RCA Engineer

21st Anniversary Issue

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Satellite communications—a catalyst for the future

As a central feature of this anniversary issue of the *RCA Engineer*, it is timely to focus on communications because we are on the threshold of expanding communications requirements and dramatic capabilities from satellite technology. Only now are we beginning to realize the potential benefits from the enormous possibilities of orbiting high-capacity low-cost communications spacecraft. And RCA is on the leading edge of this exciting development both in technology and in services throughout the 50 states.

RCA has developed and provided the first two advanced and most cost effective domestic satellites, with 4 transponders each, to operate with low-cost earth stations for the RCA Satcom system. RCA Communications enterprises will operate and use these satellite facilities for an increasing variety of conventional and specialized voice, record, and video services. The satellites—in combination with more than 140 earth stations to be installed by 1978, numerous additional receive-only earth stations, and other terrestrial facilities—will offer a new flexibility and a range of unique capabilities for serving communications demands.

RCA engineers and other dedicated people who have contributed importantly to these RCA Satcom achievements should be pleased by their accomplishments. Now, our communication programs must also focus on the satellite opportunities and challenges ahead. We can best do this by continued technological excellence and leadership, innovative and creative marketing, and efficient utilization of satellite facilities to provide the best possible service. At the same time, it is essential to plan continuously for and to seize the new opportunities which will be opened up by continued technological progress to create the greater future in RCA satellite communications.

Howard R. Hawkins
President,
RCA Communications
RCA Corporation

Our cover

This striking photo features the RCA Satcom satellite under test in the 26-ft-diameter thermal vacuum chamber at Astro-Electronics Division. The surrounding sheets of aluminized mylar provide six independent heat zones (related to simulated sun angle) for each of the sides of the cubically-shaped spacecraft.

Photo credit: Leo Cashel, Information Services, Astro-Electronics Division, Hightstown, N.J.

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RCA Engineer

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• 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 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.

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a quiet revolution

This year's bicentennial activities have focused on that period in our history starting with a small skirmish in Lexington, Mass., and ending with Cornwallis' surrender in Yorktown, Va. Perhaps the happiest consequence of re-examining the American Revolution is that we also re-examine the underlying principles of individual freedom and self-determination, which are more important than the events.

From a broader viewpoint, the American Revolution could be considered part of a larger revolution that started in America in the mid-1770's, spread to the British Isles with disturbances in Ireland and England (1781-82), and to Europe with a revolt in the Netherlands (1783-87), an uprising in Belgium (1787-90), riots in Geneva (1782), and the bloody French Revolution (1787-1799). During that era, there were also revolutions in Belgium and Germany (1792), Italy (1796), and Switzerland (1798).

Broadening our viewpoint still further, this entire period of political and social upheaval was bounded on both ends by the Industrial Revolution (1760-1840), which shifted much of the hand labor to large machines and tended to concentrate manufacturing in large establishments.

Presently, historians cannot agree as to the extent that these events are related, but there is little disagreement that the late-1700's and early-1800's marked a period of revolutionary change. More importantly, it was a time of new ideas—a demand for self-determination and personal autonomy, a rejection of norms that were in conflict with individual beliefs. This ideal, captured by many writers and philosophers of the early-1700's, transcended political and national boundaries.

It was, additionally, a time of revolutionary historical significance to us as engineers and scientists. In fact, many of our technical terms—Ohm, Oersted, Volt, Ampere, Coulomb, Henry, Watt, Gauss, Farad—as well as several basic engineering concepts, have their origins in this time period.

We are all familiar with Benjamin Franklin's lightning-rod demonstration and his part in the War of Independence. But it is often overlooked that Franklin (among others of his time) rejected the theory that there were two kinds of electricity, each distinct and opposite from the other. Franklin proposed a single "electric fluid" consisting of "extremely subtle" particles of electrical matter with positive or negative polarity determined by an excess or lack of these particles, respectively.

Another product of the revolution, Alessandro Volta (1745-1827)—stimulated by the experiments of Luigi Galvani (1737-1798) with the muscular reactions of a frog's leg in contact with two dissimilar metals—demonstrated the existence of electric current as contrasted with static electricity. These experiments led to the development of the voltaic battery as well as the discovery of electrolysis, a fundamental tool of chemical research.

Michael Faraday (1791-1867)—building on the work of Charles de Coulomb (1736-1806) and Andre Ampere (1775-1836) in France, Hans Oersted (1777-1851) in Denmark, Joseph Henry (1797-1878) in America, and George Ohm (1787-1854) in Germany—described the process of electromagnetic induction. Working in electrochemistry, he also discovered the relation between the quantity of electricity used and the amount of a substance which could be deposited on an electrode.

The atomic theory of matter was founded in this period through the independent, but related, work of John Dalton (1766-1844), Joseph Gay-Lussac (1778-1850), and Amadeo Avogadro (1776-1856).

Anton Lavoisier (1743-1794) typified the revolutionary spirit. A restless intellect and an innovator in agriculture, technology, and physiology, as well as finance, economics, social reform, and government, he was guillotined in 1794—one of the many excesses of the French Revolution. He is best known for his pioneering work in overthrowing the phlogisten doctrine and establishing oxygen's central role in combustion.

Add all the ingenious practical developments of the revolutionary period—e.g., James Watt's steam engine, Humphrey Davy's miner safety lamp, Eli Whitney's cotton gin, Richard Arkwright's spinning jenny, and Charles Babbage's analytical engine—and the list would become virtually endless.

If there is a message in these events, it is that intellectual freedom—competition among dissenting views, open discussion and criticism, pursuit of new ideas—is a practical gift as well as a precious one. And if we, as scientists and engineers, can benefit from our heritage in this bicentennial year, it is by carrying on the tradition of the more subtle, quiet revolution that shaped our profession.

—J.C.P

Government and Commercial Systems Annual Management Review Meeting

The information in this article has been compiled from information provided by the speakers, recordings, and collective notes made during the G&CS Annual Management Review Meeting. Due to space limitations, only a limited number of the professionalism talks can be summarized. Additional information may be available from the conference speakers. The complete text of the professionalism speeches given on November 10, 1975 was published in a bound copy and is on file in Advanced Programs Development, G&CS, Moorestown.

D. Shore
Division Vice President
Advanced Programs Development
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THE 1975 G&CS Annual Management Review Meeting was held on November 10 and 11 at the Sheraton Poste Inn, Cherry Hill, N.J. Our theme this year, "Be a Pro," provided an excellent springboard for presentations by outstanding professionals in our business. These men dealt with key management issues in marketing, engineering, finance, and personnel.

The review was attended by approximately 325 key managers in G&CS staff and divisions, the division general managers, and guests from corporate staff and other RCA functional organizations.

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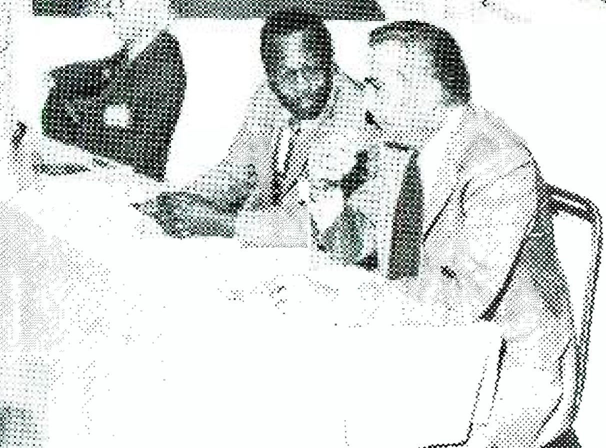
Because the response was so favorable, and the information so useful to other parts of RCA, we decided to devote a part of this issue to a review of the meeting.

As Chairman of the G&CS 1975 Management Review, my objective was to make the meeting of greatest value to all attendees. Since professionalism has been a recurring theme of Dr. Kessler's in evaluating our performance in G&CS, it seemed an appropriate theme for our 1975 meeting.



We decided that the best format would be a series of papers presented by outstanding professionals, inside and outside RCA, on the major factors in our business; and covering both commercial and government business so that lessons could be interchanged between the two.

A unique opportunity

The pressures from budget limitations, the rising cost of new weapons, and the need to introduce these weapons in adequate quantities have created an environment in which the Department of Defense is forced to change its procurement practices. Indeed, these practices are becoming much like our experience in commercial business. No longer is performance at any cost the DoD approach; it is now, "Design-to-Cost."

Since Design-to-Cost has always been the way of life in commercial products, our 1975 meeting was a unique opportunity for synergism between government and commercial activities. How does a Pro conceive, design, build, and market "to a cost?"

To answer that question, I selected a number of professionals in RCA and other organizations to give us the benefit of their experience and expertise. Following the normal genesis of new programs and products we first covered marketing, product planning, and bid preparation. Then we discussed the engineering implementation.

As a vital bridge between our government and commercial practices we were fortunate to have Robert O'Donohue from the DoD Directorate of Defense Research and Engineering discuss Design-to-Cost. Actually, this was the first time such a briefing was given by DoD to a single company. Deputy Secretary of Defense Clements was responsible for approving this innovative approach to DoD-industry communications.

