being. The means by which creativity is expressed varies among individuals. For creative thinkers, a high degree of personal happiness is gained from the mere existence of the opportunity to create. The action need only be in the abstract sense, for much of the greatest pleasure of creating comes from mental activity. Contemplation, just for its own sake, can be rewarding to a true creator. Thus, to the individual motivated by dissatisfaction, creation is a part of a larger scheme which not only imparts both dignity and meaning to what might otherwise be a tasteless life but also contributes toward the making of a better world.

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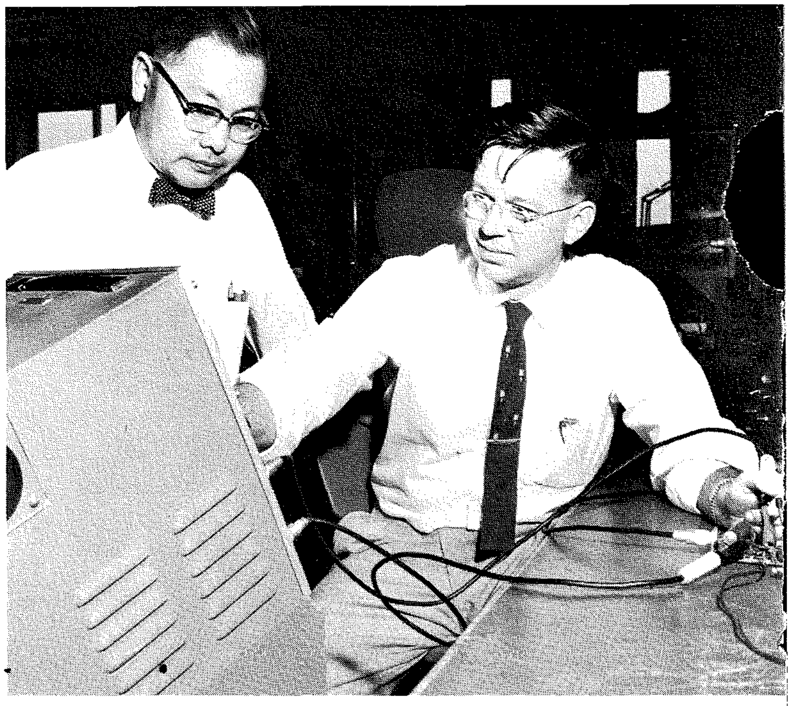

LARGE-SIGNAL TRANSIENTS IN TRANSISTORS

T. MURAKAMI and R. F. KOLAR

Advanced Development Engineering
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THIS PAPER SUMMARIZES the work done on the large-signal transient operation of alloy-junction transistors. It was the intent of this study to investigate some of the reasons why the cutoff times of the horizontal-deflection transistor was so slow compared to the rise times.

A review of the work done by others[1,2] indicated that the treatment of large-signal transients was limited to small injected current densities in the base region of the transistor. In the operation of the horizontal deflection transistor the current densities are many times larger than those assumed in previous analysis of transients. For the sake of convenience and availability of measuring devices, low power transistors were studied under relatively large signal conditions, instead of the actual type of transistor used for horizontal deflection.

PARAMETERS VARY WITH CURRENT

In the low-level theory of transistors, the injected carrier densities are assumed to be very much less than the equilibrium majority-carrier density in the base region. Under this assumption the small-signal parameters for the transistor are constant and linear theory is applicable. When the injected carrier density is increased so that it is comparable with the majority-carrier equilibrium density, the small-signal theory no longer applies. This means that the transistor parameters are not constant and the basic junction relation

$$i = i_s\left(\epsilon^{\frac{qv}{kT}} - 1\right) \tag{1}$$

where

i = current through junction
i_s = saturation current with junction reversed biased
$q = 1.6 \times 10^{-19}$ coulombs
v = voltage across the junction
$k = 1.380 \times 10^{-23}$ joules
T = absolute temperature

is not satisfactory.

The solution to the problem of large-signal transients in transistors by direct formulation of the differential equations of hole and electron flow is complex and difficult because of the non-linear nature of the problem. A more fruitful approach to this problem is attempted in this report. The transient response for large signals is found by assuming that the small-signal equivalent circuit still applies but that some circuit parameters are functions of current. The current transfer ratio is found from the equivalent circuit in terms of the variable circuit parameters and the complex frequency variable p. From the equation for the transfer ratio the transient response is found by letting $p = d/dt$ and solving the resultant differential equation with the proper initial conditions.

AN EQUIVALENT CIRCUIT FOR JUNCTION TRANSISTOR

A circuit diagram of a common-emitter transistor amplifier is shown in Fig. 1(a). The corresponding small-signal equivalent circuit suitable for transient analysis is shown in Fig. 1(b). The common-emitter circuit is chosen because it is the most commonly used circuit when large current gains are required, as in the television horizontal-output circuit. For common-emitter operation, the current gain from base to collector can be expressed as*[3]

$$\frac{I_c}{I_b} = \frac{\alpha_{FB}}{(1 + \omega_{\alpha b} R_L C_c)\, p + 1 - \alpha_{FB} + \dfrac{R_L}{r_c}} \tag{2}$$

where $p = j\omega/\omega_{\alpha b}$ and α_{FB} is the value of the emitter to collector current gain α_{fb} at zero frequency. The 3 db cutoff radian frequency for α_{fb} is $\omega_{\alpha b}$. We shall use the equivalent circuit shown above and equation (2) as the basis for the large-signal transient analysis. However, before proceeding further, the manner in which the circuit constants vary with the currents in the transistor must first be determined.

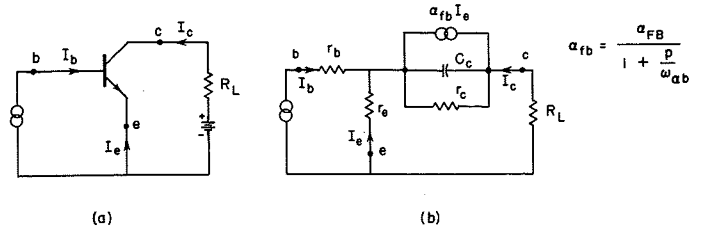
VARIATION OF CIRCUIT PARAMETERS WITH CURRENT

Variation of Base to Collector Current Gain: Webster[4] has shown how the d-c base to collector current gain α_{FE} of the junction transistor varies with the emitter current. The current gain α_{FE} when plotted as a function of emitter current takes the form shown in Fig. 2. A general equation for α_{FE} in terms of the physical constants of the transistor has been derived by Webster. This equation may be approximated by an equation of the form

$$\frac{1}{\alpha_{FE}} = a_1 + a_2 I_e + \frac{a_3}{a_4 I_e + a_5} \tag{3}$$

where $a_1, a_2, \ldots, a_5$ are constants and I_e is the emitter current. A simpler equation with sufficient accuracy to show the effect of variation of current gain on the transient response is given by

* Standard IRE notation is used throughout—*Proc. IRE,* July 1956, p. 934.



↑

Fig. 1—Above: Common-Emitter Circuit and its Small-Signal Equivalent. ← At Left, the Authors: Tom Murakami observes "Scope" and Bob Kolar makes Test-Circuit adjustments.

$$\frac{1}{\alpha_{FE}} \approx \sigma_1 - 1 + \sigma_2 \, | I_e | \qquad (4)$$

where σ_1 and σ_2 are constants. The emitter to collector current gain α_{FB} is related to α_{FE} by the equation

$$\alpha_{FB} = \frac{1}{1 + \frac{1}{\alpha_{FE}}} \qquad (5)$$

so that

$$\alpha_{FB} = \frac{1}{\sigma_1 + \sigma_2 \, | I_e |} \qquad (6)$$

Equation (6) will be used in conjunction with equation (2) to obtain the large-signal transient response which includes the effect of current-gain fall-off with emitter current.

Alpha-Cutoff Frequency: Another transistor parameter which varies with the emitter current is the alpha-cutoff frequency ω_{ab}. It is more convenient to obtain ω_{ab} indirectly by measurement of the beta-cutoff frequency ω_{ae} using the relationship[5]

$$\omega_{ab} = \omega_{ae} \, (1 + \alpha_{FE}) \qquad (7)$$

where ω_{ae} is defined as the angular frequency at which the base to collector current gain α_{FE} is down 3 db from its low-frequency value. A typical plot of f_{ae}, α_{FE}, and f_{ab} is shown in Fig. 3 as a function of emitter current for a type 2N140 alloy junction transistor. If the beta-cutoff frequency ω_{ae} can be assumed to be constant and $\alpha_{FE} >> 1$, the alpha-cutoff frequency, ω_{ab}, is nearly proportional to the base to collector current gain α_{FE} by equation (7). Thus

$$\omega_{ab} \cong K \, \alpha_{FE} \qquad (8)$$

or

$$\omega_{ab} \cong \frac{K}{\sigma_1 - 1 + \sigma_2 \, | I_e |} \qquad (9)$$

when expressed in terms of the emitter current. Equation (9) will be used in conjunction with equation (2) to show the effect of cutoff frequency variations on the large-signal transient response.

Base to Emitter Resistance: During a turnoff transient, the base-to-emitter junction is usually reverse biased so that the cutoff time may be reduced. In this cutoff interval the input resistance from base to emitter may vary from a fraction of an ohm to ten-thousand ohms or more. The base and collector current and voltage variations for a horizontal deflection transistor during cutoff is shown in Fig. 4.[6] It is noted that the ratio of base voltage to base current, e_b/I_b, is not a linear relation. The base current falls to zero in about the same time interval that it takes the collector current to fall to zero. In previous analysis[1] the decay of the base current to zero was not taken into account. Since an explicit expression for the input resistance is not available, it will be assumed that during cutoff the magnitude of the base current will be proportional to the collector current as a first approximation. Although this assumption is not the most accurate, it is better than that of assuming a constant base current for the low-impedance source considered here. When the collector current emerges from the storage region into the active region, the base current is flowing in a direction opposite to that which normally exists with the transistor turned on. It will be assumed that equation (2) is still valid under reverse base current conditions although it was derived only for forward base currents. The justification for this assumption is that when it is used for the particular conditions specified, the calculated values of fall time agree fairly well with the experimental results.

TURN-ON TRANSIENT

Variable Base to Collector Current Gain: The unit-step response of the common-emitter amplifier for large input signals will be studied under various conditions. It will be assumed in this section that the only circuit parameter which varies under transient conditions is the base to collector current gain.

Equation (2) may be written as

$$\frac{I_c}{I_b} = \frac{\alpha_{FB}}{\underline{p} + 1 - \alpha_{FB} + \frac{R_L}{r_c}} \qquad (10)$$

where $\underline{p} = (j\omega/\omega_{ab}) \; (1 + \omega_{ab} \, R_L C_c)$. When the value of α_{FB} given by equation (6) is substituted into equation (10) using the additional relation that $I_e = - \; (I_c + I_b)$ we obtain

$$\frac{I_c}{I_b} = \frac{1}{\left\{ \underline{p} \, [\sigma_1 + \sigma_2 \, (I_c + I_b)] + \left(1 + \frac{R_L}{r_c}\right) \left[\; \sigma_1 + \sigma_2 \, (I_c + I_b) \; \right] - 1 \right\}} \qquad (11)$$

If $\underline{p}$ is considered to be the differential operator $d/d\underline{t}$, equation (11) may be expressed as

$$- \, d\underline{t} = \frac{A I_c + B}{a I_c^2 + 2b I_c + c} \, dI_c \qquad (12)$$

where

$$A = 2\,\sigma_2 \qquad B = \sigma_1 + \sigma_2 I_b$$

$$a = \sigma_2 \left(1 + \frac{R_L}{r_c}\right) \qquad 2b = \left(1 + \frac{R_L}{r_c}\right) (\sigma_1 + \sigma_2 I_b) - 1$$

$$c = -I_b.$$

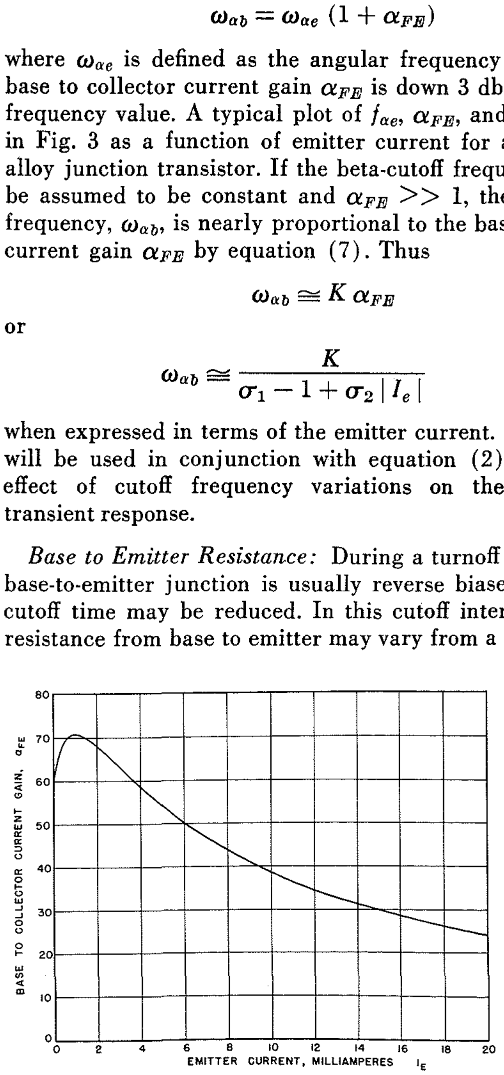
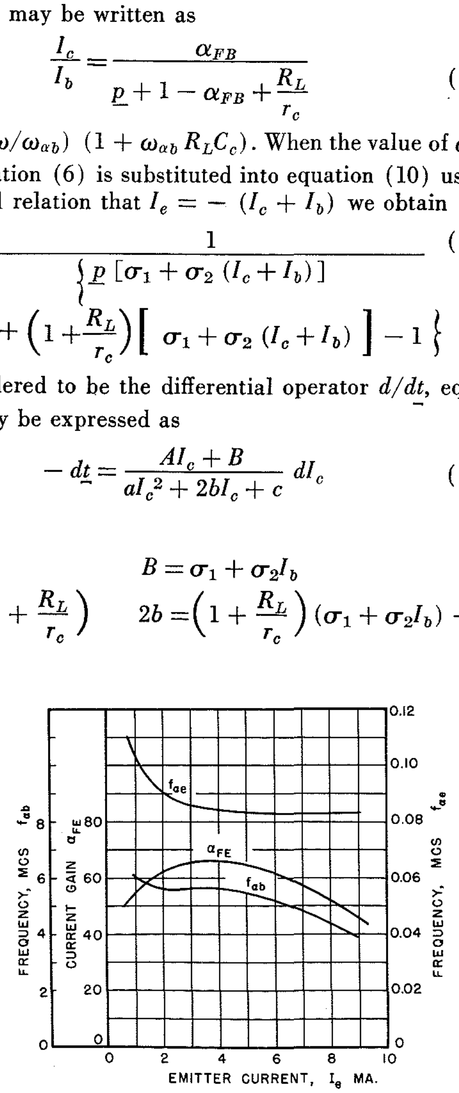


Fig. 2 — Variation of Current Gain with Emitter Current.

Fig. 3 — Transistor Parameters as Functions of Emitter Current for 2N140 Transistor, Vce = 2 volts.



Since $\underline{p} = \frac{j\omega}{\omega_{\alpha b}} (1 + \omega_{\alpha b} R_L C_c)$, the normalized time is given by $\underline{t} = \omega_{\alpha b}\, t \div (1 + \omega_{\alpha b} R_L C_c)$ by use of the change of scale formula.[7]

Equation (12), when integrated,[8] for a unit-step applied at $t = 0$, becomes

$$-\underline{t} = \frac{A}{2a} \log \left[\frac{a}{c} I_c^2 + \frac{2b}{c} I_c + 1\right] + \frac{aB - bA}{2a\sqrt{b^2 - ac}}$$
$$\log \frac{aI_c + b - \sqrt{b^2 - ac}}{aI_c + b + \sqrt{b^2 - ac}} - \log \frac{b - \sqrt{b^2 - ac}}{b + \sqrt{b^2 - ac}}. \quad (13)$$

Response Curves: For given values of I_b, σ_1, σ_2, R_L, and r_c, equation (13) is evaluated by assuming values for I_c and calculating t. The values of I_c assumed must be such that the argument of the logarithm is positive since the collector current has a maximum value at $t = \infty$, values of I_c greater than this result in a negative argument for one of the logarithms. Fig. 5 shows the calculated unit-step response of a common emitter transistor amplifier for two different values of the base current. The curves have been normalized by dividing the collector current I_c by the maximum value of the current I_{cmax}. This maximum value is obtained by taking the argument of the two logarithms in equation (13) containing I_c and equating each to zero. I_{cmax} is the smaller of the two values of collector current which result. Curve A of Fig. 5 corresponds to the step response when no variation is assumed for the transistor circuit parameters and is obtained by use of equation (10) with α_{FB} constant using the normal Laplace transform methods. Curves B and C show the responses when the base currents are steps of amplitude 0.1 and 1.0 respectively, and α_{FB} varies as in equation (6). In these cases it has been assumed that $R_L/r_c << 1$. As the input drive to the base is increased the rise time is seen to decrease. Not evident in Fig. 5 is the decrease in gain with increasing input signals due to the saturation effect of the transistor. This means that beyond a certain input signal level, the output remains almost constant for larger input levels.