Conference feedback

Most of those attending the conference have responded to a comprehensive questionnaire. Nearly all respondents evaluated the conference "above average." Some went so far as to classify it as "outstanding" or "best ever attended." Nearly all who attended expressed very high interest in the professionalism talks and requested that copies of the professionalism speeches be printed and circulated.

Comments of the responding attendees show that the objective of the meeting was met: to increse understanding of the major factors in our business and to meet and know each other better; and to meet and know the pros inside and outside of RCA. The results of the meeting were most gratifying.

The first day and a half was the instructional phase, or the "Be a Pro" clinic. As has been traditional at these annual meetings, the final portion was devoted to briefings given by the Divisional General Managers of G&CS, followed by a financial summary and then closing remarks by Dr. Irving K. Kessler, Executive Vice President, G&CS.

First day session

Dr. Kessler delivered the keynote address pointing out that the program was carefully constructed to focus on those areas of performance and measurement that will be significant to all of G&CS in 1976 and in the years to come. He cited how the professional differs from the good amateur in his economy of action and consistency of performance. (A summary of Dr. Kessler's opening and closing remarks follow.)

Marketing factors

George D. Prestwich, Division Vice President, Government Marketing, explained the whys and hows of the marketing process in getting new business. He described such vital considerations as what professionalism in the marketplace invoves and laid the groundwork for the two speakers who followed him, who spoke on product planning and proposal planning and preparation.

H. H. (Chip) Klerx, Broadcast Systems, explained the role of product planning, providing specific examples, do's and don'ts, and sequential steps to follow in product planning. Mr. Klerx concentrated on the product planning for RCA's new TK-76 electronic newsgathering tv camera. Respondents to our feedback questionnaire expressed very high interest in this talk. (A summary follows; however, reading the complete talk will be valuable to product planners.)

To complete the marketing portion of the program, Hy Silver, a management consultant, spoke on proven techniques for winning proposals. Hy's presentation was a one-hour condensation of a two-day proposal planning and preparation course, which he presents to key managers in the G&CS divisions. Proprietary constraints prevent publishing it here.

Highlight of the professionalism session was the keynote presentation on Design-to-Cost by Robert E. O'Donohue, Jr., Assistant Director of Defense Research Engineering for Planning in the Office of the Secretary of Defense. He reviewed the conditions leading to DoD emphasis on Design-to-Cost: the need to get quantity as well as quality.

Design factors

Donald J. Parker, Manager, Digital Communications Systems, GCSD, discussed design with state-of-the-art technology for government equipment, concentrating on the application of digital LSI technology. Mr. Parker cited approaches for achieving low-cost design such as modularity, design for automatic test and diagnosis, and computer-aided design.

Arch C. Luther, Chief Engineer, Broadcast Systems, provided examples and recommended step-by-step procedures for Design-to-Cost in commercial business, involving design, manufacturing, engineering programs for greater manufacturability and high reliability of product. (A summary of this talk is contained in the Dec/Jan 1975/76 *RCA Engineer*.)

Next, Ray Aires, Chief Engineer, Avionics Systems, described current activities at Avionics Systems geared toward cost-effective and reliable steps in designing for production. Ray set forth 20 rules Aviation Systems has developed in its effort to improve the design for production. Ray pointed out that design for production results in improved profitability. (See the paper by Aires in this issue.)

Ed Schecter, Manager, G&CS Government Product Assurance, emphasized that RCA's reputation in the outside world is based on the high reliability of its products—commercial and military. He described techniques and procedures available at G&CS to help in insuring product reliability. (A summary follows.)

Joe Volpe, Chief Engineer, Missile and Surface Radar Division, spoke on planning and executing software, including the issue of trading off between hardware and software. Mr. Volpe accented the need to break down the software requirements, starting from system interfaces to the smallest unit. He explained software tools such as Functional Flow and Diagram Description (F^2D^2). (A summary follows. Also see "AEGIS Weapon System Engineering Management Tools," Dr. J.T. Nessmith, Jr., *RCA Engineer*, Jun/Jul 1972.)

To conclude the first day's program, Frank Freiman, Director, PRICE Systems, G&CS, described PRICE—a unique RCA tool for use in predicting costs of new systems at the concept stage. This makes it particularly useful for Design-to-Cost. PRICE is a computerized cost-modeling program that is capable of evaluating the development and production costs of a vast variety of electronic and mechanical systems ranging from commercial broadcast equipment to complete space satellites. (A summary follows.)

The rest of the meeting was devoted to presentations by Divisional General Managers on the business progress and goals of their respective divisions. These are listed in the accompanying program. James Walker, Division Vice President, Finance, concluded the formal program with a financial summary of G&CS.

To sum up the two-day meeting, Irv Kessler issued several challenges to G&CS management.

The summaries reported in the following pages are intended to provide a general overview of the professionalism presentations. Those presentations not carried herein are available for general distribution with the exception of those by Hy Silver and John Abbott.

Highlights, observations, and challenges

I. Kessler
Executive Vice President
Government and Commercial Systems
Moorestown, N.J.

The following is a condensation of the opening and closing remarks given by Dr. Kessler at the Annual Management Review Meeting.

THE 1975 Review was the eighth opportunity I had to welcome the management group of G&CS to our annual conference. In the case of managers of our commercial operations, it was our sixth joint meeting. In looking back over the content of these meetings and the periods in which they took place, I am struck by the tremendous changes which have occurred — changes not only in structure and personnel but also to the world around us, and to our underlying concepts and goals.

Not long ago we lived in an economy of abundance, Galbraith referred to the "Affluent Society," and the only real question was how to use our productive capacity so that more and more people could have two cars, more luxurious living accommodations, better diets and wardrobes, and imaginative vacations.

Conventional wisdom, our goals and aspirations, and our image of the future have been given a rude jolt through the emergence of the third and fourth worlds (if we consider the OPEC nations and other suppliers of basic materials as a fourth world). The unlimited horizons and frontiers that we once visualized have been reconstructed. In these times, we must (and I fear perhaps with increasing pain) learn how to adjust to a world of new and different values.

Similarly, the higher prices of energy, the shortage of dollars, and the high cost of borrowing money have caused a critical re-examination of the goals and drives of industry. Indeed, these factors have brought about a searching scrutiny of the very shape of business organization and the mode of conducting business.

Not many years ago, the goal for most business was growth. The alternative was to perish. Mergers, acquisitions, and the development of conglomerates were the order of the day. Doing more and more business was a standard for measurement and evaluation, both internally and by the market analysts.

But the pendulum has swung. In adjusting to the realities of today's world and preparing for tomorrow, we must recognize the necessity for conducting our operations with greater sagacity. We also must be aware that different measurement criteria are required, whether imposed from above or not.

With limitations on capital and on the ability to borrow new money, the imposition of priorities becomes essential. Size becomes secondary to profitability. Here I must distinguish between profit *per se* and profitability—which is a measure of return on specific investment.

The ability to use our resources most effectively to produce the greatest return and, at the same time to assure the future, requires the full development of our skills. Beyond that, it requires an awareness of what needs to be done and how our performance should be measured.

Our program for the Review was carefully constructed to focus on those areas of performance and measurement which I believe will be significant to all of us in 1976 and in the years to come.

We must be increasingly selective in those business areas we pursue; we must face up to the pruning of unprofitable or marginal operations; and we must learn to maximize return through the prudent and skillful management of our resources.

As a sometime athlete, it has been my observation that the professional differs from the good amateur in his economy of action and in the consistency of his performance. The pro makes few unnecessary movements regardless of the sport, and conserves his energy for critical moments. On any given day he may play second to the amateur, but overall his economy of action and consistency will win out. In our Annual Management Meeting we heard the perspective of the pro in key areas. We hope that the concepts and practices reviewed at that meeting will add to the professionalism of each of us.

In looking back over the past eight years, I think we have brought ourselves to the point where our future has never seemed brighter. On the government side of the house, we have laid the foundation for more than doubling the size of our business in the next five years. Similarly, in the commercial area we have developed product lines and expanded market aperture so that the outlook is for continued growth and profitability.

The challenge then will be to achieve the extremely ambitious goals for 1976 and the future that is within our reach. We must do so with our own resources and with a maximization of the profitablity that I believe is inherent in the business we will do.

I am hopeful that our two days together at this meeting and our continued communication with regard to management practices will help us to achieve these goals.

I think one of the significant points brought out by our speakers is that there is indeed a new order with regard to the use of capital and investment.

To sum up the two-day meeting I issued seven specific challenges to our G&CS mangement. These are action items which are outgrowths of the two-day meeting. They call for the divisions to develop specific plans.

1) Further reduction of receivables and inventory in G&CS. I know there is a feeling that we have come pretty far but there was a feeling last year and the year before that we cannot do any more. I do not believe we have yet reached the point where it hurts. I do not believe we are at the point where we match competition. We just simply have not yet learned how to maximize our return.