The constant parameter case has a greater rise time than the variable parameter case, however, the time required for the un-normalized collector current to attain a given value is less than when the transistor parameters are variable. This is because the gain is greater in the constant parameter case, although not evident in the normalized curves.

Variable Current Gain and Cutoff Frequency: To show the effect of the simultaneous variation of the base to collector current gain and alpha-cutoff frequency on the transient response, both of these quantities will be made to vary with emitter current in accord with equations (6) and (9). Although the relations given by equations (6) and (9) were measured under static conditions, it will be assumed in the following analysis that these quantities behave in a like manner under dynamic conditions.

In order to simplify the analysis, let it be assumed that the transistor operates essentially under short circuit conditions, $R_L = 0$, so that the current transfer ratio for the common emitter connection can be written, as shown by equation (2),

$$\frac{I_c}{I_b} = \frac{\alpha_{FB}}{p/\omega_{\alpha b} + 1 - \alpha_{FB}} \quad (14)$$

where $p = j\omega$.

If the factor K in equation (9) is made equal to $\omega_o(\sigma_1 - 1)$, where ω_o is a constant, the alpha-cutoff frequency, $\omega_{\alpha b}$, at $I_E = 0$ is given by ω_o. Using this value for K in equation (9) and substituting equations (6) and (9) into (14), reresults in the equation

$$\frac{I_c}{I_b} = \frac{\sigma_1 - 1}{\left\{ \underline{p}[\sigma_1 - 1 + \sigma_2(I_c + I_b)][\sigma_1 + \sigma_2(I_c + I_b)] + (\sigma_1 - 1)[\sigma_1 - 1 + \sigma_2(I_c + I_b)] \right\}} \quad (15)$$

where $\underline{p} = j\omega/\omega_o$. This equation can be solved in a manner similar to that used for equation (10).

Response Curves: The transient response curves are shown in Fig. 6. Curve A again corresponds to the constant parameter response. Curves B and C show the normalized collector current when steps of base current of magnitudes 0.1 and 1.0 are applied to the transistor respectively and α_{FB}, $\omega_{\alpha b}$ vary as in equations (6) and (9). The normalization used on the collector current is I_c/I_{cmax}, where I_{cmax} is obtained as previously shown for equation (13). On the time axis, the normalization is $\underline{t} = \omega_o t$, where ω_o is defined as the alpha-cutoff frequency with zero emitter current. It is noted that when the alpha-cutoff frequency is assumed to decrease with increasing emitter current the rise time increases considerably over that for the case where alpha is constant.

Although the equations for the circuit are only approximate, they do show the effect of the non-linear parameter variations on the step response of the transistor amplifier. In the practical case, the circuit parameter variation may be somewhat different from that shown here and the static and dynamic characteristics of the transistor parameters may also differ.

At the present the rise time of the turn-on transient of the transistor is not a limitation of the transistorized horizontal deflection system because a diode is used to carry most of the current during the turn-on time. However, when a symmetrical transistor is developed for the horizontal deflection, the problem of rise time should be considered and some of the non-linear effects discussed here will have to be taken into account.

TURN-OFF TRANSIENT

In order to obtain a short cutoff time with a switching transistor, the step function of current applied to the base is normally of sufficient amplitude to bias the base in a reverse direction with respect to the emitter. As mentioned earlier, the turn-off transient consists of two parts as shown in Fig. 4—the *storage time* t_s, during which the transistor continues

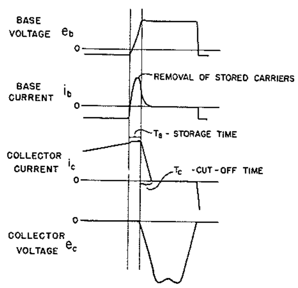


Fig. 4 — Base and Collector Waveforms During Cutoff.

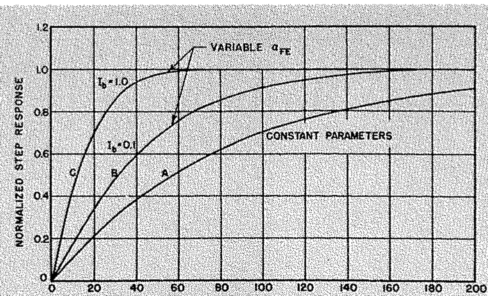


Fig. 5 — Step Response of Common Emitter Circuit with Variable α_{FE}.

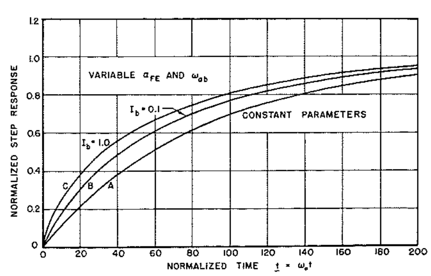


Fig. 6—Step Response of Common Emitter Circuit with Variable α_{FE} and ωab.

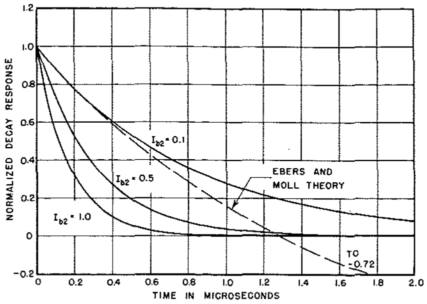


Fig. 7—Decay Transient for Common Emitter Circuit.

to act like a closed switch, and the *cutoff time* t_c, which represents the time of collector current decay.

It is seen from Fig. 4 that during the storage and cutoff intervals the base current flows in the reverse direction. Under this condition the active region parameters as such do not theoretically apply since they are defined only for forward base currents. To calculate the cutoff time, it will be assumed that equation (2) is still valid, under the condition of reverse base current flow, with certain modifications. During the cutoff interval the magnitude of the base current will be assumed to be proportional to the collector current. Thus if the collector current at saturation is I_{cs}, the corresponding base drive current $I_{b2} = -k\, I_{cs}$, where k is the constant of proportionality. Let equation (2) under a low resistance load, $\omega_{\alpha b} R_L C_c << 1$, be written in the form

$$\frac{I_c}{I_b} = \frac{-\alpha_{FB}}{\underline{p} + b_o} \tag{16}$$

where $\underline{p} = j\dfrac{\omega}{\omega_{\alpha b}}$ and $b_o = 1 - \alpha_{FB} + \dfrac{R_L}{r_c}$. The minus sign is introduced to take care of the reversed current flow.

When $\underline{p}$ is taken to be the differential operator $d/d\underline{t}$, we obtain the equation

$$\frac{dI_c}{d\underline{t}} + b_o I_c + \alpha_{FB} I_b = 0. \tag{17}$$

This can be integrated to give

$$I_c = I_{cs}\, \epsilon^{-(b_o - k\,\alpha_{FB})\underline{t}} \tag{18}$$

where $I_b = -kI_c$.

In Fig. 7 the normalized decay transient for a common-emitter transistor has been plotted for different values of the turn-off drive current I_{b2} at the base. The equation for the turn-off transient in accord with the decay time formula as given by Ebers and Moll for the common emitter amplifier is

$$I_c = -\frac{\alpha_{FB} I_{b2}}{1-\alpha_{FB}} + \left(I_{cs} + \frac{\alpha_{FB} I_{b2}}{1-\alpha_{FB}}\right)\epsilon^{-(1-\alpha_{FB})\,\omega_{\alpha b} t}. \tag{19}$$

A plot of this equation is shown in Fig. 7 with $I_{b2} = 0.1$. It is noted that the final value of collector current is negative in this case. This results since the final value of base current has not been assumed to decay to zero.

The 90 to 10 per cent decay time t_c from equation (18) can be shown to be

$$t_c = \frac{2.2}{(b_o - k\,\alpha_{FB})\,\omega_{\alpha b}} = \frac{2.2}{\left(1 - \alpha_{FB} + \dfrac{R_L}{r_c} + \dfrac{I_{b2}}{I_{cs}}\alpha_{FB}\right)\omega_{\alpha b}}. \tag{20}$$

The term R_L/r_c must be considered in this case since the value of α_{FB} is so close to unity and the quantity R_L/r_c for certain transistors becomes of the same order of magnitude as $(1 - \alpha_{FB})$ even for values of R_L as low as 100 ohms. Using equation (20) the decay time was calculated and the results are shown by the upper curve in Fig. 8 for a 2N140 transistor. The measured points are also shown for comparison. It is seen that the results agree fairly well with the theory. Use of the formula given by Ebers and Moll results in the lower curve of Fig. 8 which does not agree as well with the measured values.

A better agreement between the theoretical and experimental values for the decay time can be obtained if the quantity $I_{b2}/I_{cs} = -k$ in equation (20) is changed to $-k\gamma$ where γ is a constant multiplier. For the particular transistors measured a value of $\gamma = 1.3$ makes the deviation between the theoretical and experimental results quite small as shown by the middle curve in Fig. 8. This indicates that the direct proportionality assumed between I_b and I_c during the cutoff interval is not quite adequate, which is not surprising.

CONCLUSIONS

The equations for the large-signal transient response of the common emitter transistor amplifier have been derived for both the turn-on and turn-off conditions. It has been assumed that the transistor parameters vary during the transition period in the derivations. Empirical relations have been used to account for the variation in the transistor parameters with the emitter current during the turn-on transient. When the collector current gain of the transistor is assumed to be an inverse function of the emitter, the rise time is found to be a non-linear function of the base drive current. If both the alpha-cutoff frequency and the current gain are assumed to vary simultaneously with the emitter current, the change in the shape of the turn-on transient is less pronounced than in the case where the current gain alone varies. It is concluded that the turn-on transient in the practical case includes a combined variation somewhat less than that assumed for the case where both current gain and cutoff frequency are variables.

During the turn-off transient, the transistor is under reverse bias, with the base current flowing in a direction opposite to normal flow. Under this condition the standard transfer ratio relating the base to collector gain is not valid. However, if it is assumed that the base current decays in a manner such that it is proportional to the magnitude of the collector current, a relation for the decay time which agrees substantially with measurement is obtained.

Further work needs to be done on the theory of large signal switching transients in transistors. This study was only a first attempt to consider some of the parameter variations under dynamic conditions.

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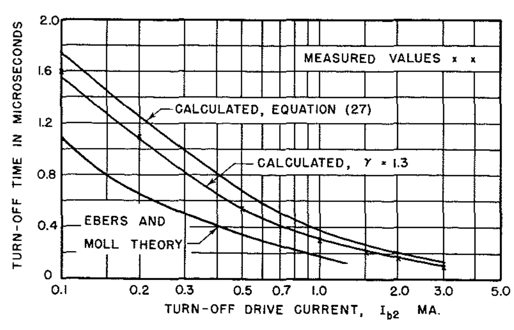
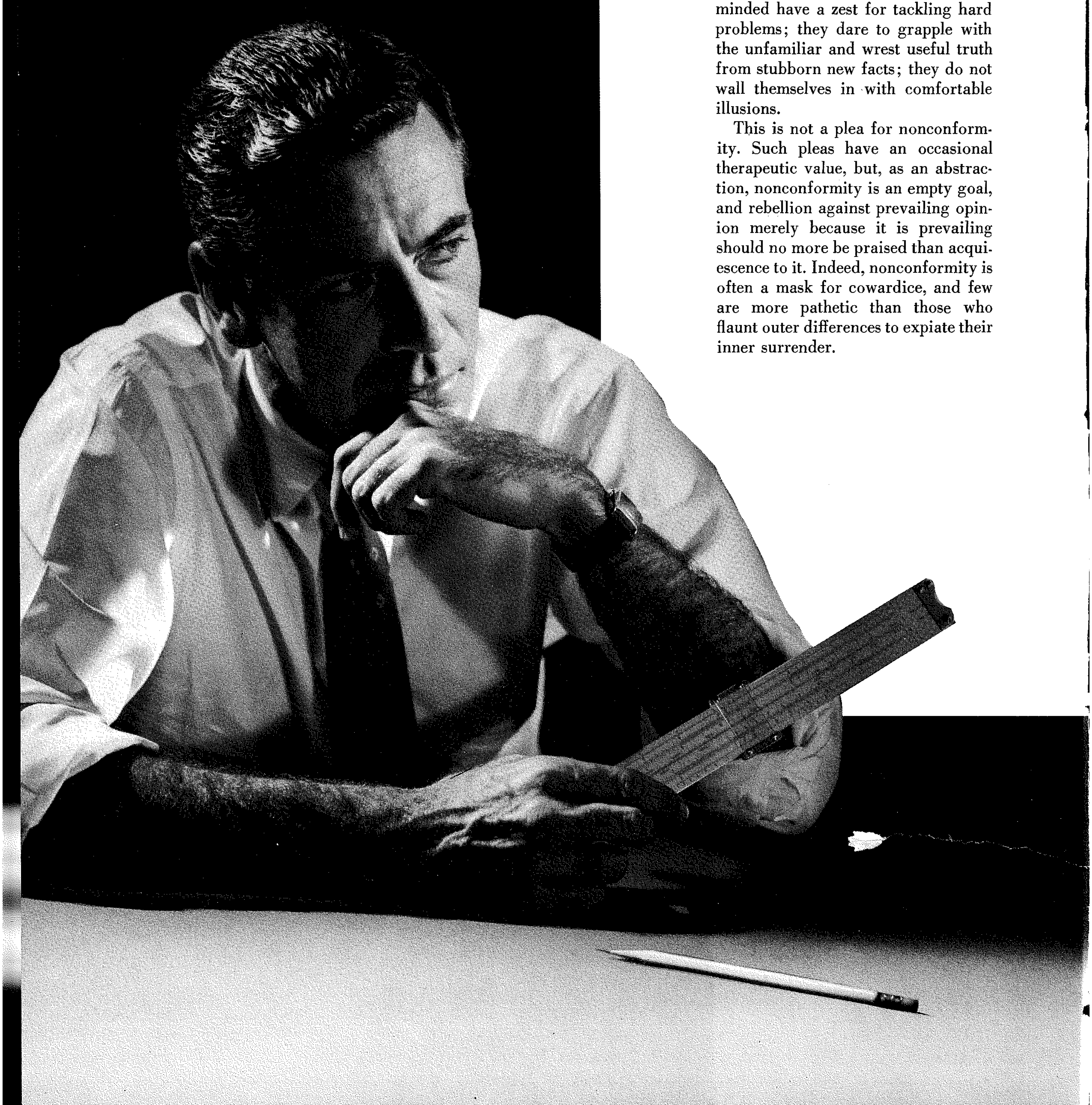
Fig. 8 — Cut-Off Time for Common Emitter Circuit for 2N140 Transistor.



TOUGHMINDEDNESS AND TOMORROW

By
G. W. CRAWFORD
Electron Tube Division
Harrison, N. J.



WILLIAM JAMES, a great teacher of philosophy at Harvard during the early years of this century, made the useful distinction between people who are "toughminded" and people who are "tender-minded." These terms have nothing to do with levels of ethical conduct; the "toughness" referred to is "toughness" of the intellectual apparatus, hardihood of the spirit, not "toughness" of the heart. The toughminded have a zest for tackling hard problems; they dare to grapple with the unfamiliar and wrest useful truth from stubborn new facts; they do not wall themselves in with comfortable illusions.

This is not a plea for nonconformity. Such pleas have an occasional therapeutic value, but, as an abstraction, nonconformity is an empty goal, and rebellion against prevailing opinion merely because it is prevailing should no more be praised than acquiescence to it. Indeed, nonconformity is often a mask for cowardice, and few are more pathetic than those who flaunt outer differences to expiate their inner surrender.

NEED FOR TOUGHMINDEDNESS

There never was a time when this quality of tough-mindedness on the part of management was more needed. A typical business readjustment reveals itself in many ways, moral as well as economic. Too many people have been trying to get something for nothing, both in business and in labor. Today our real production of goods is by no means commensurate with the number of persons employed. Many businesses and employees must begin to work with greater efficiency.