2) Increasing employment of women and minorities. I directed each General Manager to come back and tell me how he is going to get those who have the requisitions to give preference to women and non-whites in hiring. To find qualified people we must train them at entry level. People will never climb the ladder unless they put their foot on the ladder first. If they make it fine; if they fall by the wayside, this is a part of the competitive process. We will not only have a plan but George Black has an assignment to audit these plans as rigorously and scrupulously as our financial plans. We will not get ourselves into a position where we become a headline because some investigatory group says that RCA is not fair in its employment practices.

3) Increasing professionalism in proposal writing. I asked each operation to indicate how it will implement the exquisite detail required for a winning proposal.

4) I established a goal of 40% win rate on the jobs that we bid. This will require rigorous selectivity. On the government side, each division has now come up with a plan for achieving a 40% win rate. We are in the process of discussing with each their bid/no-bid procedure.

5) A program of action for the increased utilization of PRICE, as a trade-off tool in systems design. We have received national recognition for PRICE. It is used by all of the Services and by NASA, and is now being sold commercially to our competitors. Our divisions were not using PRICE routinely in checking the estimates that come in. One of its great advantages is its use as a trade-off tool to try alternate configurations.

6) Standardization of program management tools within each division and ultimately standardization at the G&CS level. We lose experience when a program finishes or a man is transferred and a novice program manager must establish his own kit of tools. Divisions variously employ DEPICT, line of balance charts, PERT, and other tools. But I would like to see standardized controls and I would like all customers to get the equivalent management treatment on jobs of equivalent size.

7) Increased international sales, both Government and Commercial. We had a rough year this year, and we knew that going into the year. In both the Commerical areas and Government areas I think we have bottomed out. I think we have turned things around. As a matter of fact, some of the forecasts in the government area seem so ambitious that we must temper our enthusiasm in making commitments. And yet when I look at the projections of future business to come from jobs that are either in hand or in prospect, we will double in five years. The projections of the divisions are that we will be at $760M factored to $640M by 1983, and we should be above the $500M by 1980.

Markets are more limited in the three commercial areas but we are constrained only by our own ingenuity and energy. We have by no means addressed all of the markets available to us; we have not yet attained optimum market share, and we have not yet maximized our return through more professional asset management. I look forward to healthy growth in volume and profit in the commerical divisions, and I believe that we will meet and exceed divisional plans.

List of Speakers

First day

Marketing factors

The marketing process — an overview, G.D. Prestwich

Product planning, H.H. Klerx

Proposal planning & preparation, Hy Silver (Consultant)

Design to cost, R.E. O'Donohue, Jr. (OD-DR&E)

Design factors

Design for state of the art technology (Government), D.J. Parker

Design for state of the art technology (Commercial) A.C. Luther

Design for production, R.H. Aires

Design for reliability, E.S. Shecter

Design for software (hardware-software trade-offs), J.C. Volpe

PRICE, F.R. Freiman

Second day

Key factors in financial management, John Abbott (Schrello Assoc.)

RCA Objectives in financial management, R.C. Butler

Professionalism in international business, E. Sekulow

Minority and women recruitment and selection, Oscar A. Peay (DCAS)

Commercial Communications Systems Division, A.F. Inglis

Mobile Communications Systems, J.F. Underwood

Broadcast Systems, N. Vander Dussen

Avionics Systems, W.L. Firestone

Government Communications Systems, J. Vollmer

Automated Systems Division, H.J. Woll

Astro-Electronics Division, C.S. Constantino

Missile & Surface Radar Division, (including AEGIS), M. Lehrer

G&CSD (RCA Limited, Canada), I.A. Mayson

Financial summary, J.H. Walker

Closing remarks, I.K. Kessler

Dynamic product planning*

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Mgr., Studio & Control
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Product planning must be a dynamic process beginning with assessment of a market opportunity, continuing through program implementation, and concluding with product introduction and marketing strategy. Product planning must also be a joint effort with representatives from Engineering, Marketing, and Manufacturing participating in preparing the plan. The steps involved in Broadcast Systems' product planning efforts are listed as they relate to an emerging new market opportunity—electronic newsgathering.

Assess market opportunity

The first step in our product plan was to become involved with the customer and assess the market opportunity from within. Our objectives were to understand present methods of operation and identify factors that could influence future trends.

Today 16-mm film is the principal medium used for coverage of news events. However, television cameras, videotape recorders, and electronic transmission systems are steadily gaining in popularity.

Understand user needs

In planning a new product or family of products, it is important to understand present methods of operation. This was done by analyzing both electronic and film newsgathering methods, equipment, and cost.

Identify system requirements

The significant broad characteristics of the system can be summarized as follows. One man should be able to operate the equipment over a wide range of environmental conditions, and consistently achieve performance equivalent to the latest Eastman Kodak news film stock. The specifications for the major elements of the system reflected this requirement.

Conceptualize system

This phase of the plan should not be inhibited by engineering or present technology limitations, but rather should establish a "challenge" to Engineering, while at the same time provide Marketing an opportunity to test the concept. In order to achieve film camera maneuverability, weight and size were key factors. Actual-size models were constructed to these weights and used to demonstrate our concept to over 100 customers.

Develop program plan

After four months of market research and product feasibility studies, sufficient information had been accumulated to enable a first attempt at preparing an overall program plan.

By the end of 1976 we planned to have all major elements of the system available. Highlights of the Investment Summary reflected a multi-million dollar investment to reach a potential $200M market. RCA's projected share is $50M over the estimated life of the product. Based on information presented, Management approval was obtained and a design program implemented in August of 1974.

Review technology alternatives

Selection of the right technology is critical. For a period of time we conducted parallel programs, utilizing both the CCD and the 2/3-in. plumbicon. In spite of the small size of the CCD in contrast to tube and related yoke assemblies, we decided to build a tube-type camera. Utilization of advanced technology is a good way to get ahead of competition. However, it must enable you to get to the marketplace on a timely basis with a product that will indeed meet the cost and performance objectives.

Establish engineering challenge

This should be emphasized not only in product concept, but schedule, cost of product, and performance as well. Frequent monitoring of the program by both Engineering and Marketing management is essential with any resulting change in scope formally documented.

Conduct periodic design reviews

As our program progressed, a preliminary design review was in order. Using tubes rather than CCD's required a larger size camera. This required another series of discussions with users to obtain again first hand reaction. The resulting data further highlighted the need to review our challenge to Engineering and update our product plan.

Reassess product plans

Six months after program implementation, we reassessed our program. Competitive developments were reviewed, and a revised program plan accelerating the project was prepared along

*The complete text of Mr. Klerx's speech is available from the author.

with a corresponding marketing plan calling for earlier product introduction.

Demonstrate product

Demonstrations are another important part of a product plan because they provide an opportunity to obtain industry reaction, product performance, and reliability data. The end result is a better product/market interface.

Finalize design program

During the course of product design, frequent product reviews are held and a final engineering model is produced. At this point the design program should be finalized, and the product plan updated.

Because the final engineering model was not going to be available until November, we decided to build four mockups. Our marketing strategy was to use these mockups in an intensified demonstration program, accompanied by sales presentations organized to convince customers of RCA's superior product features, and that it was a product worth waiting for.

Initiate product promotion

The timeliness of starting such promotion is very important. A premature start can lose its impact and possibly affect supplier credibility. On the other hand, when you have an exciting new product that is superior to anything competition might offer, you pull all stops as we did and are continuing to do.

Today, all signs indicate that we will achieve our objective. We have a substantial number of backorders. The balance of our product plan is yet to be accomplished. The final design model was working in time for our presentation at the Fall 1975 G&CS Annual Management Review. This was 30 days ahead of schedule.

Develop prototype plan

As soon as the performance evaluation of the engineering model is completed, we will begin construction of three production prototypes. The prototypes will be built to drawings as released to manufacturing and, therefore, will be the closest thing we have to our final product.

The protoype plan should take into account all known internal, as well as external, usage requirements. Reliability testing is an important part of this plan.

Prepare manufacturing plan

As the date for design release to manufacturing approaches, it is time to revise and complete a manufacturing plan in more detail.

Update marketing plan

As we entered 1976 we again updated our marketing plan. Existing competition has increased its efforts, and new competitors are joining in the race to capture a share of this exciting new market.

As can be seen, there are many steps in the evolution of a dynamic product plan, any one of which should be revised as changing conditions warrant. The involvement of all departments is essential to the successful introduction of a new product.

Design-to-cost

R.E. O'Donohue, Jr.
Asst. Director (Planning)
Office of the Director of
Defense Res. and Engrg.
Office of the Secretary of Defense

This is a very condensed version of Mr. O'Donohue's talk given at the G&CS Management Review. The first portion covered "Where we stand and why a planner from Department of Defense is so worried about design-to-cost." Due to space limitations that portion has been omitted from the text. The portion printed here is also condensed. The total text is extremely useful in understanding DoD's cost problems and design-to-life-cycle cost. Copies of the original text are available from G&CS.

I will discuss the design-to-cost process. Not quite in "cookbook" form, but at least how I perceive it from the third floor of the Pentagon.

Following is a definition of design-to-life-cycle cost from DoD Directive 5000.1, the fundamental material acquisition directive in the Department of Defense, written by Dave Packard, a man who is a practical, pragmatic designer of some of the best test equipment in the world. He tried to bring good commercial practice to DoD.

> "Cost parameters shall be established which consider the cost of acquisition and ownership: discrete cost elements (e.g., unit production cost, operating and support cost) shall be translated into "design-to" requirements. System development shall be continuously evaluated against these requirements with the same rigor as that applied to technical requirements. Practical trade-offs shall be made between system capability, cost and schedule."

Key points
1. "Design-to" acquisition costs.
2. "Design-to" ownership costs.
3. Trade-offs between capability, cost, and schedule.

- **A process:**
  - **—to get *modern* DOD systems**
  - **—in sufficient quantity to provide a military meaningful deterrence and war-fighting capability**
  - **—at a cost we can *afford***

Fig. 1 — Design-to-cost/design-to-life cycle cost.

To me, design-to-cost is a *process* (Fig. 1) It isn't an "ility"—it can't be an "ility." The last thing we need to make design-to-cost work is a design-to-cost manager with an office down the hall filled with people sitting on overhead. That's not the way it's done at Dassault or Kelly Johnson's "Shunk works" — *everybody* is a reliability engineer, *everybody* is a cost engineer, *everybody* is an estimator. We have to get away from this age of overspecialization—that every time we have a new initiative from the Pentagon, a new "mafia" gets created, a new special interest group.

Design-to-cost is a process of getting modern systems we can afford that are *militarily useful*. DTC does *not* mean building cheap junk! It means building systems with 90-95% of "ultimate" effectiveness at 50-75% of the cost of the "ultimate," because some tough SOB sat everyone down, let them each make their case for their "gold watch," and then made tough decisions on getting rid of the "gold plate." That is the key—as early as possible in Phase 0 *all* interests that can impact on life-cycle cost should be brought in, their "requirements" aired, and the cost impact of these requirements estimated, so that a complete set of trade-offs can be made.

- **Make cost (LCC) equal partner with "cost drivers"**
- **Convince everyone you're serious (D-X competition)**
- **Early goal establishment based on affordability**
  - **In terms designer can relate to (allocate down WBS)**
- **Flexibility — in schedule and perf/"ilities"/specs**
  - **Functional spec *not* detail design spec**
- **Define and challenge "cost drivers" incl "sacred cows"**
  - **Strong dialogue between developer and user**
- **Use technology to lower LCC rather than to increase performance — *cultural change* needed**
- **At *both* the prime and *subcontractors*:**
  - **Track estimated cost *vs.* DTC goal**
  - **Strong, constant *2-way communication* between designer, estimator, production, materials, test/QA, logistics support people with low LCC the goal**
- **Pick bidder making the best trades, the best *alternative* proposal**

Fig. 2 — Design-to-life-cycle-cost process.

Fig. 2 shows the major elements of the process. The first one is "cost drivers." Some cost drivers are shown in Fig. 3. There's nothing magic in here. Consider technology. For the last 30 years people have been pinging on engineers to get performance at any price—make it lighter, get the range longer—rather than saying "Look, I've had enough new performance. Use that technology to make it lighter, cheaper, more maintainable." There's a strong bias against that. A *cultural* revolution is required in the technological community to emphasize cost rather than performance—at least make it an equal partner.

Cost drivers *to be avoided*:
- **Undisciplined imposition of performance "requirements"**
- **Using technology to push performance rather than to lower unit and life-cycle cost**
- **Indiscriminate imposition of military specs without first evaluating their cost impact**
- **Unstable program plans (usually beyond the program manager's control)**

Fig. 3 — The bad guys.

It behooves you in industry to tell us where the cost drivers are in these specs. And it behooves us in the government to be flexible enough to accept cost-saving trade-offs. Too often specs are blindly imposed on a program without sufficient consideration of their cost impact.

Now we come to a couple of my "pet-peeve" cost drivers: missionization and consideration (Fig. 4). There is a stage in a program's life when it goes from the validation or prototype phase into the full-scale development phase. In the Pentagon we have a Major Milestone II (DSARC II), where the top Defense Assistant Secretaries meet and advise the Secretary of Defense on whether or not he should take that step. If proper trade-offs, including *all* interests that can impact program cost have not been made prior to this, it is at this interface point, when a program goes from a prototype competition to full-scale development, that "goodies" creep in, and costs go up. It's at this point that I worry whether design-to-cost is really going to work or not.

- **"Missionization"**
  - **An excuse to drop DTC principles**
  - **Process of making an "austere" prototype "militarily useful"**
  - **Occurs just prior to full scale development — a crucial time**
  - **Often drives up cost by 1/4 - 1/3 or more, with questionable marginal utility**
- **"Consideration"**
  - **Normal procurement practice when buyer allows seller a reduction in requirements**
  - **De-incentivizes seller from offering cost-saving trade-offs**

Fig. 4 — Other 'bad guys' to be avoided.

"Missionization" is a euphemism for "mini" gold plating. ("Full" gold plating has hopefully passed away with the likes of the C-5, F-111, MBT 70, or the Cheyenne helicopter.) Missionization is the excuse that now is used when costs are added to programs during the process of moving them from the prototype phase to full-scale development. We are told that missionization is "required" to make a prototype "militarily useful."

Back to Fig. 2. Pentagon top management policy for system acquisition is to be flexible and make trade-offs that save cost while not overly compromising useful military capability. But we need acceptance of this in government and industry program offices. I tell government program managers: "What you've got to do is to convince your people that you're serious. Convince the Vice President and General Manager from the contractor you're serious and, in turn, get them to convince their people *and* their subcontractors that you're serious. Or otherwise lower level back-channel communication between special-interest groups on the government and industry sides will defeat the process." They will say: "Design-to-cost is all very well and good, but not for *my* part of the program. *My* part is too important." Communication of your intent is the key.

Early goal establishment based on affordability is very important. There are really two design-to-cost goals. The first should be set early in the program, based on an assessment of how much you can afford, like $3M for the Lightweight Fighter. If no one can judge what we can afford, the goal should be related in some way to the cost for the present system. In today's fixed or declining Defense budget climate, cost growth can only lead to reduced quantities and stretchouts. Later on, when the validation phase is complete, and we are ready to enter full-scale development, there is a second design-to-cost goal, $4.6M in the case of the F-16, that is based on an assessment of cost estimates for the design that is about to be developed. That is a different design-to-cost goal than the first one. There is less flexibility in a program when it gets to the stage of going into full-scale development than when it is just a conceptual idea. The trade-off effort and the money spent in early phases are highly leveraged because more flexibility exists before metal is cut. This is recognized in the Pentagon, and we're trying to determine how to improve the "front end" process, perhaps taking a little longer to think through programs in the conceptual phase.

Flexibility is very important. There must be a willingness to trade by the buyer and by the user. In the case of the military, the user is different from the buyer. There's got to be communications there.

Industry can help. Industry people often "help" write the RFP and the requirements documents. One of our challenges is to figure out how to incentivize you in industry to want to bring in a lower cost system when you are often incentivized the other way by the cold facts of doing business.

We in DoD are trying to get the RFP's to specify that we're going to pick the bidder making the best trades. That's a novel idea. We don't have any cookbook but the people who sit on source selection and evaluation panels seem to need a cookbook approach. They're not really equipped to deal with a non-cookbook approach to proposal evaluation.

Goal definition
Flowdown to subcontractors
Government furnished equipment
Acquisition cost *vs.* life-cycle cost

Abnormal economic escalation
Congressional impact
Goals based on good cost estimates
Working level acceptance

Government
Industry

Fig. 5 — Design-to-cost-problems.

Fig. 5 shows some of the problems. I've dealt with most of them already.

Acquisition *vs.* life-cycle cost. Before now most design-to-cost goals were in terms of the unit cost of the hardware. The XM-1 tank is $507,000, the F-16 is $4.6M, and sometimes trade-offs get made to meet that unit cost which are detrimental to life-cycle cost. We recognize this, we're trying to work on it. Our problem is that the visibility that we have of actual operation and support costs of a system are poor compared to what we've had of acquisition and R&D costs. Until we get that problem solved we don't really know what life-cycle cost is, other than in terms of related parameters such as reliability, availability, maintainability, and the number and quality of people involved.

Estimates have to do with a design-to-cost goal in the second part of the program when the full-scale engineering and the acquisition phase starts. Then it is based on good estimates of the design to be developed. Design-to-cost trade-offs should continue in engineering development phase.

- **Ability to *measure* LCC inadequate**
  - **— Design to unit "flyaway" or procurement cost**
- **DEPSECDEF support cost visibility task force**
  - **— Improve measurability of operation & support costs**
  - **— Aircraft systems first such effort**
- **RFP must make DTC/DTLCC equal partner with performance in source selection**
  - **— Buyer should have short spec which allows common sense trade-offs in bidders' respone**
  - **— Rest of RFP package must be consistent with DTC/DTLCC too, not just "boiler plate"**

Fig. 6 — Life-cycle-cost trades.