Yet back of some of these surface manifestations are legitimate social claims and genuine grievances which business must still find a way to meet. Many of these developments represent aspirations with which we must learn to deal. Let us not forget that basically top management must strive harder to learn how to give labor, and even the lower ranks of management itself, a sense of "belonging."

As we look abroad, the tide of totalitarianism menaces all Europe. The world is lurching back into the old ruts of nationalistic rivalry. Freedom of trade, freedom of movement, and freedom of information are rapidly becoming lost ideals. The vision of "One World" has vanished. The United States faces a great test to measure up to the requirements of its position in the world. The United States has undertaken the burden of economic world leadership; and we must remember that part of that world expects, and hopes, that we shall fail, fail not only to bring about European recovery, but fail to maintain a balanced economy and a high level of employment at home.

Hence, there never was a time when skilled administration in business and economic affairs was more essential.

Now skilled administration calls for tough-mindedness. Again, I repeat that this toughness is toughness of the intellectual apparatus. It doesn't mean getting tough with your associates or even getting tough with the Russians. It means tackling your administrative problems in a tough-minded way that is not satisfied with *easy* answers.

You have often heard the statement that knowledge is power. Too frequently, this statement is interpreted to mean that knowledge *confers* power. Nothing could be less true, I think, than that passively acquired knowledge confers any power on the recipient. This fact is something which many college graduates learn to their sorrow. When *we* say "knowledge is power" we mean something quite different. *We* mean that true knowledge *consists* of power, power to tackle a problem, to break it down, sort out the facts, see what must be done, and then get it done.

CHARACTERISTICS OF TOUGH-MINDED PEOPLE

If in your educational venture you have been successful in becoming tough-minded, you *will not* be looking for the easy answers. Business problems don't lend themselves unfailingly to one simple right method of analysis which inevitably arrives at the one and only correct answer. If knowledge of a few formulas and ability to manipulate a slide rule were enough to produce able people, the need for really good business executives would not so greatly exceed the supply. Business can hire plenty of average-grade technicians who can figure the right answers to the problems that lend themselves to exact routines and procedures. But business, by and large, doesn't pay a very high price for that kind of ability. What business does pay a premium for, and what the business community vitally needs, are qualities of judgment and leadership. You have found, I am sure, that you can't develop those qualities if you are looking for the easy answers. To oversimplify the world they live in is a favorite device of the tender-minded.

Finally, if you have been successful in developing these tough-minded qualities, you won't always try to play safe. Playing it safe is a comfortable refuge of the tender-minded. But if you are really tough-minded, you will cultivate qualities of intiative and venturesomeness. You will not be afraid to act, even if you have to act on imperfect knowledge, because you will realize that all knowledge is imperfect and experimental rather than final. And you will not be afraid to take chances. It is a mistake to think that the proper use of education is to enable you to avoid all risks. The *essence* of profit in a changing world is risk and uncertainty. Your objective should not be the avoidance of risk, but the intelligent assumption of risk.

Today, more than ever, it is more —not less—risk-taking that American Business vitally needs. So don't use your training to seek a stodgy, conservative safety, because, paradoxically, when all business tries to play it safe there is no safety for any business. College and universities are successful only if they produce men with a genius for risk-taking and leadership.

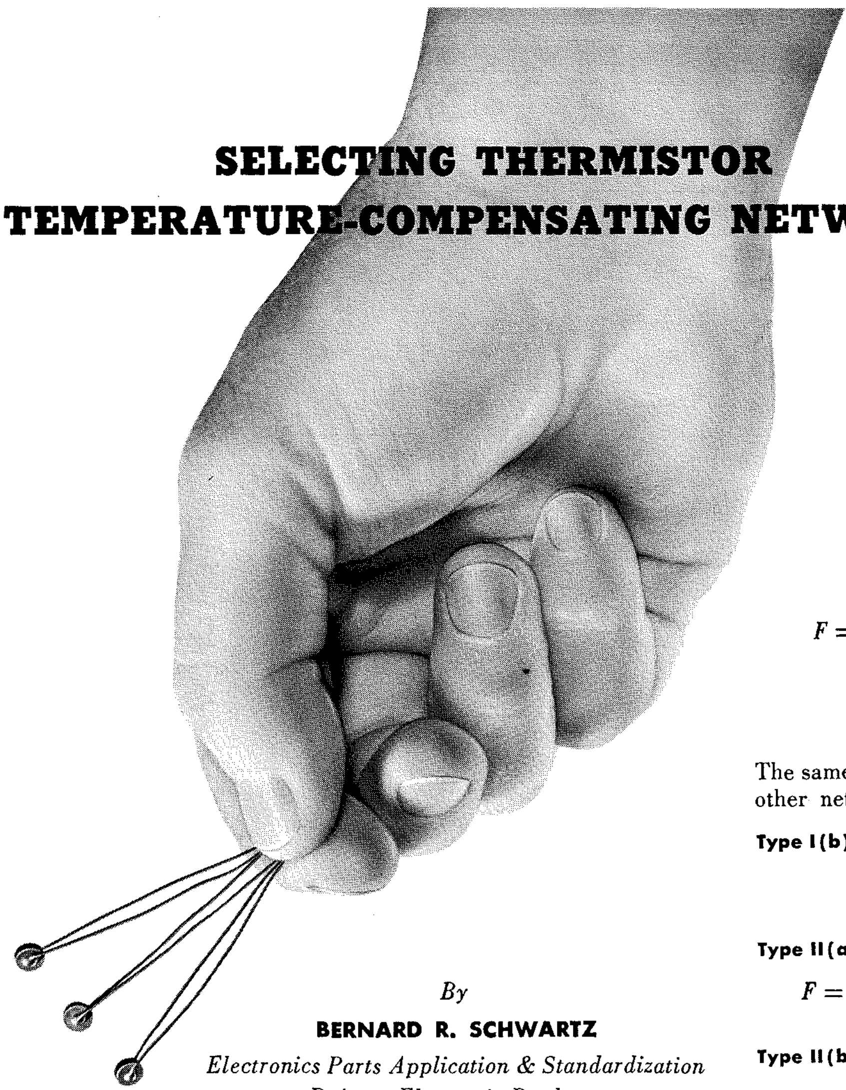
G. WALLACE CRAWFORD has lived all of his life in Jersey City, and studied electrical engineering at the Newark College of Engineering. He recently celebrated his 40th anniversary with RCA, having joined the company in September 1918 as an engineering aide. He progressed through positions in both engineering and management to his present position of plant manager of the Harrison Tube Plant. Because of his extensive background and experience in the electron-tube field, he has been called on to set up tube manufacturing plants in Italy and France, and has recently consulted with the Indian government in regard to the production of electron tubes in that country.

PRESENT OPPORTUNITIES

Clark Kerr, Chancellor at the University of California at Berkley, has this to say about loyalty and the importance of independent tough-mindedness: "The danger is not that loyalties are divided today but that they may be undivided tomorrow . . . I would urge each individual to avoid total involvement in any organization; to seek to whatever extent lies within his power to limit each group to the minimum control necessary for performance of essential functions; to struggle against the effort to absorb; to lend his energies to many organizations and give himself completely to none; to teach children, in the home and in the school, to be laws unto themselves and to depend on themselves, as Walt Whitman urged us many years ago—for that is the well source of the independent spirit."

You have heard much to the effect that the doors of opportunity are rapidly being closed in this country. I believe that if there are any doors of opportunity being closed in this country, they are not doors of the environment, but doors of the human spirit. If you are tough-minded you will use your educational knowledge to open those doors, not to close them.

SELECTING THERMISTOR TEMPERATURE-COMPENSATING NETWORKS



By

BERNARD R. SCHWARTZ

Electronics Parts Application & Standardization
Defense Electronic Products
Camden, N. J.

HIGHLY SENSITIVE TO temperature changes—yet small and stable—thermistors (thermally sensitive resistors) are versatile circuit elements that can provide an ideal solution to temperature compensating network design. Thermistors are made of sintered metallic oxide semiconductor materials, treated and aged to obtain the desired thermal properties. As a result of years of research and development since the early thirties, stable, rugged and reliable thermistors are now available. These and other desirable properties have been responsible for large scale applications as bolometer elements, time delay devices, thermometry equipment, volume limiters and expanders and for protective devices.

TEMPERATURE COMPENSATION

The most obvious application of thermistors is to use them to compensate for electrical circuit d-c resistance changes caused by changes in ambient temperature. When combined with series and/or shunt resistors, these networks have been utilized to effectively compensate transistor circuits, deflection yokes, and meters. Published literature indicates methods for the solution of these networks by graphical means (1, 2, and 3) and for compensating copperwound components (4).

The approach taken here is that the designer has already made suitable tests to determine the resistance-temperature characteristic required. Thus, by selecting the desired performance from normalized temperature characteristics curves a rapid solution of the circuit values is possible.

Temperature-compensating networks (See Table I) involving one or two additional resistors together with a thermistor have been investigated. It was assumed that the resistors were temperature-passive compared with the thermistor, which exhibits a negative-temperature characteristic approximated by:

$$r_t = r_{t25}\varepsilon^{-\beta\left(\frac{1}{T_t}-\frac{1}{298}\right)} \quad (1)$$

The solution of the type I(a) circuit equation, using the indicated nomenclature, proceeds as:

Type I(a)

$$R_t = \frac{R_1 r_t}{R_1 + r_t} \quad (2)$$

$$F = \frac{R_t}{R_{t25}} = \frac{r_t}{r_{t25}}\left(\frac{R_1 + r_{t25}}{R_1 + r_t}\right) = f\left(\frac{k_1+1}{k_1+f}\right) \quad (3)$$

The same analytical method used for the other networks yields these equations:

Type I(b)

$$F = \frac{k_2 + f}{k_2 + 1} \quad (4)$$

Type II(a)

$$F = \left(\frac{k_2+f}{k_2+1}\right)\left(\frac{k_3+k_2+1}{k_3+k_2+f}\right) \quad (5)$$

Type II(b)

$$F = \left(\frac{k_1+1}{k_1+f}\right)\left[\frac{k_4(k_1+f)+k_1 f}{k_4(k_1+1)+k_1}\right] \quad (6)$$

These equations are solved for the quantity F, by the substitution of appropriate values for f, k_1, k_2, k_3 and k_4. The following values of k were substituted for individual calculations: 0.01, 0.02, 0.05, 0.1, 0.2, 0.5, 1, 2, 5, 10, 20, and 50.

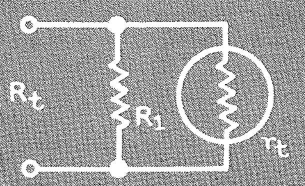
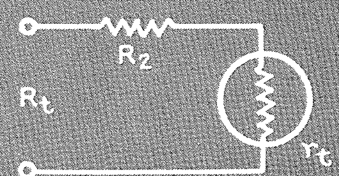
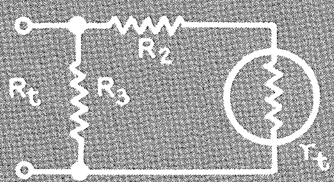
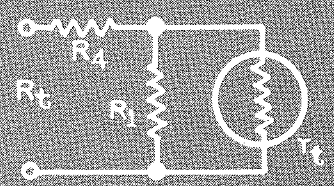
Fig. 1 shows the curves obtained for the Type I(a) circuit. Note that the curve labeled $k_1 = \infty$ represents the resistance-temperature characteristic of thermistor material #1 (f) alone.

Utilization of other thermistor materials would only require that their particular normalized temperature response values be inserted in these equations.

For the sake of brevity the appropriate graphs and nomograms for the other circuits have been omitted from this article. Together with additional material they are available from the author's group, Electronic Parts Application and Standardization, Central Services and Engineering, DEP, Camden.

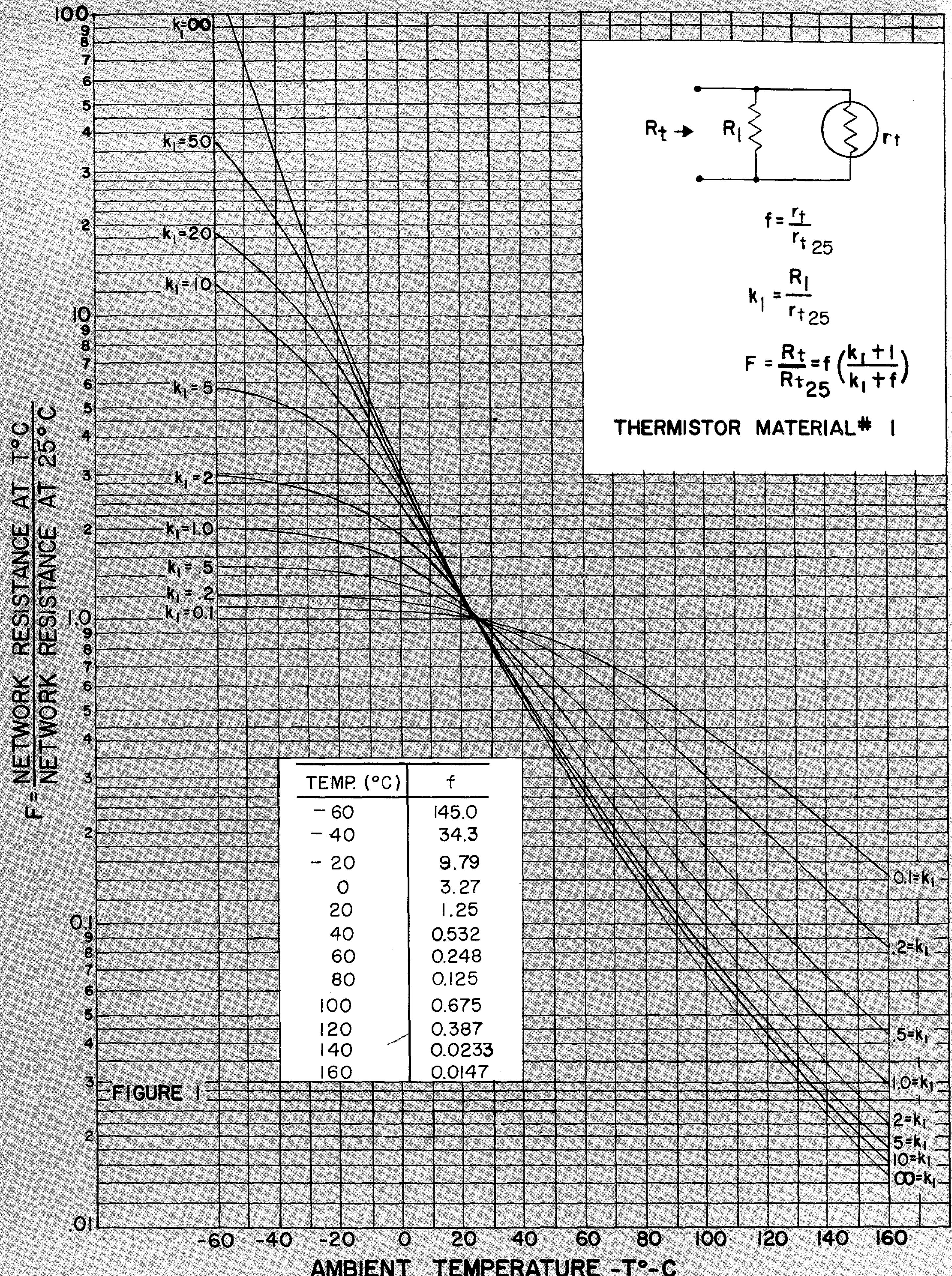
HOW TO USE CHARTS

The user selects the normalized d-c resistance temperature response he desires from the various curves.

NO. OF ADDITIONAL RESISTORS	TABLE I. GENERAL FORMS FOR TEMPERATURE-COMPENSATING NETWORK	
ONE	TYPE I(a) 	TYPE I(b) 
TWO	TYPE II(a) 	TYPE II(b) 

GLOSSARY

r_t	d-c resistance value of thermistor at temperature (t) °C; $r_{t_{25}}$ is d-c resistance value of thermistor at 25°C.
β	thermistor material constant in exponential equation which approximates actual resistance-temperature response.
R_t	d-c resistance value of network at temperature (t) °25C; $R_{t_{25}}$ is d-c resistance value of network at 25°C.
$f = \frac{r_t}{r_{t_{25}}}$	normalized thermistor d-c resistance value at temperature (t) °C with respect to its 25°C value.
$F = \frac{R_t}{R_{t_{25}}}$	normalized network d-c resistance value at temperature (t) °C with respect to its 25°C value.
$k_n = \frac{R_n}{r_{t_{25}}}$	ratio of d-c resistance value of temperature-passive circuit resistor ($R_n = R_1 \ldots R_4$) with respect to the thermistor's d-c resistance value at 25°C.