The lower half of Fig. 6 indicated my idea of a good RFP: a short *spec*. The Lightweight Fighter initial spec was five pages. The negative psychological impact of sending you a 500-page bid package defeats the whole purpose of design-to-cost and trade-offs.

- **Iterate—don't accept the first solution**
- **Communicate management's intent to enforce targets**
- **Parametric cost estimating is useful and appropriate**
- **Use experienced people working as a team**
- **Keep specifications simple and test-result oriented**
- **Achievement of modularity requires discipline in design management**

Fig. 7 — Design-to-cost lessons learned.

Fig. 7 shows a lessons learned chart from a major contractor who builds both commercial and defense equipment. They built a piece of RF prototype hardware, on in-house funds before a "formal" requirement existed, "betting on the come" and won a recent competition. Iteration is important, but sufficient time is needed. Notice also the emphasis on communicating top management's intent.

Establishes, as a design goal, a unit production cost derived from the price that the marketplace is willing to pay for a given volume and performance.

This unit production cost is a primary design parameter equal with performance.

Fig. 8 — Design-to-cost.

Fig. 8 shows a definition from a presentation given by a major builder of pocket calculators. Unit cost drives this particular project because of the large quantity.

- **Project manager**
  - **—authority to make timely trade-offs**
- **Principal responsibility vested in small, highly skilled team**
- **Continual trade-off reiterations**
  - **—Cost reductions *vs.* performance**
  - **Assessment of new findings**
- **Periodic reviews with central management**
- **Continuity of project management conception through manufacturing**

Fig. 9 — Design-to-cost implementaion.

The first point on Fig. 9 is important. In some project manager schemes, we have matrix organization with the so-called project manager off on the side. He's really a project coordinator trying to work through all of the functional departments to get things done. He must have authority. Same point for "principal responsibility." Continuity is an important point. The manager ought to stick around long enough so he can reap the ills as well as the profits of his venture.

Fig. 10 is my checklist for what makes a good design-to-cost RFP. The "Spacecraft X" column is based on my review of a draft of a recent major spacecraft RFP.

First and foremost, the top manager must get up and tell the bidders that he's really serious and he is going to tell all his troops that he's serious and to stop all the back-channel communicaiton to the contrary between the various "mafias."

Next, I would put the cost goals on the first or second page, succinctly and unambiguously stating what is really wanted.

Key Question	Spacecraft "X" RFP	DTC RFP
• All-out effort made to convince industry DTC is critical?	no	yes
• DTC goal stated?	no	yes
— On page 1 or 2 of RFP?	no	yes
— Unambiguously?	no	yes
— Allocation methodology given?	no	yes
• Functional spec instead of detailed spec?	yes?	yes
• Award to bidder making best trades (#1 priority)?	no	yes
• Bidders required to specify "cost drivers?"	yes?	yes
• Technology utilized to lower LCC rather than drive performance?	no?	yes
• Spacecraft spec not "RSS" of everybody's "good idea?" (forces "camel" response)	?	yes
• Schedule flexibility to allow trades?	no (IOC driven)	yes
• Sufficient emphasis on management approach to meet DTC goal?	no	yes
• Cost estimating and tracking required?	yes	yes
—Methodology specified?	no	yes
• Sufficient emphasis on DTC approach at subcontractor level?	no	yes
• "Technical leveling" avoided?	?	yes
• Sufficient time given in phase I to make trades and redesigns, especially critical sub-systems?	?	(also in phase II)
• Strong emphasis in RFP on planning and management for phase I?	?	yes
• Detailed design required at end of phase I?	yes	trades reqd in all phases
• Proposal evaluation concentrates on big cost items (or must every "square" be filled)?	no	yes

Fig. 10 — Design-to-cost RFP checklist.

Functional spec—simple. What do you want to do from a military standpoint? Not how do do it.

Award to bidder making best trades is very important—often the "nonresponsive" bid, a revolutionary notice by today's standards. Using technology to lower cost is another revolutionary idea. Commercial industry has been using it for years!

The allocation methodology and the cost estimating and tracking can be back on page 40 of the RFP because this is a *method*, a tool—this is not design-to-cost.

Sufficient time—it takes three months for each complete design iteration.

The last point is important. Filling all the "squares" can be wasteful of valuable resources. In the DX competition, Litton was required to expend a tremendous amount of effort defining the galley because there is a galley "mafia" in NAVSEA. Yet, the galley was of trivial overall importance.

- **Life-cycle cost is the key parameter**
- **Specify "affordable" total program cost early in phase 0**
  - **— Relate to cost of present capability, if no other approach available**
- **Adapt policy of flexibility in performance and schedule**
  - **— Functional spec *not* design spec**
- **Different DTC goals for different "chunks"—but *process* same:**

Chunks	*Process*
—RDT&E	**—Define "cost drivers" and go after each to eliminate frills**
—Spacecraft and related systems	
—Launch and support	

- **Allocate initial DTC goal down 4-5 levels in WBS in individual work packages**
- **Translate goal to terms meaningful to designer**
  - **— Current yrs or man-hours**
  - **— Back to first and subs units—individual goal**
  - **— Break down low enough in WBS so one person has responsibility and authority over achievement**
- **Tiger team on each WBS level; team to include design, materials, production, estimating test, support people**
- **Similar approach with subcontractors**
  - **—Requires flexibility, *incl.* contractual (especially schedule)**

Fig. 11 — Design-to-cost for low-production programs.

A lot of people say DTC doesn't apply to low-production programs (Fig. 11). When the program is a low-production program, you have to look at the "chunks" that drive the cost of the program; which are these, for example, for a spacecraft (4th bullet). Look at the cost drivers in these "chunks." The rest of the methodology for low-production programs is essentially the same.

- **Management desire**
- **Contract rqmt - definitized guidance needed**
- **Flexible customer *re* requirements**
- **Cost-reduction studies**
- **Cost trade studies**
- **"Grinding" job — attention to details**
- **Engineers "key"**
- **Management visibility**
- **Control ECP's — nice to have**
- **Escalation considerations**
- **Competition when possible**
- **Development cost and schedule flexibility**
- **Subcontractor review and control**

Design-to-cost can work and is working. *But* cost reduction doesn't come naturally. Management must make it happen.

Fig. 12 — Lessons learned summary.

We looked at 20 successful design-to-cost programs to see what thread ran through them (Fig 12). Management desire was critical to all successful DTC program.

Attention to detail. Engineers are the key people, not the office down the hall with "Design-to-Cost" over the door.

Cost reduction is a key point—it doesn't come naturally. Management must *make* it happen. You've got to pound all the "goodies" out of all your "mafias" and the program manager on the government side hopefully has the guts to pound it out of his "mafias."

- Cost a major concern for foreseeable future
- DTC can work—is working
- O&S cost will receive increased emphasis
- Production cost growth must be controlled
- Issues will continue to receive major OSD attention

Fig. 13 — Summary.

Fig. 13 is self-evident. These points flow from what I've already said. DTC is no longer a buzz word. We must make it work because we can't afford to modernize our forces otherwise, and if we don't modernize our forces the Russians are really coming. In fact, Mal Currie (Director of Defense Research and Engineering), in his speech to the NSIA a few weeks ago, said that based on his analysis, if current trends continue, the Russians will be the dominant world power by 1985. Now that's only 10 years away. Kids that aren't born today will only be in the fifth grade then—guess they'll be learning Russian. By 1985 the Russians will be the dominant world power if current trends continue. Only by making such tools as design-to-cost work will we be able to get the affordable, effective military needed to reverse this trend.

Design for reliability

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The mark of a professionally executed product is its reliability. Our current environment compels us to make RCA synonomous with reliability because:

1) our customer's expectations are greater than they have ever been;
2) the competition is improving their equipment reliability;
3) reliability increases our product's sales acceptance; and,
4) it adds to our reputation.

By "designing-in" the proper amount of reliability, we can make a reasonable profit.

Reliability must be designed in from the beginning, and is a continuing process. We need information feedback through the entire life cycle of the product to do the job successfully, and the earlier we get this feedback, the more cost effective we will be.

Essentially, we must establish a tolerable time to failure. We must strike a balance between the product cost, including a given level of reliability, and the operating cost. One way to measure this reliability is mean time between failures (MTBF). Once an analysis has been made during the product planning cycle, the desired MTBF can be determined, and, once determined, it must be included as an item in the specification, just as other performance parameters are included. The overall system reliability is a composite of the individual subsystem reliabilities. Each component must, therefore, have reliability specified so that the allocations are consistent with the overall system requirement.

Since we cannot afford to build a reliability department, the individual designer must be trained to assess his designs interactively during the design process. There are five feedback loops (Fig. 1).