TEMP. (°C)	f
− 60	145.0
− 40	34.3
− 20	9.79
0	3.27
20	1.25
40	0.532
60	0.248
80	0.125
100	0.675
120	0.387
140	0.0233
160	0.0147

Fig. 1—Resistance-Temperature Characteristic Curves of Type I(a) circuit using Thermistor Material #1.

A particular curve is selected and the value of the "k" constant(s) noted. Interpolation between plotted curves is possible. With the noted "k" value(s), the appropriate nomogram quickly permits determination of the ohmic values of the resistor(s) and the thermistor at 25°C. Note that the nomograms' scale for network resistance value at 25°C have a multiplier at 10×. The appropriate value of the thermistor's resistance is therefore scaled by the same 10× multiplier.

Example 1

A network is desired which has the resistance-temperature response shown below, within 5%.

Step 1

The variation of network resistance value is then "normalized" with respect to its 25°C value.

Fig. 1 shows a curve having markedly similar response to the required one. When $k_1 = 0.2$, the listed network values are obtained:

	Network Required		Fig. 1 Values
Temperature (°C)	Resistance (ohms)	F	F ($k_1 = 0.2$)
−55	19,500	1.22	1.20
−25	18,900	1.18	1.18
0	18,500	1.15	1.14
25	16,000	1.00	1.00
50	11,000	0.70	0.72
80	7,700	0.48	0.46

These values meet the tolerance of the required response.

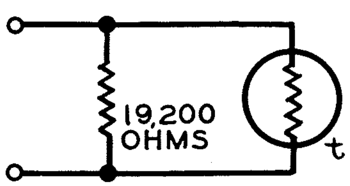
Step 3

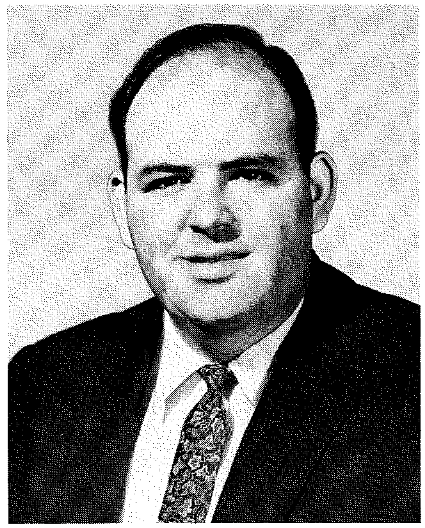
A line is then drawn on the nomogram, Fig. 2, between the 0.2 point on the k_1 scale and the 1.6 point on the network resistance scale. This line intersects the thermistor resistance scale at 9.6.

Step 4

Since the 10× scale factor of the network resistance value at 25°C scale used $X = 4$, the same $X = 4$ is used for the thermistor resistance value at 25°C scale. The required thermistor is then obtained as 96,000 ohms at 25°C. R_1, then is equal to k_1 (0.2) times 96,000 or 19,200 ohms. The solution for the required circuit appears as shown in the schematic below

96,000 ohms at 25°C,
$\beta = 3{,}900 \pm 55$°K





BERNARD R. SCHWARTZ received his B.E.E. degree from The College of the City of New York in June 1949 and a M.S. in E.E. degree from Newark College of Engineering (Newark, N. J.) in June 1953. Upon graduation, Mr. Schwartz became associated with the Signal Corps Engineering Laboratory, Fort Monmouth, N. J. where he was responsible for evaluating resistors and metallic rectifiers.

In 1955, Mr. Schwartz joined RCA as a Component Standards Engineer, acting as a consultant to design groups in the application of linear and non-linear resistive elements and responsible for standardization and preparation of drawings and purchase specifications in this component area.

Mr. Schwartz is a Member of the I.R.E. and the Professional Group on Component Parts. He is Secretary of Electronic Industry Association Subcommittee SQ6.1 on Precision, Film Resistors. He is also a member of the parent SQ6 Committee and the SQ6.2 and SQ6.3 Subcommittees on Fixed, Accurate, Wirewound Resistors and Precision Potentiometers.

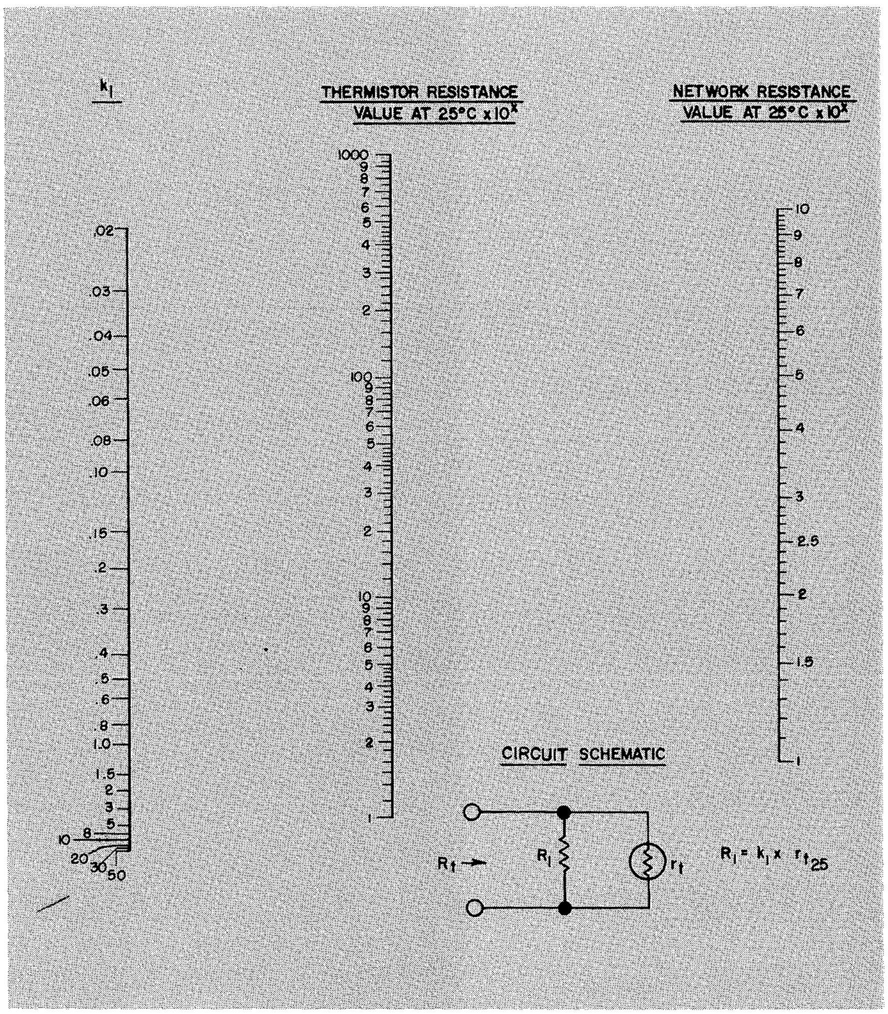


Fig. 2—Nomogram for Solution of Circuit Values.

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2. "Designing Thermistor Temperature-Correcting Networks Graphically" F. A. Bennett, *Control Engineering*, November, 1955.
3. "Shaping the Characteristics of Temperature-Sensitive Elements" E. Keonjiian and J. S. Schaffner, *Electrical Engineering*, October, 1954.
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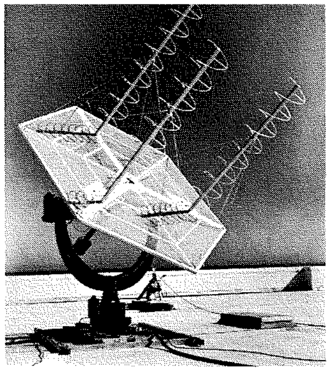
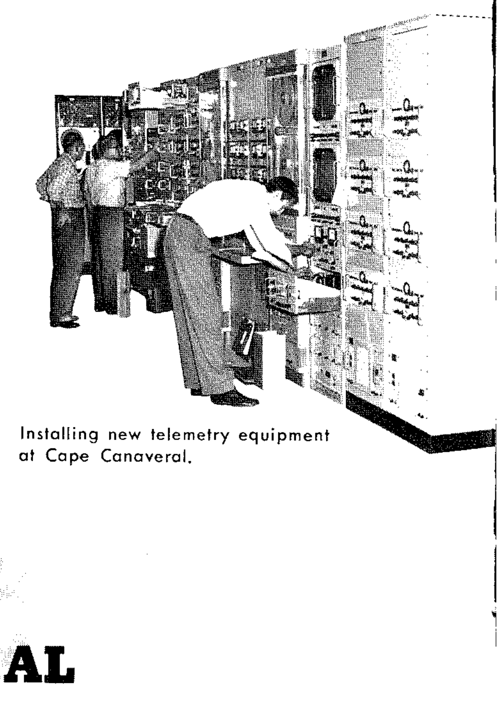


Helical telemetry antenna at Cape Canaveral.

This Automatic Tracking Telemetry Antenna, installed at Cape Canaveral, dwarfs the man standing on its base as he looks up at the 60 foot wide spider web-like equipment which towers higher than a seven story building.

The antennas will be used as an aid in tracking ballistic missiles, and will cover the 5000 mile test range with a moderate amount of overlap.



Installing new telemetry equipment at Cape Canaveral.

RCA AT CAPE CANAVERAL

PART II — TELEMETRY IN MISSILE TESTING

by

ANTHONY L. CONRAD, Vice Pres.

Government Service Department

RCA Service Company

Cherry Hill, N. J.

PRELIMINARY TESTING of individual missile components for the most part can be accomplished in the laboratory. Successful development of these components as an integrated system, however, depends upon considerable amount of actual static and flight testing. These tests must, therefore, be adequate and thorough.

In the days of early aircraft testing, the man in the cockpit acted as both pilot and data recorder. From the pilot's notes the designer could, after several flights, determine the broad aerodynamic characteristics of the airplane and thereby work toward the design of a better aircraft. As technology progressed and aircraft became more complex, it also became physically impossible for the test pilot to provide the designer with all of the engineering data needed for complete and accurate analysis.

The development of supersonic aircraft rapidly extended the need for measuring and recording systems capable of automatic operation without distraction to the pilot.

In the development of unmanned craft such as drones, missiles, and satellite transport vehicles, the ability to measure a wide variety of electrical and mechanical phenomena as they occur in flight is essential.

Telemetry has become, therefore, one of the most valuable tools available to a missile designer. For this reason as many as 1,000 internal missile sources of information are presently being instrumented during flight in developmental missiles at the Air Force Missile Test Center. Characteristically, the telemetry system is called upon to measure information such as acceleration, vibration, pressure, temperature, strain, fuel flow, valve functioning, cosmic ray effects, micrometeorite counts, and voltages. The types of information may vary at a rapid rate or remain essentially constant. Accuracy requirements also vary widely, depending largely on the type of information required.

A basic telemetry system typically consists of the airborne equipment, ground receiver, tape recorders, monitoring devices and a data playback facility. Telemetry systems in common usage employ essentially similar pick-up and display devices. This is a logical consequence of standardization of both measurement technique and data records. Major differences in approach exist in the methods used in multiplexing, modulation and demodulation of telemetering apparatus.

AFMTC TELEMETRY

At the Air Force Missile Test Center the RCA Service Company is responsible for the engineering, installation, maintenance and operation of the telemetry ground installations situated on the Atlantic Missile Range. These facilities consist of several Telemetry Receiving Sites and a Telemetry Data Reduction facility.

TELEMETRY RECEIVING

Telemetry Receiving instrumentation on the Atlantic Missile Range provides coverage in the vicinity, the launching site at Cape Canaveral AAFB and at each island station to Ascension Island, 5,000 miles southeast of the Florida coast. Supplementing this fixed station coverage are several telemetry picket ships located between shore stations to provide coverage in open ocean areas. This instrumented chain is believed to be the longest in the world.

A telemetry receiving system can usually be separated into three main subsystems: antenna, receiver, and recorder.

ANTENNA SYSTEM

Important design considerations relating to telemetry receiving antennas, include gain, polarization, impedance, and physical characteristics. Receiving antenna gain is inherently important because of the limited space, weight and power available for the telemetry transmitter. These limitations result in low transmitter power output. The missile antenna pattern also has specific null sectors that result in the loss of several decibels of gain.

Polarization of received signals is usually not constant during flight and may vary from one missile to another.

It is often extremely desirable to continue the gathering of data after a missile malfunction if possible. When this situation occurs, the unpredictable motions of the missile may rotate the wave polarization.

Impedance of the receiving antenna must be compatible with the existing equipment and should be such that standard commercial components and transmission methods may be used.

The physical characteristics of receiving antennas are extremely important because of the environmental conditions encountered in field use. All external antenna components must withstand the effects of constant sun and salt spray exposure, wind gusts up to 50 miles per hour, and must not impede rapid, accurate tracking.

RECEIVING SYSTEM

The telemetry receiving system proper must have sensitivity, stability, selectivity and fidelity. Because this equipment is often used at great distances from supporting supply facilities, ease of maintenance and reliability are highly important factors. The large number of links and receivers required make it necessary to provide a distribution system so that several receivers may be operated from a single antenna. This distribution system must have a low noise component and avoid excessive signal loss of range due to decreased sensitivity.

RECORDING

The majority of telemetry data gathered at the Air Force Missile Test Center is recorded on magnetic tape. This permits easy handling, storage and expeditious reduction of telemetry data. Both dual-track (¼-inch) and seven-track (½-inch) tape recorders are commonly used.

Not all of the data are recorded on magnetic tape. Some data are presented to the contractor in the form of oscillographic records and meter presentations. The oscillographic records are used, in general, for early analysis by the missile contractor.

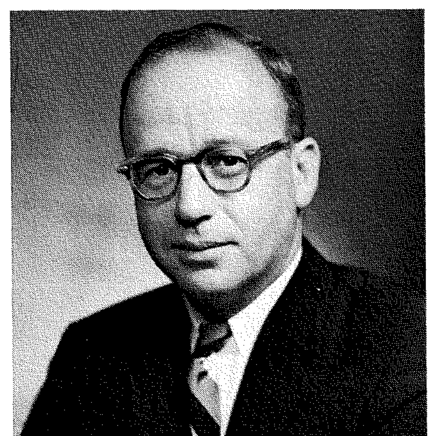
Certain of the internal missile functions are displayed for use by the Range Safety Officer and the missile contractor in the form of meter readings. These readings allow on-the-spot analysis.

MONITORING

During a missile flight, the missile contractor is interested in specific flight function information, including skin temperature, pitch, yaw and engine thrust. To utilize this information in flight control the contractor maintains an instrumentation console in his blockhouse at the Cape Canaveral launching site. The console displays "real time" oscillographic and meter readings of data required for flight control.

As the missile proceeds on its flight down the range, it soon leaves the effective receiving area of the Cape Canaveral telemetry sites. Signals are then received by similar Down Range telemetry systems. Over the first 1000 miles, telemetry data are transmitted in "real time," to the contractor's console at Cape Canaveral via submarine cable.

For Anthony L. Conrad's biography, see Vol. 4, No. 3, page 50.



WORKSHEET GIVES OPTIMUM CONDITIONS*

by **CHOU HSIUNG LI**
Electron Tube Division
Harrison, N. J.

PRACTICALLY ALL ENGINEERS and scientists have to run experiments. When these experiments involve only two or three factors or independent variables, they are easily dealt with, although the methods and efficiencies of experimentation vary.

In the "trial and error" or "shotgun" method, the experimenter selects and makes a few random tests, hoping to hit the best conditions. This method depends entirely on intuition and luck. It is not reliable and seldom gives the best results.

The classical mehod of experimentation is to keep all factors except one constant, and determine the best condition for this tested factor. The best condition for this first factor is then used throughout the later tests to find the best conditions for the other factors, one at a time. The major disadvantages of this method are: (1) It fails when the factors are related to one another; (2) It is inefficient; and (3) It requires as many series of tests as the number of factors under test, which may be too time-consuming.

When the orthodox statistical method is used, a statistician chooses a proper design to test either all possible combinations of the factors, or a systematic fraction of these possible combinations. This method not only finds the effect of all factors, but reveals any possible interactions among them. It is generally very efficient. The disadvantages are: (1) The number of tests become too large when many factors are to be studied; (2) Either a statistician is needed or the engineer has to be thoroughly trained on this method; (3) A machine calculator is indispensible; and (4) The careful planning and execution of the experiment, as well as the involved analysis of test results, cause unavoidable delays to get the desired results. These delays are often intolerable.

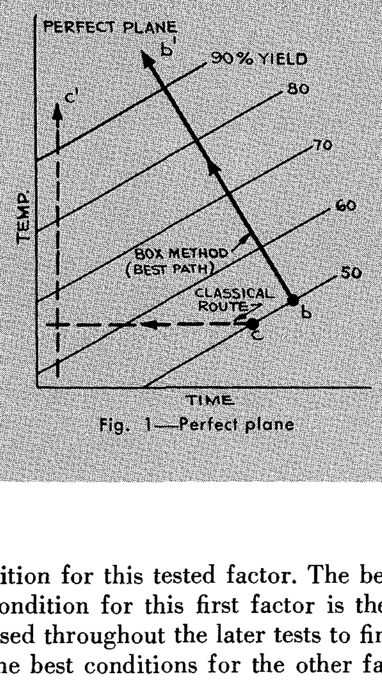


Fig. 1—Perfect plane

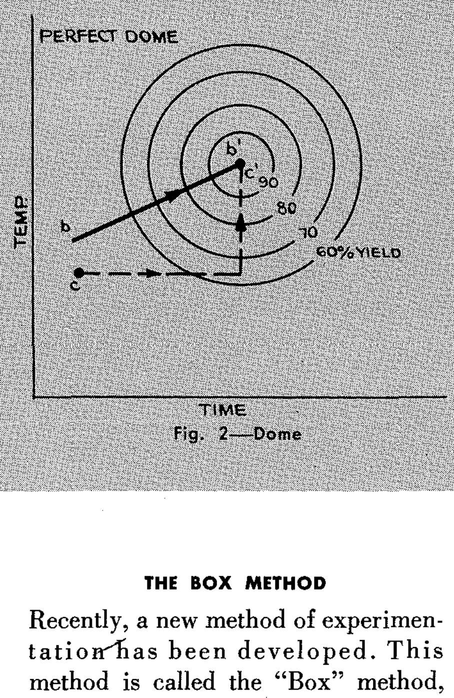


Fig. 2—Dome

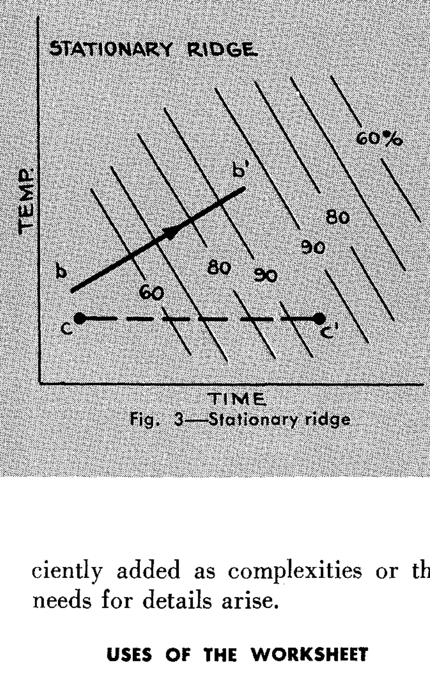


Fig. 3—Stationary ridge

THE BOX METHOD

Recently, a new method of experimentation has been developed. This method is called the "Box" method, after the originator G.E.P. Box. It is dynamic, flexible, and yet very efficient.

In this method a series of small experiments are set up so related together that the results of previous tests are fully used, yet without loss of efficiency common with short-run tests. It has been successful in chemical and other industries.

In principle, the Box method is identical to the familiar scientific method of experimentation, only it is made more systematic by applied Statistics. As usual, the experimenter sets up and makes some tests, analyzes the results, and make some more tests, and so on. Yet in this case, the experimenter uses known techniques of good experimental planning and data analysis, foresees any possible outcomes of the tests, and plans his first experiments with an eye on the last. Besides, each test result is used not just once, but many times to get better means, more accurate average effects, or more reliable conclusions, in the later tests.

Plant managers and project engineers should like the Box method because it gives useful conclusions from the very first few tests made. Further, the tests can be conveniently stopped at any moment when satisfactory results have been obtained, or when facilities on the project are suddenly ended. Yet more tests can also be efficiently added as complexities or the needs for details arise.

USES OF THE WORKSHEET

When conditions are suitable, the worksheet may be used in following cases:

1. Trouble-shooting on an urgent research or production problem when quick results and immediate actions are needed.
2. Developing a new alloy or composition by finding the effect of all ingredients and their best combinations.
3. Designing the proper types of

*Published in *Chemical Engineering,* April 7, 1958.

machine components including their dimensions for best performance of a given mechanical or electrical device.

4. Improving a production process on yield, cost, or product quality.

5. Scanning a great number of factors or independent variables for the most important few to be closely studied.

6. Setting-up the first runner of a possibly large project, to be effectively supplemented by future tests when needed.

THE WORKSHEET

The worksheet to be presented here has the following features:

1. It is designed for engineers or even foremen who may have no background on Statistics. The procedure of its use is given in a cook-book fashion.

2. The worksheet is self-contained. All the data on object and date of experiment, dependent and independent variables, experimental layout, details of data analysis, precision of tests, and other important conclusions are given on a single page.

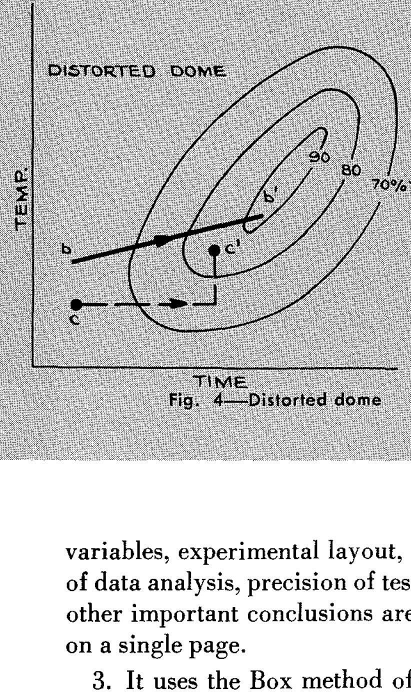


Fig. 4—Distorted dome

3. It uses the Box method of locating the response surface and following the steepest ascent line.

4. Only four or eight tests are needed to establish the response contours and to find the effect of various factors. These tests may be followed by a few more tests to reach the maximum point by the steepest ascent method.

5. It applies the Yates method of data analysis. The calculations are so simple that an engineer or foreman can mentally figure them out in a few minutes' time.

6. Up to seven factors can be tested with a single worksheet. Fewer factors should be selected, however, if they interact.

7. The worksheet may be used in a sequential manner. A group of four tests may first be run to study up to three factors. A second group of four more tests may, if desired, next be made; not only to study up to four more factors, but also to improve the conclusions from the first group of tests. The response surfaces may be located and the steepest ascent method applied for each or both of the two groups of four tests.

The design of the worksheet may be summarized as follows:

1. The eight treatment or factor combinations (one for each sample) are selected from an orthodox statistical design given in Table 10A.1 on page 485 of reference 1. Technically, it is called a 1/16-replicate of a seven-factor design, each factor having two levels or conditions tested.

2. The eight combinations are so arranged as to enable the use of the Yates method of data analysis; either simultaneously on all eight test results, or separately on the first or second group of four test data for sequential application of the worksheet.

3. The effect of various factors as found by the Yates method are next used to locate the steepest ascent line and to find the maximum point by a few more tests.

The following assumptions are made in the design of the worksheet:

1. The precision of tests or experimental error is small. If the error is not small, the tests may have to be repeated. Each sample number then is actually a sample group number.

2. The data or test results are normally distributed. Abnormal data may be transformed into normal data (3). If the tests are repeated, particularly if repeated a number of times, the averages from any data become nearly normal.

3. When four or more factors are tested with a single worksheet, it is assumed that interactions among these factors either are absent or are very small. This assumption is generally true. If interactions may exist, fewer factors should be put in each experiment. For example, if three factors are tested on eight units, all main effects and interactions can be estimated; whereas if four factors are tested with the same number of samples, only one prespecified interaction is lost. Another way to resolve doubt on interactions is to run a follow-up or confirmation experiment in which the same factors are assigned to different columns on the worksheet. Contradictory results from the two experiments may reveal interactions.

4. The response surfaces are not too complicated. Most response surfaces known to real systems have one or two maximum peaks, and the response contours are not difficult to establish. If complex response surfaces do exist in the small experimental region, erroneous conclusions may be drawn. The possibility of reaching wrong conclusions, however, is ever present with any method of experimentation, particularly when the system of factors is complex. Here again, special confirmation tests may be needed.

EXAMPLES OF USE

The use of the worksheet is best illustrated by analysis of the following two hypothetical examples.

Example 1: To find the best composition of an alloy for a special use.

Example 2: To optimize a certain process for minimum "scrap" or cost.

Example 1: Alloying design for very high hot strength. For the particular usage, cost considerations indicate that an iron-base material is desirable. Additions of various elements will be made to achieve the desired properties, including chromium, nickel, molybdenum, vanadium niobium, manganese, and carbon.

The following steps are involved in the procedure (See Table 1):

1. Heading—The name and object of the experiment are first entered, together with the data to be taken and the date.

2. Factors selection—The elements the amounts of which will be varied are entered as factors A to G. Metallurgical and economic considerations determine the base levels and units of variation for some elements. For the other elements, these values are esti-

mated. The high levels (starred in the worksheet) are obtained by adding the units of variation to the respective base levels, and the low levels by subtracting the units of variation from the base levels.

3. Number of test — Because the number of factors in this problem is seven, eight tests must be made. The number of tests must be at least one greater than the number of factors.

4. Order of test—The order of test is determined by the random drawing of eight numbered chips and the recording of the numbers drawn in sequence. If chip 3 is drawn first, for example, test 1 is to be made on sample 3.

5. Treatment of samples — Each sample is composed of high- or low-level amounts of the various elements, as indicated by the presence or absence of stars in the worksheet. Sample 1, for instance, has low levels of all elements. Sample 2 has high levels of chromium, nickel, niobium, and manganese, but low levels of molybdenum, vanadium, and carbon. To fill in this information on the composition of the different samples, it is convenient to work through each element or column at a time, filling in the four starred spaces on the worksheet with the high-level conditions, and then the remainder with the four low-level conditions.

6. Sample preparation and testing —The samples are prepared by special melting and working in the assigned order, and are then tested for the desired property, i.e., tensile strength at 800°C. Test data are entered in the data column H.

7. Data analysis — Results of the eight tests are analyzed by the Yates method. First, the results are divided into four consecutive pairs. The two numbers in each pair are then added together to give the first four figures in the J column (1.5 + 3.5 = 5.0; 6.2 + 3.2 = 9.4; 5.3 + 5.1 = 10.4; 5.3 + 5.8 = 11.1), and the first number of each pair is subtracted from the second to give the last four figures in the J column (3.5 — 1.5 = 2.0; 3.2 — 6.2 = —3.0; 5.1 — 5.3 = —0.2; 5.8 — 5.3 = 0.5). These processes are repeated on column J to obtain the values for column K, and repeated on column K to obtain column L. The values in column L are then divided by the number of tests (i.e., 8) to yield the figures for the "effects" column, M. The effects are identified by letter symbols in the last column, N.

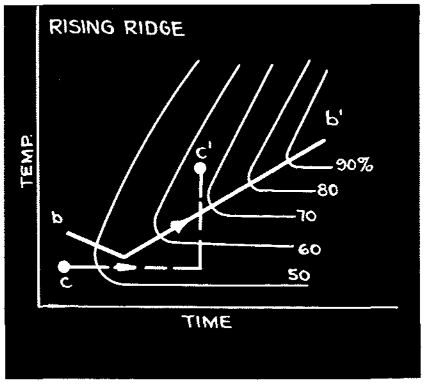


Fig. 5—Rising ridge

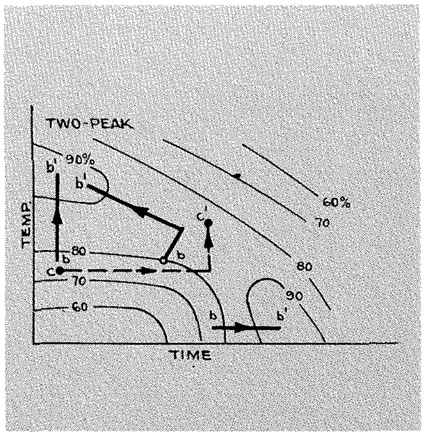


Fig. 6—Two-peak

8. Effects—The effects listed in columns M and identified in column N are entered in line 15, with caution as to signs (plus or minus) and positions (A to G).

9. Preliminary conclusions—First, the average tensile strength at 800°C for the eight samples is 4,490 psi. This value is the expected hot strength of a sample having all alloy additions at the base levels, i.e., 4% Cr, 2% Ni, 0.1% Mo, 0.02% V, 0.1% Nb, 0.4% Mn, and 0.4% C.

Second, vanadium appears to have the greatest effect, increasing the hot strength by 890 psi for each 0.02% added. In other words, each 0.1% of vanadium added raises the hot strength by 4,450 psi. Chromium, molybdenum, niobium, and carbon increase the hot strength by 71, 640, 540, and 460 psi, respectively, for each 0.1% of alloy addition. Manganese and nickel, however, probably have little or slightly negative effects on the hot strength.

The probable error of a single test is estimated by examination of the smallest effects, in this case 0.09 or 90 psi due to addition of nickel and 0.16 or 160 psi due to manganese. For this problem, the error is of the order of 250 ($90 \times \sqrt{8}$) psi (if nickel has no effect at all) or less.

METHOD OF STEEPEST ASCENT

The "Box" method of "steepest ascent" may now be applied if desired. In this method, a few additional tests located on the line of expected maximum response are selected, and the following extra steps are taken:

10. Proposed change—The effects in line 15 are multiplied by the respective units of variation in line 4, giving line 16. If it is desired to change the unit of variation for one of the elements to a more convenient amount (chromium, for example, may be varied in the additional tests by 0.8% rather than the odd number 0.71%), all the values in line 16 must be increased proportionately by the same factor (e.g., 0.8/0.71 = 1.13) to yield line 17.

11. Path of steepest ascent—The best path is then determined by successive additions of the proposed changes in line 17 to the corresponding base levels in line 3. Thus, line 18 = line 3 + line 17; line 19 = line 3 + (2 × line 17); line 20 = line 3 + (3 × line 17); and so on.

12. Extra tests—An extra melt is then made according to the composition given in line 22, which is considerably different from the base-level conditions. Because of the encouraging result of 10,300 psi, melt 10 (line 24) is made, followed in order by melts 11, 12, and 13 (lines 25, 26, and 27). The results of hot-strength tests on all these additional melts are entered in column H.

13. Final conclusion—By inspection, it is seen that the maximum hot strength is reached on melt 11. Consequently, the best composition is as follows: 10.4% Cr, 1.2% Ni, 0.66% Mo, 0.18% V, 0.58% Nb, 0.24% Mn, and 0.80% C. The expected hot strength of this combination is 11,500 ± 250 psi.

Example 2: Processing design for minimum scrap. A number of processing factors are likely to affect scrap of a certain product. Some of these factors are listed below, together with the suggested low- and high-level conditions:

Factor A: Prefire temperature — 100 vs. 200°C.