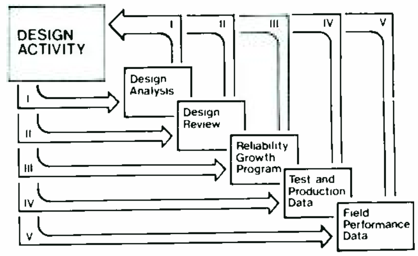
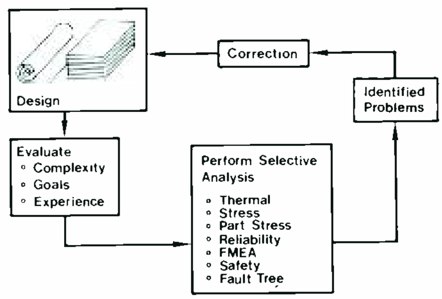


Fig. 1 — The five feedback loops.

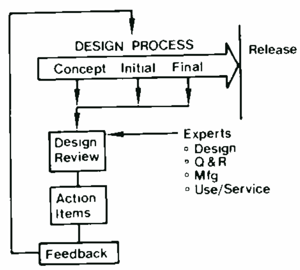
Analysis feedback loop

As the designer includes reliability elements in his design, it becomes necessary to assess the degree to which he has reached his goal. The reliability analysis methods available to do this include parts count analysis, stress analysis, or failure mode and effects analyses.



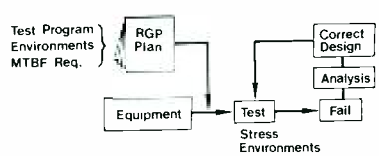
Design review feedback loop

Here we do a creditable job and keep innovating. For instance, recent design reviews in broadcast have introduced field support personnel at the design review stage to get field and installation experience incorporated into the early design trade-off decisions.

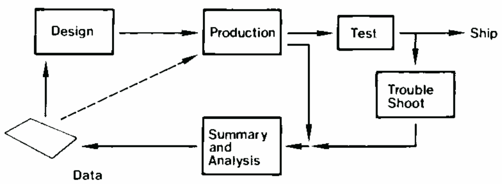


Reliability growth program feedback loop

Reliability studies made in government and commercial applications have shown that the reliability achieved on early models is only about 20 to 25% of the designed-in reliability. By using the reliability growth testing program, we can approach the designed-in or inherent reliability faster than other methods. For a more extensive discussion, see the paper by Aires in this issue.

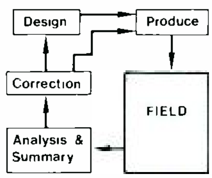


Production feedback loop



One of the principal purposes of test should be the generation of data that engineering can use to correct the design and that manufacturing can use to improve yield. What we propose to do, therefore, is introduce, in the quality assurance operations, methods of data collection and analysis that will improve feedback to the activities which can implement corrective action.

Field data feedback loop



While this has the disadvantage of being late in the game, it still can make a contribution to improved reliability, for it is the only measure of performance in the actual customer environment.

Each of these five feedback loops is important in arriving at a cost effective design that meets ours and our customer's *requirements* — and is profitable!

Application to government operations

This iterative design approach applies to government operations as well, but, in addition, we must be concerned about the changing government environment.

- Joint Logistics Commanders workshops
- Life-cycle cost
- Design-to-cost
- Reliability improvement warranty

In May of this year, the Joint Logistics Commanders sponsored a workshop that was the culmination of working sessions held since November, 1974. It identified over 170 action items including: developing improved methods of defining mission profiles, improving software reliability, defining better reliability testing programs, and improving field feedback systems.

Another effort centers in the Air Force. A new program office called PRAMPO (Producibility, Reliability, Availability and Maintainability Program Office) has been established. It's principal function is to reduce operation and support costs in fielded and new equipments. It plans to channel funds through program offices to improve this equipment reliability and maintainability as well as to support these new methodology developments.

The government is also moving in the direction of life-cycle cost. Life-cycle costs are to be a proposal evaluation criteron, and it is necessary to demonstrate how these criteria will be used to make *optimum design decisions* to minimize the total life-cycle cost.

A reliability improvement warranty will appear in some new contracts. This is an attempt to capitalize on the commercial warranty practice. It requires the contractor to maintain his equipment under warranty for an extended period of time—perhaps five years. Care must be exercised in accepting this type of contract.

Conclusion

To achieve our goal of customer acceptance, low warranty costs, and higher profitability, reliability must be designed in from the beginning. Management must provide engineers with the tools to design interactively so that the five feedback loops are closed. Close contacts should be maintained with new developments in reliability methodology.

Software by design

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In a company with a well-deserved reputation for high-performance hardware, we are sometimes uncomfortable in the world of computer software—a world in which we increasingly find ourselves. However, as we dig into computer programming, we quickly find (sometimes to our surprise) that the disciplines and managerial techniques we have developed and refined in years of hardware experience are quite usable and adaptable to software. The secret, however, is to recognize that the types of people involved and the degree of product visibility are different. In enlarging this theme we can see how the principles we already know and apply in our daily lives in hardware development can be used to achieve software:*by design*. Four topics are considered here in our pursuit of the overall goal of better design for software 1) the characteristics of real-time systems; 2) the development cycle necessary for good software; 3) the available system design aids; and 4) the trade-offs to be evaluated for any complex system.

Characteristics of real-time systems

Looking at the key parameters of a real-time system, the most obvious characteristic of real-time systems is the fact that the computer and its attendant software are an embedded part of a system. This means the computer has many and varied interfaces with the other subsystems in the overall system package. Fig. 1 suggests some of the characteristics of real-time computer systems.

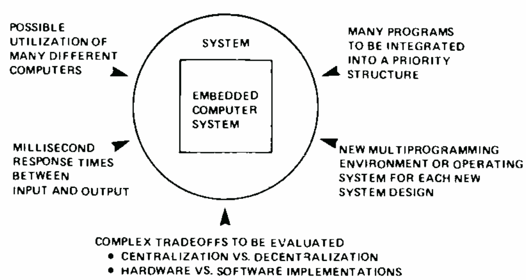

Fig. 1 — Characterization of real-time systems.

To complicate the decision-making process, significant cost and staffing considerations exist. We must consider cost when sizing computing hardware because the unit cost of a completed instruction increases significantly as the limit of available core or computing time is approached. We must also consider the skills as well as the interactions of the people involved since software development is such a people-dependent process.

Development cycle

The development cycle for software should be, but seldom is, a highly organized, tightly disciplined, preplanned process. Software development is a complicated process for a variety of reasons: 1) the magnitude and the number of computational processes to be planned and executed make the system complicated, 2) the process is highly people-dependent, 3) overall optimization of the entire software system is unlikely, and 4) the impossibility of testing all paths mandates that trade-offs and compromises be made. Fig. 2 shows a well thought-out development cycle. One caution is in order here. Often we forget to budget time and money for the iterative interactions shown by the solid arrows and for the documentation shown by the dashed arrows. Consequently, we end up with downstream schedule crises.

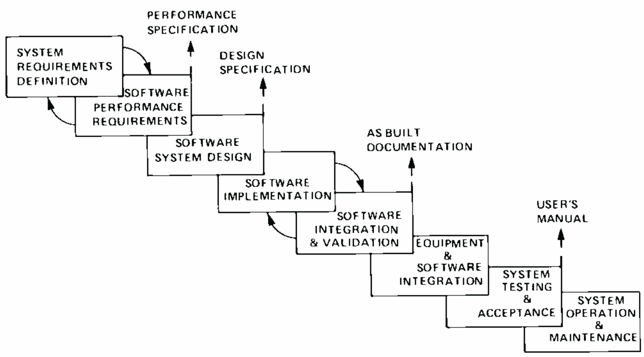

Fig. 2 — Software development process.

System design

We cannot discuss software design without considering system design. A powerful systematized design methodology, the Functional Flow Diagram and Description (F^2D^2)[1] helps in breaking down the most complicated system into the lowest functional elements of the system. Function block diagrams and functional descriptions for every level of system operation solve the engineering Tower of Babel problem. In short, F^2D^2 provides a common language for the system, hardware, and software engineers, and the design reviewer.

Table I — Trade-offs to be evaluated when choosing a centralized or decentralized processing system.

	Centralized	*Decentralized*
Operational speed	High	Moderate
Efficiency	High	Moderate
Level of control	Low	High
Problem visibility	Low	High
Test time	High	Moderate
Skill requirements		
Programming	High	Moderate
Computer	High	Moderate

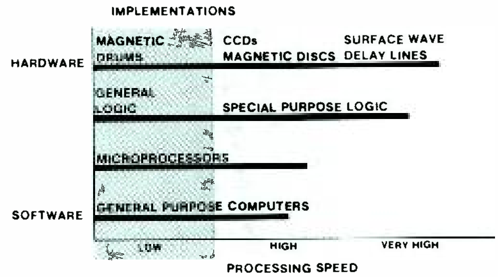

Fig. 3 — Hardware *vs.* software trade-offs to be evaluated when choosing an implementation approach.

Trade-offs

Table I and Fig. 3 demonstrate the major areas of trade-off to be analyzed: 1) centralized versus decentralized processing capability and 2) hardware versus software capability. Assessing the key parameters listed in the table, we note pluses and minuses for each approach. Similarly in Fig. 3 we see that the advance of technology is continuously muddying the waters of the hardware/software trade-off process. The clear conclusion is that there is no one universal right way.