TABLE 1: EXAMPLE 1 ON ALLOYING DESIGN

Experiment: Special Iron-Base Alloy   Object: Maximum Hot Strength   Data: Tensile Strength at 800°C, in 1000 psi   Date: 10/1/56

Error of Test = e ≐ 0.25
= 2.83 x smallest effect
Error, Effect = $\sqrt{e^2/8}$
= 0.354 e
=

I = ABCD
= −BCE = −ADE
= −ACF = −BDF
= −ABG = −CDG

Line	Factors Studied		A	B	C	D	E	F	G	H	J	K	L	M	N
1	Factors Studied		A	B	C	D	E	F	G						
2			Cr	Ni	Mo	V	Nb	Mn	C						
3	Base Level		4%	2%	0.1%	0.02%	0.1%	0.4%	0.4%						
4	Unit		1	1	0.1	0.02	0.1	0.1	0.1						
5	High Level		*5	*3	*0.2	*0.04	*0.2	*0.5	*0.5	H	J	K	L	M	N
6	Low Level		3	1	0	0	0	0.3	0.3	Data	Calculation				Effect
7	Sample 1	Test 5	3	1	0	0	0	0.3	0.3	1.5	5.0	14.4	35.9	4.49	Average
8	2	8	*5	*3	0	0	*0.2	*0.5	0.3	3.5	9.4	21.5	−0.7	−0.09	B
9	3	1	*5	1	*0.2	0	*0.2	0.3	*0.5	6.2	10.4	−1.0	5.1	0.64	C
10	4	3	3	*3	*0.2	0	0	*0.5	*0.5	3.2	11.1	0.3	−4.3	−0.54	(−A4)=BC=AD=−E
11	5	4	*5	1	0	*0.04	0	*0.5	*0.5	5.3	2.0	4.4	7.1	0.89	ABC=D
12	6	6	3	*3	0	*0.04	*0.2	0.3	*0.5	5.1	−3.0	0.7	1.3	0.16	AC=BD=−F
13	7	2	3	1	*0.2	*0.04	*0.2	*0.5	0.3	5.3	−0.2	−5.0	−3.7	−0.46	AB=CD=−G
14	8	7	*5	*3	*0.2	*0.04	0	0.3	0.3	5.8	0.5	0.7	5.7	0.71	A
15	Effect		0.71	−0.09	0.64	0.89	0.54	−0.16	0.46						
16	Effect times Unit		0.71	−0.09	0.064	0.018	0.054	−0.016	0.046						
17	Change		0.8	−0.1	0.07	0.02	0.06	−0.02*	0.05						
18	Best Path		4.8	1.9	0.17	0.04	0.16	0.38	0.45						
19			5.6	1.8	0.24	0.06	0.22	0.36	0.50						
20			6.4	1.7	0.31	0.08	0.28	0.34	0.55						
21			7.2	1.6	0.38	0.10	0.34	0.32	0.60						
22	Trial 9		8.0	1.5	0.45	0.12	0.40	0.30	0.65	10.3					
23			8.8	1.4	0.52	0.14	0.46	0.28	0.70						
24	Trial 10		9.6	1.3	0.59	0.16	0.52	0.26	0.75	11.0					
25	Trial 11		10.4	1.2	0.66	0.18	0.58	0.24	0.80	11.5					
26	Trial 12		11.2	1.1	0.73	0.20	0.64	0.22	0.85	11.2					
27	Trial 13		12.0	1.0	0.81	0.22	0.70	0.20	0.90	10.1					

Conclusions:

Best composition (melt 11)

Cr	10.4%
Ni	1.2%
Mo	0.66%
V	0.18%
Nb	0.58%
Mn	0.24%
C	0.80%

Expected tensile strength:

11,500 ± 250 psi

TABLE 2: EXAMPLE 2 ON PROCESSING DESIGN

Experiment: Processing part #X-5   Object: Minimum scrap   Data: % defective in 100 parts   Date: 10/1/56

Error of Test = e ≐ 0.6
= 2.83 x smallest effect
Error, Effect = $\sqrt{e^2/8}$
= 0.354 e
=

I = ABCD
= −BCE = −ADE
= −ACF = −BDF
= −ABG = −CDG

Line	Factors Studied		A	B	C	D	E	F	G	H	J	K	L	M	N
1	Factors Studied		A	B	C	D	E	F	G						
2			Temp. pref.	Clean-ing	Reagent	Additive	Press.	Voltage	Time						
3	Base Level		150	—	15	—	350	9	15						
4	Unit		50°C	—	5 lbs.	—	50 psi	3	5 min.						
5	High Level		*200	*yes	*20	*#2	*400	*12	*20	H	J	K	L	M	N
6	Low Level		100	no	10	#1	300	6	10	Data	Calculation		Effect		Effect
7	Sample 1	Test 4	100	no	10	#1	350	9	15	12	16	28	Ave low D	7.0	Average
8	2	2	*200	*yes	10	#1	*350	* 9	15	4	12	−6	B	−1.5	B
9	3	1	*200	no	*20	#1	*350	9	*15	5	−8	−4	C	−1.0	C
10	4	3	100	*yes	*20	#1	350	* 9	*15	7	2	10	−A	2.5	(−A4)=BC=AD=−E
11	5	8	*200	no	10	*#2	300	*12	*20	8	13	23	Ave high D	5.8	ABC=D
12	6	6	100	*yes	10	*#2	*400	6	*20	5	10	−1	B−F	−0.2	AC=BD=−F
13	7	5	100	no	*20	*#2	*400	*12	10	4	−3	−3	C−G	−0.8	AB=CD=−G
14	8	7	*200	*yes	*20	*#2	300	6	10	6	2	5	A−E	1.2	A
15	Effect		−2.5	−1.5	−1.0	−0.6	−3.7	−1.3	−0.2						
16	Effect times Unit		−125	—	−5.0	—	−185	−3.9	−1.0						
17	Change		42	—	1.7	—	62	1.3	0.3						
18	Best Path		192	yes	16.7	#2	412	10.3	15.3						
19			234	yes	18.4	#2	474	11.6	15.6						
20	Trial 9		276	yes	20.1	#2	536	12.9	15.9	2					
21	Trial 10		318	yes	21.8	#2	598	14.2	16.2	1					
22	Trial 11		360	yes	23.5	#2	660	15.5	16.5	0					
23	Trial 12		402	yes	25.2	#2	722	16.8	16.8	2					
24			444	yes	26.9	#2	784	18.1	17.1						
25															
26															
27															

Conclusions:

Effects: D = (5.8−7.0)/2 = −0.6
E = A−1.2 = −3.7
F = B+0.2 = −1.3
G = C+0.8 = −0.2

Best Combination (Trial 11)

Prefire temp.	360°C
Cleaning	yes
Reagent added	23.5 lbs
Additive	#2
Pressure	660 psi
Voltage	15.5 v
Treat time	16.5 minutes

Expected scrap: around 0%

Factor B: Special cleaning—no cleaning vs. cleaning.

Factor C: Amount of reagent added —10 vs. 20 pounds.

Factor D: Special additive—Additive #1 vs. #2.

Factor E: Applied pressure on a certain equipment—300 vs. 400 pounds.

Factor F: Applied voltage on another equipment—6 vs. 12 volts.

Factor G: Treatment time—10 vs. 20 minutes.

The experimental design may be as follows. At first, four tests are made on samples 1 to 4, in the random order 4, 2, 1, 3. Factors A, B, and C are varied, other factors being kept constant: D at the low level; E, F, and G at the base levels, in order to fully use the worksheet. The data analysis is similar to that in Example 1, except that only two, instead of three, cycles of arithmetic operations are involved, each on four figures, rather than eight. The average effects found are A = −2.5; B = −1.5; and C = −1.0. The negative signs indicate that these factors all tend to reduce the scrap figure, factor A being the most effective.

The above conclusions may be used as such. However, it may be decided to introduce the four additional factors D, E, F, and G. Only four more tests are next made on samples 5 to 8. The average effect of these additional factors can be found as shown.

Finally, the method of steepest descent can be applied if needed.

A useful concept brought in by the Box method is the response surface. Engineers have always been dreaming of showing the desired responses on the dependent variables, such as yield, quality, and cost, in spatial relationship with the various factors. By the use of the Box method, these response surfaces can be established with but a few tests.

For simplicity, only response surfaces for two factors are shown in this paper. A common way of showing these response surfaces in graphical form is to draw lines of equal responses on these surfaces. These lines or response contours are like similar lines on weather or topography maps. Some typical examples of response surfaces are shown in the following figures, which also compare the Box method with the classical one-factor method of experimentation under the various conditions.

All these figures show the variation of yield with temperature and time. Yield is the dependent variable, while temperature and time are the factors or independent variables.

Fig. 1 shows a case where the response surface for yields is a perfect plane. The response contours or lines of equal yields are therefore parallel, straight lines. The classical experimenter would probably start testing at point *c* by varying the time but keeping temperature constant. A first series of constant-temperature tests along line *c-t* locates the temporary maximum point *t*. The maximum point *c′* is reached after a second series of constant-time tests along line *t-c′*. The experimenter using the Box method would set up four tests around starting point *b*, and add a few more tests on the steepest ascent line *b-b′*. Both experimenters would reach the same maximum yield. The classical experimenter, however, usually must make more tests to reach the same goal.

When the response surface is dome-shaped, the response contours may be concentric circles. Such a case is shown in Fig. 2. In Fig. 3, the response surface is a stationary ridge, the yield being maximum on the inclined ridge line and decreasing as the distance from this ridge line increases. The same notes given in Fig. 1 apply in both cases shown by Figs. 2 and 3.

Fig. 4 shows a situation where the response contours are a series of near ellipses. In this case, the classical experimenter may make many tests without reaching the maximum yields.

The response contours shown in Fig. 5 are for a response surface of the rising-ridge type. Here again, the classical experimenter may miss the maximum yields. Using the Box method first locates a temporary maximum point *p*, from which the true maximum yield *b′* is reached by tests along the new steepest ascent line *p-b′*.

Fig. 6 shows a case where the response surface has two regions of maximum yields. In this instance, the classical experimenter may miss both of them. The Box method insures reaching either or both of them no matter where the tests are started.

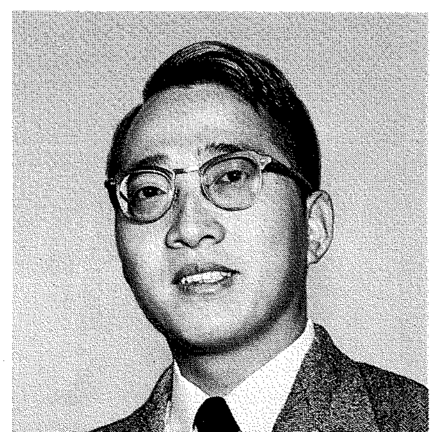
In summary, the Box method consists of:

1. Running a few selected tests around a chosen point within the experimental region.
2. Analyzing the test results to find the effects of the various factors.
3. Establishing from the same results the response surface and contours in and near the tested area.
4. Marking the line from the chosen experimental center to climb the response surface at maximum rate. This line is at right angles to all response contours crossed, and is therefore called the line of steepest ascent.
5. Making some more tests along this line to reach the maximum point on the response surface. This step ends the first cycle of experimentation by the Box method.
6. If desired, a second cycle may be started around this maximum as the new experimental center, to see if further improvement is possible. More accurate response contours may be established around this new center, and another line of steepest ascent drawn across these response contours, followed by actual tests selected on this line.

REFERENCE

1. Davis, O. L., *Design and Analysis of Industrial Experiments*, Hafner Publishing Co., N. Y., 1954.

C. H. LI was born in China in 1923. After receiving the B.S. degree in mining and metallurgical engineering from Chiao Tung University in 1944, he worked on developmental aspects of ferrous and non-ferrous melting and foundry in an arsenal and later worked in a steel plant in Shanghai. He came to the United States in 1948, and received the M.S. and Ph.D. degrees in metallurgy from Purdue University in 1949 and 1951, respectively. He joined the Tube Division of the Radio Corporation of America at Marion, Indiana in January, 1951. He is now located at the Harrison, N. J. plant, where his work includes research, development, and controlled experimentation. Dr. Li is an associate member of Sigma Xi, a senior member of Am. Soc. of Quality Control, and an "American Man of Science."



Patents Granted TO RCA ENGINEERS

Based on Summaries Received over a period of about two months

DEFENSE ELECTRONIC PRODUCTS

Moorestown, N. J.

Inductive Circuits
Pat. No. 43,239—granted Sept. 25, 1957 to T. Douma.

Storage Tube Circuit Employing Amplitude and Phase Comparison
Pat. No. 2,837,643—granted June 3, 1958 to Miles C. Johnson and W. V. Goodwin no longer with RCA.

Information Handling System
Pat. No. 2,848,607—granted Aug. 19, 1958 to I. Maron.

Camden, N. J.

Indicator for Storage Devices
Pat. No. 2,851,677—granted Sept. 9, 1958 to H. N. Crooks.

Compression System
Pat. No. 2,853,698—granted Sept. 23, 1958 to A. D. Beard, D. L. Nettleton, IEP, Camden, and G. W. Booth no longer with RCA.

Information Selecting Circuit
Pat. No. 2,854,652—granted Sept. 30, 1958 to J. N. Smith.

Automatic Gain Control System
Pat. No. 2,857,482—granted Oct. 21, 1958 to F. L. Putzrath and K. Solomon.

ELECTRON TUBE DIVISION

Harrison, N. J.

Beam Convergence Apparatus for Tri-Color Kinescope
Pat. No. 2,855,542—granted Oct. 7, 1958 to O. H. Schade.

Lancaster, Pa.

Electron Tube
Pat. No. 2,853,640—granted Sept. 23, 1958 to M. V. Hoover.

Color-Kinescopes, etc.
Pat. No. 2,855,529—granted Oct. 7, 1958 to A. M. Morrell.

RCA LABORATORIES

Princeton, N. J.

Stabilized Transistor Signal Amplifier Circuit
Pat. No. 2,847,519—granted Aug. 12, 1958 to A. I. Aronson.

RECORD DIVISION

Indianapolis, Ind.

Automatic Variable Pitch Control Apparatus for Disc Recorders
Pat. No. 2,847,514—granted Aug. 12, 1958 to A. G. Evans.

Sheet Feeding Assembly
Pat. No. 2,848,228—granted Aug. 19, 1958 to J. J. Kimbro.

Magnetic Recording Transducer
Pat. No. 2,848,556—granted Aug. 19, 1958 to H. E. Roys and D. R. Andrews, R & V, Cherry Hill, N. J.

Automatic Molding Apparatus
Pat. No. 2,853,737—granted Sept. 30, 1958 to L. C. Harlow.

RADIO & "VICTROLA" DIVISION

Cherry Hill, N. J.

Magnetic Recording Transducer
Pat. No. 2,848,556—granted Aug. 19, 1958 to D. R. Andrews and H. E. Roys, Indianapolis, Ind.

RCA VICTOR TELEVISION DIVISION

Cherry Hill, N. J.

Transistor Signal Translating Circuit
Pat. No. 2,851,540—granted Sept. 9, 1958 to G. E. Theriault.

High Level Contrast Control for Video Amplifiers
Pat. No. 2,853,549—granted Sept. 23, 1958 to B. E. Denton.

Protective System
Pat. No. 2,855,547—granted Oct. 7, 1958 to C. S. Shepherd.

Voltage Rectifying Systems
Pat. No. 2,855,559—granted Oct. 7, 1958 to H. C. Goodrich.

RCA SERVICE COMPANY

Cocoa, Florida

Magnetic Recording and Reproducing Apparatus
Pat. No. 2,782,263—granted Feb. 19, 1957 to F. B. Hills and J. J. Hoehn, IEP, Camden, N. J.

Magnetic Recording and Reproducing Apparatus
Pat. No. 2,838,305—granted June 10, 1958 to F. B. Hills and J. J. Hoehn, IEP, Camden, N. J.

INDUSTRIAL ELECTRONIC PRODUCTS

Camden, N. J.

Magnetic Recording and Reproducing Apparatus
Pat. No. 2,782,263—granted Feb. 19, 1957 to J. J. Hoehn and F. B. Hills, RCA Svc. Co., Cocoa, Fla.

Magnetic Recording and Reproducing Apparatus
Pat. No. 2,838,305—granted June 10, 1958 to J. J. Hoehn and F. B. Hills, RCA Svc. Co., Cocoa, Fla.

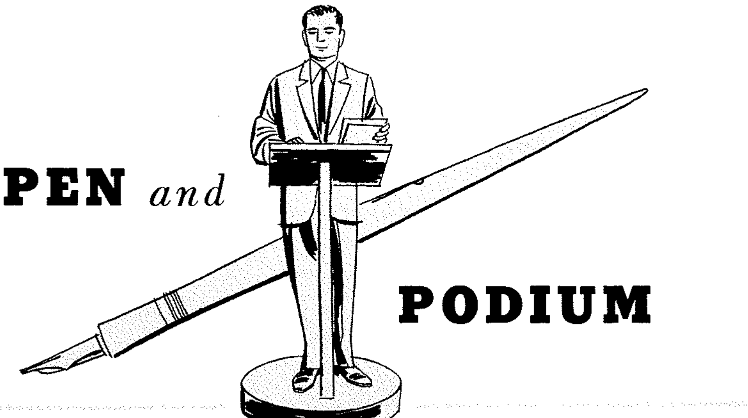
Television Intermediate Frequency Amplifiers
Pat. No. 2,840,645—granted June 24, 1958 to M. D. Nelson and B. Fisher no longer with RCA.

Electrostatic Printing
Pat. No. 2,851,988—granted Sept. 16, 1958 to H. G. Reuter, Jr.

Compression System
Pat. No. 2,853,698—granted Sept. 23, 1958 to D. L. Nettleton, A. D. Beard, DEP, Camden, N. J. and G. W. Booth no longer with RCA.

Monostable Multivibrator
Pat. No. 2,857,512—granted Oct. 21, 1958 to A. C. Luther, Jr.

Wave Generating System
Pat. No. 2,857,514—granted Oct. 21, 1958 to A. C. Luther, Jr.



PEN *and* PODIUM

BASED ON REPORTS RECEIVED OVER A PERIOD OF ABOUT TWO MONTHS

ELECTRON TUBE DIVISION

Lancaster, Pa.

Planning and Operating a Clean Shop
By W. T. Dyall and L. C. Herman: Presented at ASTM Symposium on Cleaning of Components and Materials, Philadelphia, Pa., Oct. 13-14, 1958. An over-all guiding philosophy for obtaining clean electron tubes, covering all critical fabricating phases, is described, as well as the planning necessary to achieve a practical clean shop.

The Adsorption and Desorption Characteristics of Graphite Conductive Coatings
By H. A. Stern and D. J. Donahue: Presented at ASTM Symposium on Cleaning of Components and Materials, Philadelphia, Pa., Oct. 13-14, 1958. This paper describes a new measurement technique which makes it possible to define the adsorption, evolution, retention, and mechanisms of adsorption of carbon dioxide by graphite conductive coatings during electron-tube processing and operation.

Cathodic Electrocleaning of Molybdenum Wire Prior to Gold Plating
By R. W. Etter: Presented at ASTM Symposium on Cleaning of Components and Materials, Philadelphia, Pa., Oct. 13-14, 1958. This paper describes the investigation of types of contaminants on hot-drawn molybdenum wire used in electron-tube grids to determine optimum cleaning prior to gold plating. Cathodic electrocleaning improved adherence of gold plating and reduced blisters, pinholes, and bare spots.

Use of Radiotracers in Parts-Cleaning Evaluation
By M. N. Slater and D. J. Donahue: Presented at ASTM Symposium on Cleaning of Components and Materials, Philadelphia, Pa., Oct. 13-14, 1958. This paper describes the use of radiotracer techniques in the study of the removal of a soluble inorganic salt by water, and the effects of various rinsing and firing processes on the removal of acid etchant from electron-tube cathode sleeves.

Improved Vidicon Focusing and Deflecting Coils
By B. H. Vine: Presented at SMPTE Meeting, Detroit, Michigan, Oct. 22, 1958. This paper describes a suitable coil configuration for eliminating the effect known as "beam landing error" or "porthole" in vidicon cameras. A particular coil design and the results obtained are discussed.

The Use of Mathematics in Engineering at RCA
By R. W. Engstrom: Presented at East Hempfield High School, Lancaster, Pa., Oct. 23, 1958. The importance of mathematics to an engineer in a company such as RCA is illustrated by general discussion of the sort of problem encountered and the type of mathematics required.

Rules for the Design of Improved Vidicon Focusing and Deflecting Coils
By B. H. Vine: Presented at IRE Electron Devices Meeting, Washington, D. C., Oct. 30-31, 1958. This paper describes two basic principles for the elimination of the effect called "beam landing error" or "porthole" in vidicons: proper choice of the length and position of the deflecting coils to yield zero radial component of electron velocity at the target, and proper degree of flare of the magnetic focusing field at the target end of the vidicon to yield zero tangential component of velocity.

Harrison, N. J.

The Design and Control of Computer Tubes
By F. T. Gusler: Presented at Twin-City Electronic Wholesalers' Association, Minneapolis, Minn., Oct. 4, 1958. This paper discusses design requirements of three types of electron tubes used in electronic computer circuits: multigrid tubes for gating circuits, triodes for switching circuits, and diodes for logic circuits.

Concepts Involved in the Determination and Control of the Properties of Ceramic Parts
By W. F. Lawrence: Presented at American Ceramics Society Fall Meeting, Asbury Park, N. J., Oct. 9, 1958. This paper discusses certain concepts involved in the control and study of the properties of precision ceramics. The relationship between other parameters and density is described.

Practical Transformer Effects on Output-Tube Performance in High-Fidelity Amplifiers
By L. Kaplan: Presented at National Electronics Conference, Chicago, Ill., Oct. 13, 1958. This paper analyses interactions between output tubes and practical output transformers and shows how complete and valid solutions of output-stage design problems can be obtained by graphical methods.

New Techniques for Measuring VHF Loading of Miniature Tubes
By F. Sespico and W. Troyanoski: Presented at IRE/EIA Radio Fall Meeting, Rochester, N. Y., Oct. 28, 1958. This paper discusses a unique approach and versatile method of measuring input loading of miniature tubes intended for vhf applications. The test chassis is described, as well as the measurement techniques.

Temperature Compensation of Permanent-Magnet Focus Stacks for Traveling-Wave Tubes
By E. E. Bliss: Presented at IRE Electron Devices Meeting, Washington, D. C., Oct. 30-31, 1958. This paper describes the use of temperature-compensating magnetic shunts in periodically focused traveling-wave tubes to extend the ambient operation range up to 250 degrees C.

A 50-Watt Grid-Controlled X-Band Traveling-Wave Tube Using Periodic Magnets
By G. Novak and W. Caton: Presented at IRE Electron Devices Meeting, Washington, D. C., Oct. 30-31, 1958. This paper describes features and performance data of a developmental traveling-wave-tube amplifier designed to have minimum weight and size for use in airborne electronic equipment.

A Method of Measuring the Optical Sine-Wave Spatial Spectrum of Television Image Display Devices
By O. H. Schade: Published in JOURNAL OF THE SMPTE, Sept. 1958 issue. This paper describes the measurement of the resolution characteristic (or "spatial spectrum") of kinescopes with electrically generated sine-wave patterns.

SEMICONDUCTOR AND MATERIALS DIVISION

Somerville, N. J.

Area Control in Diffused-Silicon Devices through Variations in Diffusant Surface Concentrations
By L. D. Armstrong: Presented at Electrochemical Society Fall Meeting, Ottawa, Canada, Sept. 29, 1958. This paper describes how diffused junction areas may be controlled by successive diffusions under conditions of controlled surface concentrations of diffusants.

A 25-Watt High-Quality Transistorized Audio-Frequency Power Amplifier
By R. Minton: Presented at Audio Engineering Society Meeting, N. Y. City, Sept. 29, 1958. This paper describes the use of transistors in a high-quality, a-f power amplifier having low harmonic and intermodulation distortion and a good frequency response.

Elements of Transistor Physics and their Application to Computer Transistor Design
By R. C. Pinto: Presented at Rutgers University, Oct. 9, 1958. This paper describes the distinguishing design and fabrication features of transistors and the special requirements of devices for computer applications.

The Formation of a P-N Junction by Ni Diffusion and Leaching
By S. W. Daskam and A. L. Kestenbaum: Presented at IRE Electron Devices Meeting, Washington, D. C., Oct. 30-31, 1958. This paper describes two diffusion methods (and equations) for producing p-n junctions: diffusion of nickel into an n-type wafer and subsequent leaching, and simultaneous diffusion and leaching.

A Developmental High-Frequency Silicon Transistor
By W. A. Bosenberg and A. L. Kestenbaum: Presented at IRE ELECTRON Devices Meeting, Washington, D. C., Oct. 30-31, 1958. This paper describes the construction of an n-p-n transistor by the use of both silicon-oxide and photoresist masking in combination with boron and phosphorus diffusion. Electrical characteristics are given for a developmental type.

Application of RCA Drift Transistors to FM Receivers
By J. W. Englund and H. Thanos: Presented at IRE/EIA Radio Fall Meeting, Rochester, N. Y., Oct. 28, 1958. This paper discusses design and application considerations involved in the use of drift transistors in the r-f amplifier, oscillator, and i-f amplifier stages of standard FM broadcast receivers.

RCA VICTOR TELEVISION DIVISION

Cherry Hill, N. J.

Television Receiving Antennas
By R. K. Kolar: Presented at the IRE Subsection Meeting, Lancaster, Pa., Nov. 12, 1958. A summary of receiving antenna fundamentals and the characteristics of various commercially available antenna types is discussed with emphasis on the needs in the Lancaster area.

DEFENSE ELECTRONICS PRODUCTS

Camden, N. J.

Micro-Module Concept Specifications
By H. J. Laiming: Presented Dept. of Interior Auditorium, Wash., D. C., June 3, 1958. A brochure was prepared for distribution at a Symposium held in Washington, D. C., on June 3, 1958, for the purpose of familiarizing various branches of the Armed Services and representatives from Industry with the Micro-Module Production Program.

Coincident Current Applications of Ferrite Apertured Plates
By W. G. Rumble: Presented Western Electronics Convention, Los Angeles, Calif., Aug. 19, 1958. A description of the ferrite apertured plate, a 256-bit magnetic storage element, is given.

The Confidence That Can Be Placed On Various Reliability Tests
By C. M. Ryerson: Presented at the Western Electronic Show & Convention, Aug. 18-19, 1958, Los Angeles, California. Various theoretical approaches to reliability testing are reviewed and the practical significance of each is explained. The useful applications of various mathematical distributions is given.

Storage Capacity in Meteor-Burst Communication
By W. A. Helbig: Published in the Sept. issue of the IRE PROCEEDINGS. This paper presents the design equations needed to specify the storage capacities (transmitter and receiver) necessary in certain types of meteor-burst communication equipments.

A Night Television System
By C. T. Shelton, B. F. Walker and D. E. Townsend: Presented at the Engineers Research and Development Laboratories, Fort Belvoir, Va., Oct. 7, 1958. The Night Vision Branch of the Engineers Research and Development Laboratories is at present sponsoring a program at RCA for the development of a system producing television images under night time illumination conditions. The basis of this system is an image intensifier orthicon. The objective is to provide images on moonless, cloudy nights.

A Magnetic Head for Stereo or Half Track on One-Eighth Inch Tape
By H. R. Warren: Presented at the Tenth Annual Convention Audio Engineering Society, Hotel New Yorker, N. Y., Oct. 2, 1958. This paper describes the design and development of a magnetic record-reproduce head for magnetic tape.

A Magnetic Head for Grooved Magnetic Recording Disks
By H. R. Warren: Presented at the Tenth Annual Convention Audio Engineering Society, Hotel New Yorker, N. Y., Oct. 2, 1958. This paper describes the design and development of a magnetic record-reproduce head for operation with magnetic grooved disks.

Moorestown, N. J.

Digital Ranging System
By A. J. Lisicky: Presented 2nd Nat'l. Convention on Military Electronics, Wash., D. C., June 17, 1958. A range tracking unit for fire control radars which utilized digital techniques was described. The digital range unit possesses a number of advantages.

The Army Micro-Module Design Concept
By J. P. Gilmore: Presented Conference on Modular Packaging, Redstone Arsenal, Huntsville, Ala., July 24, 1958 and IRE Joint Session on Micro-miniaturization, New York, Oct. 16, 1958. The basic micro-module concept is described, including goals and objectives leading to size reduction.

Synthesis of Distributed Element Wave Patterns
By N. I. Korman: Presented Univ. of Penna. for Degree of Doctor of Philosophy, June 11, 1958. The subject dissertation investigates the synthesis of distributed element filters to fit prescribed reflection coefficient and transmission coefficient functions.

Value Engineering Analysis and Reliability
By R. M. Jacobs: Presented at the Military Electronics National Convention, Wash., D. C., June 16-18, 1958. The increasing demands for the improvement of equipment reliability has continued in the face of rising costs of design, manufacture and maintenance. Value Engineering activities have been successful in reducing the costs of an equipment without compromising performance or value to the customer and frequently improves Reliability at the same time. It is the intent of this paper to present a number of actual case histories showing where cost-reductions through VE and reliability improvements have been accomplished.

Publications and the Project Organization
By M. H. Lowe, N. E. Gilberg, H. D. Albrecht and J. L. Sarafian: Presented at the WESCON Convention, Aug. 22, 1958. This paper represents a case history of the publications program for the Talos Land Based Weapon System. The topics which are covered include: initial planning, task assignment, participation by sub-contractors, facing the changing demands of an R&D program, engineering review and approval processes, up-dating of material to cover the de-bugging and evaluation periods, and the like.

An Application of Numerical Analysis to Analog Computation
By J. R. Levitt: Presented at the Second International Conference for Analog Computation, Strasbourg, France, Sept. 1, 1958. Techniques of numerical mathematical analysis which have traditionally been reserved for Digital Computation are examined for application to Analog Computation. Specifically, the well known Lagrange interpolation formula is adapted to the analog generation of functions having more than one argument. The actual implementation on the analog computer is described in detail.

Rapidly Tunable Wide Range UHF Cavity
By T. Douma: Presented at the National Electronics Conference, Chicago, Ill., Oct. 13, 1958. This paper discusses design principles for rapidly tunable wide range resonant circuits mainly for use in the UHF band.

A Broad Band Circularly Polarized C-Band Antenna
By R. M. Smith: Presented at the Fourteenth Annual National Electronics Conference, Chicago, Ill., Oct. 13, 1958. This paper described the design of a modification kit, whose function was to convert a linearly polarized monopulse radar to a circularly polarized monopulse radar.

INDUSTRIAL ELECTRONIC PRODUCTS

Camden, N. J.

Control Knobs for Military Electronic Equipment
By T. G. Nessler: Published in ELECTRICAL MANUFACTURING, Sept. 1958 issue. The article provides design engineers with a comprehensive guide to the selection and application of control knobs for military electronic equipment.

An Electronic Data Processing System and Standardization
By M. Macchia: Presented at the Seventh Annual Meeting of Standards Engineers Society, Philadelphia, Pa., Sept. 22, 1958. A description of the RCA 501 System enhanced by RCA's Accuracy Control philosophy in Electronic Data Processing was presented. Analysis techniques, file requirements, and a centralized Electronic Data Processing operation was discussed.

The 501 System
By J. A. Brustman: Presented at the Technical University, Vienna, Austria, Oct. 16, 1958. The RCA 501 is a new electronic data processing system which employs solid-state components throughout. The system is extremely flexible and has been specifically designed for commercial data processing applications.

Television X-Ray Observation in Industry from a Systems Standpoint
By H. E. Haynes: Presented at the 18th Annual Convention of the Society for Nondestructive Testing, Cleveland, Ohio, Oct. 28, 1958. X-ray intensification and remote-viewing systems of many types are currently appearing. This paper discusses inherent limitations of such systems, and the demands they make on the image transducing elements incorporated in them.

Evaluation of a Modulated Air-Flow Loudspeaker
By A. L. Witchey, J. C. Webster, and R. G. Klumpp: Presented at the Fall Meeting Acoustical Society of America, Chicago, Ill., Nov. 20, 1958. As part of an overall evaluation of the USNEL Flight Deck Communication System, an RCA Modulated Air-Flow Loudspeaker (Air Horn designed primarily as a High Noise Level Reliability Testing Facility) was tried out as a speech and alarm signalling transducer on the flight deck of an aircraft carrier. Overall levels of wide-band (200-6000 cps) noise reached 130 db at optimum points on the deck, as compared to 110 db for the present system.

The Effect of Statically Applied Stresses on the Velocity of Propagation of Ultrasonic Waves
By R. H. Bergman and R. A. Shahbender: Published in the JOURNAL OF APPLIED PHYSICS, Nov. 1958 issue. The paper gives the results of an experimental investigation of the changes in the velocities of ultrasonic waves propagating transverse to the direction of applied stress in an aluminum column.

AWARD SET UP FOR UNIVERSITY OF MAINE STUDENTS IN HONOR OF DR. BEVERAGE, RETIRING FROM RCA

Shown at the retirement dinner for Dr. Beverage at the Hotel Pierre, N. Y., on October 17, 1958, from the left: Dr. Beverage, Mrs. Beverage, Dr. E. F. W. Alexanderson, and Mrs. Alexanderson.

Dr. Harold H. Beverage, Vice President, Research and Development, RCA Communications, Inc., and Chief Technical Advisor, Communications, RCA Laboratories, has retired on October 31, 1958, after forty-three years of service with RCA.

Establishment of the Award which has been set up at the University of Maine was announced by Mr. John L. Callahan, Administrator of RCA's Radio Research Laboratory at Rocky Point, Long Island. The Award has been sponsored by friends and associates of Dr. Beverage. It will be administered by the University and will provide a modest monetary award to outstanding electrical engineering students majoring in communications.

Dr. Harold H. Beverage, Vice-President, Research and Development, of RCA Communications, Inc. and Chief Technical Advisor, Communications, of RCA Laboratories, is one of the outstanding pioneers in the field of radio communication.