In analyzing these trade-offs, we must consider the individual contract requirements. We must also weigh heavily *what the customer wants* as well as what we think is best for him.

Summary

If we are perceptive enough to understand the customer and his requirements, if we are realistic enough to recognize the problems of software development, and if we take advantage of the skills and technology we already possess, we can surely develop both the competence and confidence we need to achieve software—by design.

Reference

1. Lurcott, E.G.; "Functional flow diagrams and descriptions for AEGIS—a systems engineering management tool," *RCA Engineer*, Vol. 10, No. 1 (June-July 1973) pp. 34-37.

PRICE*

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PRICE (Programmed Review of Information for Costing and Evaluation) is an RCA-developed parametric cost-modeling technique. It provides reliable estimates of system acquisition costs (development and production), based upon physical parameters such as quantity, size, weight, power consumption, environmental specification, type of packaging, and level of integration; and schedule parameters such as months to first prototype, manufacturing rate, and amount of new design. PRICE has been particularly useful in developing relative costs of competitive systems.

Early cost measurement of concepts is crucial to a new venture, since there is little opportunity to change program costs significantly once a design has been detailed. PRICE was developed to operate with a limited description of a concept so that many alternatives can be cost examined before designs and bills of material are finalized. It is also used extensively for independent assessment of conventionally prepared cost estimates. However, PRICE was never intended to be a substitute for detailed cost estimating; its value lies in the parametric testing of reasonableness of the detailed estimates. If deviations from established trends are indicated by PRICE, the detailed estimates should be investigated.

PRICE does not provide computer software or life-cycle cost predictions. These areas are currently under active study and will be cost-modeled in the near future. PRICE also does not provide costs for brick and mortar, and there are no plans to add such capability to the model.

Numerous parametric cost models exist throughout industry and government agencies, each designed to cover a specific range of products or systems and requiring its set of unique inputs (which include performance features, technologies, and quantities). Numerous models are required because different systems have different cost-significant characteristics that require unique mathematical regressions to quantify the cost effects.

PRICE was formulated as a universal system to generate appropriate regressions or CER's (cost-estimating relationships) for a range of products or systems. In essence, it performs a multidimensional extrapolation of past experience to predict cost.

Inputs to PRICE cover an infinite range of systems. Since all products must have weight and size, these are used by PRICE as the principal descriptors. Electronic areas are characterized by their componentry. Mechanical structures can be described in terms of types of material, construction, and densities. Procedures of PRICE have been developed to process situations where weights and sizes are not known. In these cases, the physical characteristics can be generated by the program.

In addition, certain PRICE inputs describe the way an organization operates: its way of doing business. Thus, the model can be customized to reflect appropriate cost element definitions.

PRICE outputs feature costs for the development and production phases. Outputs are categorized by such elements as Drafting, Design, Project Management, Prototype, and Special Tools and Test Equipment. PRICE can also develop an engineering schedule or measure the reasonableness of an input schedule. Variations of parameters such as physical features, componentry, percentage of new design, and reliability (MTBF) can be quickly assessed. Integration and test costs for both engineering and production can be developed by PRICE at any level of the work breakdown structure.

PRICE has provisions to include the costs for GFE and purchased items. It can also evaluate the costs of their testing, modification (if necessary), and integration and test with other equipments.

Fig. 1 shows a PRICE output for a cost study on a hypothetical military airborne radar. The top third of the format lists the program inputs. The rest of the format includes the derived estimates, schedules, and cost ranges.

PRICE automatically computes the effects of phase interactions between engineering and manufacturing. In addition to considering a normal performance period, PRICE can output cost manifestations due to accelerated or protracted enginering schedules or due to an operation plan that requires stops and restarts of production effort with varying intervals.

```
AIRBORNE RADAR     MIL-SPEC     STANDARD     MAY 10,1876

INPUT DATA
QTY        200. PROTOS     10.0 WT       45.000 VOL       0.780 MODE       1.
QTYSYS       1. INTEGE    1.000 INTEGS    1.000 AMULTE 125.00%. AMULTM 125.00%

MECH STRUCT
WS       10.000 MCPLXS    0.000 PRODS     4.200 NEWST     0.900 DESRPS    2.000

ELECTRONICS
USEVOL    1.000 MCPLXE    0.000 PRODE     4.300 NEWEL     0.800 DESRPE    2.000
PWR       0.000 CMPNTS       0. CMPID     0.000 PWRFAC    1.000 CMPEFF    1.000

ENGINEERING
ENMTHS     6.0 ENMTHP      0.0 ENMTHT      0.0 ECMPLX     1.200 PRNF      0.200

PRODUCTION
PRMTHS    25.0 PRMTHF      0.0 LCURVE    0.000 ECNE       0.000 ECNS      0.000

GLOBAL
YEAR     1976. ESC       8.30% PROJCT    1.000 DATA       1.000 TLGTST    1.000
PLATFM   1.800 SYSTEM    1.000 PPROJ     1.000 PDATA      1.000 PTLGTS     1.00

PROGRAM COST              DEVELOPMENT        PRODUCTION        TOTAL COST
ENGINEERING
 DRAFTING                        256.               25.              280.
 DESIGN                          950.               74.             1024.
 SYSTEMS                         152.                0.              152.
 PROJ MGMT                       197.              332.              529.
 DATA                             62.               16.               78.
  SUBTOTAL(ENG)                 1617.              447.             2064.

MANUFACTURING
 PRODUCTION                        0.             6800.             6800.
 PROTOTYPE                       744.                0.              744.
 TOOL-TEST EQ                    100.              202.              301.
  SUBTOTAL(MFG)                  844.             7002.             7846.

  TOTAL COST                    2461.             7449.             9910.

VOL       0.780 AVCOST    34.00 TOTAL AV PROD COST  37.25 LCURVE  0.897
WT       45.000 ECNE      0.072 ECNS     0.021 DESRPE 0.494 DESRPS  0.210

MECH/STRUCT
WS       10.000 WSCF     12.821 MECID    0.000 PRODS  4.200 MCPLXS  5.602
ELECTRONICS
WE       35.000 WECF     44.872 CMPID    0.000 PRODE  4.300 MCPLXE  7.903
PWR     178.598 CMPNTS    3969.                PWRFAC 1.000 CMPEFF  1.000

SCHEDULES
ENMTHS    6.000 ENMTHP   14.874 ENMTHT  24.679 ECMPLX 1.200 PRNF    0.200
PRMTHS   25.000 PRMTHF   50.229 AVER. PROD RATE PER MONTH           7.928

COST RANGES               DEVELOPMENT        PRODUCTION        TOTAL COST
     FROM                       2152.             6205.             8358.
     CENTER                     2461.             7449.             9910.
     TO                         2916.             9289.            12205.
```

Fig. 1 — Typical PRICE output.

PRICE can measure many aspects of a proposed project to determine their significance and their level of influence. It can direct attention to those factors whose modification can be most rewarding. For example, a change of engineering schedule from 8 to 10 months and release of production at the 11th month might result in reduction of the total cost of a particular project even more than reducing the product weight by 10%. Under another set of conditions however, a reduction of assembly weight might far outweigh any conceivable schedule change. On occasion, technology will completely govern the pattern of cost variations.

There is a mode of PRICE called GEOSYN—an acronym for geometry synthesis, which is truly a design-to-cost procedure. For GEOSYN, the target cost, quantities, product class, and level of technology are entered as inputs. GEOSYN outputs include design limits, i.e., weight, size, component count, and power dissipation. For the design-to-cost project, therefore, if the design is held to the GEOSYN-derived limits, there is a good chance that the cost target will be met.

In 1971, the U.S. Air Force and NASA were the first to contract with RCA for services of the PRICE model. Their usage has increased each year since and several other Government agencies are now using PRICE. Records indicate that the various Government agencies have processed thousands of cost studies.

Many aerospace and electronics companies learned of PRICE through its widespread government use. Because of expressed industry interest, RCA Management chartered the G&CS PRICE Systems Activity to offer PRICE commercially in August 1975.

Since then, agreements for the use of PRICE have been effected with eleven major companies and others are now actively evaluating their potential use of the model.

*For additional information about PRICE, contact PRICE Systems, (609) 755-3529.

RCA's economic outlook—the path is up

R.J. Eggert| J.R. Lockshin

What's going on in this complicated, agitated world and what is the likely effect on me? — Questions we have probably asked ourselves many times in the past few years. This paper may help to give the answers by providing insight into the economist's point of view, showing the status of important economic indicators for the future, and providing an outlook of their meaning.

PROBLEMS with the world economy during the past years have challenged industry's capability to perform satisfactorily. Among these problems have been persistent inflation, high unemployment, double-digit interest rates, instability in international monetary markets, shortages of energy and raw materials, restrictive monetary policies, restrictive government regulations, etc.

Within the ever-changing economic environment, the industrial economist is both an advisor to management and a forecaster, assisting sound decision making in both corporate and divisional planning.