Upon graduation from the University of Maine in 1915, Dr. Beverage became a radio laboratory assistant to the noted scientist, Dr. E. F. W. Alexanderson. When, in 1920, Dr. Alexanderson was named first Chief Engineer of the newly formed Radio Corporation of America, Dr. Beverage was transferred to the new organization to head a laboratory investigating radio propagation and the development of trans-oceanic radio receiving systems.

His work led to the conception of the Beverage wave antenna, for which achievement he received the Morris Liebmann Memorial Prize of the Institute of Radio Engineers in 1923. He also was co-inventor of the diversity reception system which solved the problem of local fading in the reception of high-frequency radio signals.

In 1929, Dr. Beverage was appointed Chief Research Engineer of RCA Communications, Inc. Under his direction, there were many major developments in all branches of radio communication—among them the first commercial ultra-high-frequency communications system, installed in the Hawaiian Islands in 1930 to provide inter-island telephone communication and the first television relay system, developed for RCA's field tests of television between New York City and Camden, N. J. in 1934.

In 1940, Dr. Beverage was elected Vice-President, Research and Development, of RCA Communications, Inc. and two years later was also named Director of the Radio Research Laboratory of RCA Laboratories.

Early in World War II, Dr. Beverage was appointed Consultant to the Secretary of War on communications problems. For his contributions, he was awarded the Signal Corps Certificate of Appreciation in 1944 and the Presidential Certificate of Merit in 1948.

Among the honors bestowed upon Dr. Beverage are the Medal of Honor of the Institute of Radio Engineers in 1945, the Armstrong Medal of the Radio Club of America in 1938 and, most recently, the Lamme Medal of the American Institute of Electrical Engineers, awarded to him in 1956 for his contributions to national and world-wide radio communications.

Dr. Beverage, who is listed in American Men of Science, is a Fellow and Past-President of the Institute of Radio Engineers. He also is a Fellow of the American Institute of Electrical Engineers, the American Association for the Advancement of Science, and the Radio Club of America. He was elected, in 1955, an Eminent Member of Eta Kappa Nu, honorary electrical engineering fraternity.

ENGINEERS IN NEW POSTS

In the Radio and "Victrola" Div., Ch. Eng. **J. L. Franke** announces his staff as follows: **P. R. Bennett,** Mgr. Advanced Development; **A. D. Burt,** Mgr. Record Changer Engineering; **D. H. Cunningham,** Radio and Phonograph Engineering; **C. E. Miller,** Mgr. Cambridge Resident Engineering; **E. E. Moore,** Mgr., Eng. Services; and **W. D. Rhoads,** Mgr. Canonsburg Resident Eng. . . . **D. H. Cunningham** announces **A. Bisti** as Mgr. Mechanical Eng., and **L. M. Krugman,** Mgr. Electrical Eng. with himself acting as Mgr. of Transducer Eng.

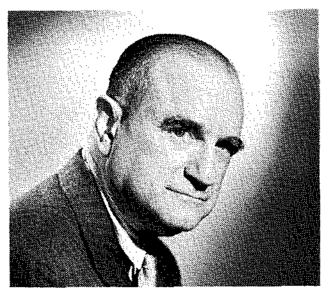
A. J. Bianculli

D. H. Cunningham

In IEP Communications Chief Eng. E. I. Anderson announces his staff as follows: **N. E. Edwards,** Mgr. Microwave Communications Eng.; **C. E. Moore,** Mgr. Radar Eng.; **K. L. Neumann,** Mgr. Fixed Communications Eng.; **C. A. Rammer,** Mgr. Mobile Communications Eng.; and **K. E. Thomas,** Mgr. Communications Eng. Admin. and Drafting.

In the Electron Tube Division, **H. R. Snow,** Mgr. of Woodbridge Plant Production Eng. announces **Mrs. Janet C. Deckert** Mgr. Glass Tube Prod. Eng. and **Joseph N. Koff** Mgr. Special Tube Prod. Eng. . . . **A. J. Bianculli** becomes Mgr. Special Tube Lab. in Receiving Tube Operations at Harrison. He is replaced by **V. T. Valva** who becomes Mgr. Microwave Development Shop.

DR. A. N. GOLDSMITH JOINS BOARD OF RCA COMMUNICATIONS, INC.

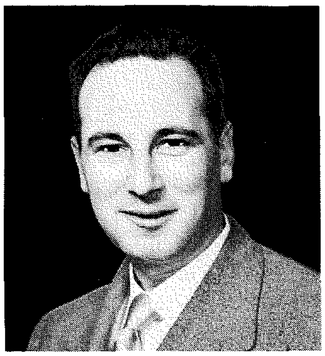


Dr. Alfred N. Goldsmith, consulting engineer in the electronics and motion picture fields, has been elected to the Board of Directors of RCA Communications, Inc., it was announced recently by David Sarnoff, Chairman of the Board of RCA and RCA Communications, Inc.

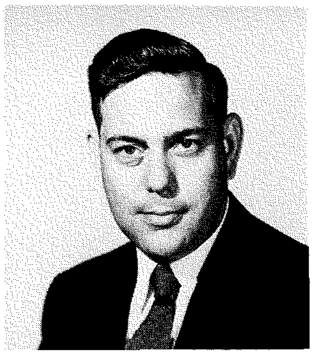
Dr. Goldsmith joined RCA in 1919 and for 12 years served as Director of Research, and then Vice President and General Engineer. Since 1931 he has served as a technical consultant to RCA.

He holds the degrees of B.S. (C.C.N.Y.); Ph.D. (Columbia), and D.Sc. Hon. (Lawrence College).

RCA FORMS NEW ORGANIZATION TO DEVELOP ADVANCED MILITARY SYSTEMS



Dr. N. I. Korman



David Shore

A new high-level scientific and technical organization known as Advanced Military Systems has been established to create and develop new and advanced weapon system concepts, **Arthur L. Malcarney,** Executive Vice-President, DEP, announced recently.

The new group will be located in a building to be constructed adjacent to the Princeton Laboratories, and will report to **Dr. C. B. Jolliffe,** Vice-President and Technical Director of RCA and of RCA DEP.

Mr. Malcarney announced at the same time the appointments of **Dr. Nathaniel Korman** as Director and **David Shore** as Associate Director of the new organization. Both have been associated with the Missile and Surface Radar Department, DEP, Moorestown, N. J.—Dr. Korman as Chief Systems Engineer, and Mr. Shore as Manager, Systems Development and Planning.

Describing the purpose and function of the new activity, Mr. Malcarney said:

"The creation of modern weapons in the new age of missiles and space technology, has become more and more a matter of conceiving and developing intricate technical systems. These draw upon our advanced scientific technology and require the highest calibre of engineering skill. In line with this trend, and in view of its current responsibilities as a major contributor to our national security, RCA has formed Advanced Military Systems to 'spearhead' studies leading to the creation of new, complex and more effective weapons systems.

"The objectives of the group will be first to determine the need for specific types of systems to meet specific requirements, and then to originate detailed proposals upon which such systems may be based."

SOME AFTERTHOUGHTS ON TOUGHMINDEDNESS

After reading G. W. Crawford's excellent article in this issue, "Toughmindedness and Tomorrow," you will agree that books could be written on the subject, and that further exploration into any of its many facets would certainly tickle the imagination. As a matter of fact, Mr. Crawford came to us just before press-time with an interesting additional sidelight to this theme with the hope that we could include it with his article. Unfortunately, our page make-up was too far advanced for this, but the anecdote was too good to pass up. We hope you will react as we did.

"As important as a person's ability to reason capably, is his willingness to make a decision—a decision the wisdom of which only time and circumstances will reveal in cold reality. When a decision should be made, many are gripped with fear, uncertainty, and worst of all, lethargy. In many cases the personal penalty for making no decision at all is minor. However, the purposeful person does not want his headstone to read,—'No Hits, No Runs, No Errors'. Each time the toughminded man gets up to the bat, he has one thing in mind, and that is to belt the ball out of the park—not to wait out the pitcher with the hope that he'll receive a free ticket to first base.

"A short time ago I had lunch with Gil MacDougald—the Yankee's great shortstop—and I asked him how he compared Mickey Mantle, Ted Williams and Willie Mays. I was pleased to hear him say that although Willie is not as great as Mantle and Williams at the bat, he puts his best into every play of every inning of every game—and *that* to Gil overshadowed everything else."

COMMITTEE APPOINTMENTS

A. G. Evans, Record Engineering, Indianapolis, has been elected Central Vice President of the Audio Engineering Society.—*S. D. Ransburg*

George G. Thomas, Mgr. of Industrial Tube Products Quality Control at Lancaster, has been elected Chairman, Harrisburg-York-Lancaster Section ASQC for the 1958-59 season.—*W. G. Fahnestock*

Recently elected officers of the Lancaster Sub-section of the Philadelphia Chapter of IRE 1958-59 are: Chairman, **Paul W. Kaseman,** Engineering Conversion Tube; V. Chairman, **Donald J. Ransom,** Color Kinescope Engineering and Sec.-Treas., **Alfred W. Comins,** Equipment Development Engineering.—*D. G. Garvin*

MEETINGS, COURSES AND SEMINARS

The following engineers from the RCA Victor Record Division, Indianapolis, Indiana, are taking graduate work sponsored by Purdue University: **D. H. O'Herren, A. Skele, N. L. Covey, A. J. Viere, A. G. Evans, B. J. White and S. W. Liddle.**

Mr. T. C. Lu, Engineer, and **Dr. A. M. Max,** Manager of the Chemical and Physical Laboratory, Record Engineering, Indianapolis, Indiana, are teaching courses in Calculus and Electroplating, respectively, at the Purdue University Extension, Indianapolis, Indiana.—*S. D. Ransburg*

COMPUTING SYSTEMS ENGINEERS GRADUATED

On September 30, 1958, the second group of Service Company Computing Systems Engineers was graduated. Certificates were presented to graduates of the five month specialized course by **Edward Stanko,** Manager, Engineering Technical Products, following a dinner at Comptons' Log Cabin. The graduates were addressed by **J. Wesley Leas,** Chief Engineer of Electronic Data Processing, IEP.

Those graduating were **D. Jaffe, J. Foster, R. Levin, H. Weisberger, S. Muir, H. Mogensen** and **R. Bernitich,** who was given special recognition as class honor man.

The course instructors were **J. Anderson, G. Kropp, T. Seetoo, D. Phelps, L. Gallo** and **R. Heacock.**—*E. Stanko*

MANUFACTURING EQUIPMENT, METHODS AND TECHNIQUES

Mr. A. G. Cattell, Manufacturing Superintendent, DEP Fabrication, Camden, arranged a seminar consisting of six, one-hour sessions, spaced one week apart. Mr. Cattell and members of his staff discussed and demonstrated the features and advantages of interesting new equipment, methods and techniques. Particular emphasis was placed on the vital importance of standards in exploiting the new manufacturing facilities.

The program was designed specifically for the engineers of Corporate Standardizing. Sessions started November 4 and continued to December 9.

Burtis H. Conely, Engineer, Industrial Receiving Tube Manufacturing, Harrison, attended the Advanced Conference Series on Statistical Quality Control recently held at Rutgers University. The Conference consisted of twelve sessions held over a two-week period. Discussions included application and use of Statistical Quality Control, particularly as applied to the chemical and electronic fields.

RCA ACTIVE AT PGEWS SYMPOSIUM

The IRE Second National Symposium on Engineering Writing and Speech was held on October 1-2 at the Hotel Biltmore, New York.

Program co-chairmen were T. T. Patterson and C. W. Sall, both of IEP Camden, and Symposium secretary was Miss E. L. McElwee of Tube Division Commercial Engineering at Harrison. Toastmaster was C. W. Sall, and the keynote speaker was Dr. George H. Brown, IEP's Chief Engineer. Charles A. Meyer of Tube Division Commercial Engineering, Harrison, was a session moderator. Miss McElwee and Messrs. Patterson, Meyer and Sall are members of the Professional Group Administrative Committee.

Tom Murakami's daughter, Marcia, compares *origami* techniques with her father. (Photos by Phila. Inquirer)

NATIONAL ENGINEERS' WEEK PROCLAIMED

The ninth anniversary of the celebration of NATIONAL ENGINEERS' WEEK, sponsored by the National Society of Professional Engineers, will be observed this coming year from February 22-28, 1959. This period naturally is selected closest to George Washington's birthday as a tribute to him, not only as a soldier and statesman, but as one of our first engineer-builders.

Engineers' Week will be proclaimed throughout the land. President Eisenhower, together with the governors of our states and mayors from numerous cities, will pay tribute to our engineers and their accomplishments. Mayor Richardson Dilworth of Philadelphia will officially proclaim Engineers' Week for Delaware Valley on Friday, February 20, 1959, at 11:30 A.M. in City Hall. The public as well as all engineers are invited to attend the reading of this formal proclamation.

The theme for the 1959 celebration is:

ENGINEERING—FOR THE AGE OF SPACE

This theme is very appropriate in view of the engineers' determination to solve the problems of outerspace travel by conquering the many obstacles now being confronted. From reports, the results are gratifying, for according to General Donald N. Yates of the U. S. Air Force, during an interview on MEET THE PRESS, November 16, 1958, he was very pleased with the (engineering) progress of his personnel.

The purpose of National Engineers' Week is to acquaint all persons with the functions of the engineering profession and the part it is playing in our modern society, both for national defense and our commercial needs. This is best promoted through the media of radio and television, displays and publicity made possible by many engineering firms and industries, and above all by our schools and engineering institutions.

Most of the thirty-five engineering societies operating in Metropolitan Philadelphia plus the Engineers' Club of Philadelphia and the Franklin Institute are taking an active part in this celebration; they have appointed representatives, and their participation is very gratifying. We expect great success.

G. B. CRANSTON, *Chairman*
Radio and TV Committee and
Vice Chairman of Engineers' Week,
RCA Corporate Standardizing Division

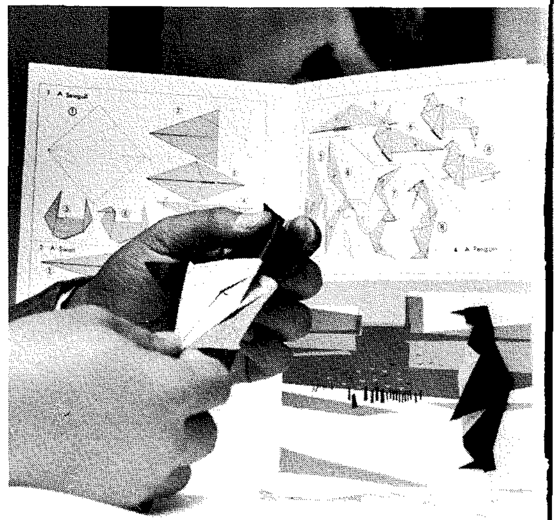
ORIGAMI—A FASCINATING HOBBY

In our years of association with RCA engineers, their personalities have led us to expect one thing—the unexpected. For example, the highly sophisticated technological skills developed in engineering are often adroitly applied in leisure avocations—and this is so in the case of Tom Murakami of RCA—Cherry Hill.

Most of us can make a paper hat from a sheet of newspaper, or fold a paper "airplane." But the Japanese and Chinese have developed the art of paper folding to a high degree of skill and artistry.

Beginning in the Orient long before the birth of Christ, *origami* came to this country only in recent times. Some artists and art connoisseurs here who knew the late Yasmatsu Onaga, a sculptor, were introduced to *origami* many years ago. Onaga, to entertain them, often folded birds and a frog that could be inflated.

Tom Murakami folds from examples in books that his wife brought back from Japan last year when she visited her mother. He enjoys figuring out the paper folding from the diagrams, and teaching his children and Sunday school pupils examples of the art.



Tom Murakami completes a penguin folded from instructions shown in the book.

ENGINEERING MEETINGS AND CONVENTIONS

December, 1958-January, 1959

DECEMBER 2-4
Reliable Electrical Connections, EIA
Statler-Hilton Hotel, Dallas

DECEMBER 3-5
Global Communications, AIEE, PGCS of IRE
Colonial Inn Desert Ranch
St. Petersburg, Fla.

DECEMBER 3-5
Eastern Joint Computer Conf.,
AIEE, ACM, IRE
Bellevue-Stratford Hotel, Philadelphia

DECEMBER 4-5
Vehicular Communications,
Annual Meeting, PGVC of IRE
Hotel Sherman, Chicago

DECEMBER 9-11
Mid-America Electronics Convention
MAECON
Municipal Auditorium,
Kansas City, Mo.

JANUARY 12-14
Reliability and Quality Control
PGRQC of IRE, ASQC, EIA
Bellevue-Stratford Hotel, Phila.

JANUARY 29-30
Long-Distance Transmission
by Waveguides,
Institution of Electrical Engineers,
London, England

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