Usually, the economist's prime mission is forecasting, for which he uses a number of methods:

- His own judgment
- Judgment of economists outside his company
- Quantitative analysis techniques
- Leading indicators
- Surveys and consumer plans

He combines these methods using advanced mathematical methods *and* personal judgment to arrive at his forecasts.

At this point, we should mention econometric models, which represent an attempt to express an economy in mathematical terms. Econometric models are based on the premise that by studying past relationships between certain economic factors—for instance, between capital investment and interest rates—it is possible to develop a series of forecasting equations. Econometric models come in various sizes. Those designed to incorporate the entire U.S. economy are incredibly complex, and usually contain several hundred equations. Smaller versions, such as those built for a single industry, may consist of less than a dozen equations.

Although some of the results in this paper are based on RCA econometric models, their details are not included. Those interested should see Ref. 1.

Generally forecasts fall into two categories: *macroeconomic*—concerned with the entire economy—or *microeconomic*—dealing with specific industries, including interaction between consumers and procedures.

Reprint RE-22-1-18 Final manuscript received March 15, 1976; minor revisions June 2, 1976.

How good are forecasts?

Forecasting accuracy is a good measure of an economist's success. The track record for the years 1970-1975 attests to the degree of excellence of RCA's economic forecasting. Some years have been better than others!

Preparation of forecasts requires, in addition to study of economic data and mathematical modeling, frequent

Robert J. Eggert was appointed Staff Vice President-Chief Economist for the Business Research area of Corporate Development of RCA in January, 1974. Mr. Eggert earned the BS and MS in Marketing, Economics, and Statistics, at the University of Illinois. He completed the preliminary work for a doctorate at the University of Minnesota. Prior to joining RCA in 1968, Mr. Eggert was with Michigan State University, where he was Director of a new Agri-Business program for the College of Agriculture and College of Business. Before that he held economic planning, marketing research, and scheduling positions with the Ford Motor Company for 17 years, the American Meat Institute for 11 years, and was an assistant professor at Kansas State College for 3 years. Mr. Eggert is also a member of the Harvard Business School Discussion Group of Industrial Economists and received their prestigious "Seer of the Year Award" in 1973 for accuracy in forecasting. He has received numerous other awards and is active in several business associations and on key government committees.

Since this article was written, Mr. Eggert has retired.

RCA's track record

...in inflation forecasting
(inflation — GNP deflator)

% Change from previous year			
Year	Forecast	Actual	(actual vs. forecast)
1970	3.8%	5.3%	1.5%
1971	4.2	5.0	0.8
1792	3.3	4.2	0.9
1973	3.5	5.8	2.3
1974	7.0	9.4	2.4
1975	10.5	8.9	-1.6

Average absolute error = 1.6%

SOURCE: Forecasts from RCA's Economic Forecasting Model. Projections were those made in the first month of the year (January) for the full year ahead. Actual from the U.S. Department of Commerce—revised data one year later.

...in economic forecasting
("real" GNP)

% Change from previous year			
Year	Forecast	Actual	(actual vs. forecast)
1970	0.8%	-0.3%	-1.1%
1971	2.4	3.0	+0.6
1972	5.6	5.7	+0.1
1973	5.9	5.3	-0.6
1974	1.6	-1.8	-3.4
1975	-3.0	-2.0	+1.0

Average absolute error = 1.1%

SOURCE: Forecasts from RCA's Economic Forecasting Model. Projections were those made in the first month of the year (January) for the full year ahead. Actual from the U.S. Department of Commerce — revised data one year later.

...in color tv forecasting
(millions of units)

	Forecast	Actual	% error (forecast vs actual)
1970	5.1* (EIA only)	8.8	6.2
1971	5.6 (EIA only)	6.2	-9.7
1972	7.9**	8.4	-6.0
1973	8.3	9.3	-10.6
1974	8.0	7,8	2.6
1975	6.6	6.7	-1.5

Average absolute error = 6.1%

*Before release of 1969 fourth quarter data.
**Forecast made using only the information available as of January 1972, but done later in the year.

SOURCE: Forecast from RCA Economic Research's color tv model. Projection made after the release of the previous year's economic data, usually January or early February of the year cited. Actuals are based on data one year later.

Jane R. Lockshin, Director and Senior Economist, Economic Research, New York, N.Y., has been with RCA for the past six years, the last two in her present capacity responsible for defining the future economic environment for RCA planning. In addition, she provides the corporate staff with economic analysis and forecast for the RCA Industries. Mrs. Lockshin earned the BA in mathematics from Barnard College in 1965 and the MS, also in mathematics, from the Carnegie Institute of Technology in 1966. She began her career at RCA as an Economist; in 1970 was promoted to the position of Senior Economist; and then to Manager, Economic Research in 1972. From 1967 to 1969 Mrs. Lockshin was an Associate Economist at the First National City Bank in New York. Prior to that, she was Lecturer in Mathematics at the City College of New York.

Since this article was written, Ms. Lockshin has been named Director, Financial Analysis

contact with other economists in business and government—generally by participation in groups that meet regularly to cover economic issues and the business outlook.

To put the role of the economist's forecasts in perspective, it should be pointed out that business planning is based on many inputs. Each industry or product division contains specialized organizations very familiar with their product lines. They develop both technological and marketing forecasts. They use their own methods of forecasting but often work closely with the economist's models. In the end, all available information is used in an attempt to find the best business approach. While there are exceptions for most products, an improving economy helps the "bottom line"; a declining economy hurts.

The information shown below is presented in the manner and format the economist uses to inform his company of his findings. The factual summaries—all charts and tables—are updated each month or each quarter depending on the flow of basic information from the government, trade associations, or private research organizations.

Macroeconomics

A look at the U.S. economy

We now turn our attention to the U.S. economy and first look at some of the most significant indicators.

In general, the economic recovery continues—buoyed, for the most part, by consumer spending.

a look at the US economy

GNP, inflation, and unemployment—This table shows the percentage change from 1975 and compares the RCA figures to those of other responsible forecasters. It indicates 5.6% real growth, 5.7% inflation, and 7.5% unemployment.

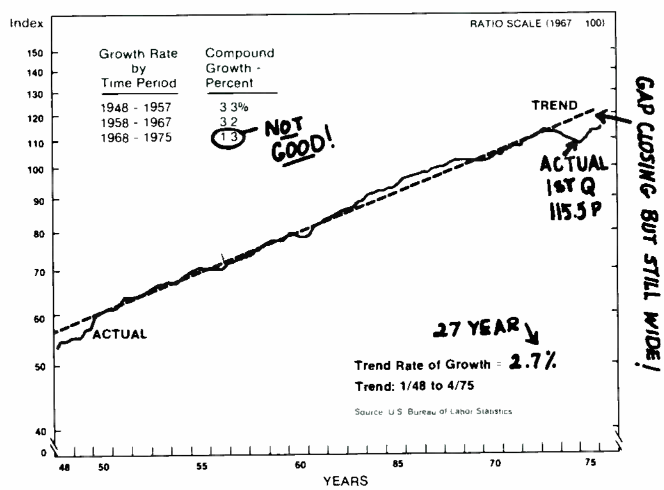
Percentage change 1976 from 1975

	Constant GNP	*GNP deflator*	*Current $ consumer durables*	*Pre-tax corporate profits*	*Current $ GNP (billons)*	*1976 unemployment rate (percent)*
Manufacturers Hanover Trust * (Mar)	6.8%	5.8%	21%	33%H	$1694	7.2%
Conference Board (Apr 22)	7.0H	5.5	22H	33H	1693H	7.1L
W.R. Grace * (Nov. 26)	6.5	6.5H	17	23	1674	7.7
Union Carbide * (Jan. 13)	6.4	5.0	18	29	1651	7.8
B.F. Goodrich (Feb. 10)	6.4	5.6	18	26	1684	7.2
Chase Econometrics (Jan 27)	6.5	5.5	20	29H	1684	7.2
Mellon Bank (Apr 23)	6.8	5.3	20	29[2]	1686	7.3
Equitable Life (Apr 28)	6.0	6.2	16	25	1680	7.5
Bankers Trust (Apr 26)	6.5	5.4	19	26	1683	7.3
E.I. Dupont de Nemours (Jan. 28)	5.9	5.7	16	32H	1678	7.6
Schroder, Naess & Thomas (Jan. 30)	5.9	5.8	16	29	1681	7.5
Prudential Insurance (Apr 29)	6.5	5.5	22H	26	1684	7.3
Data Resources * (Feb 3)	5.9	6.1	16	25	1660	7.6
U.S. Trust (Apr 26)	6.3	5.3	21	25	1675	7.3
Irving Trust (Feb 5)	5.8	6.0	18	23	1681	7.6
Wells Fargo Bank (Feb. 18)	5.7	5.2	NA	26[1]	1667	7.8
Security Pacific Natl. Bank (Feb. 26)	5.7	5.5	17	31	1672	7.6
American Express * (Dec. 15)	5.7	6.1	15	27	1657	7.6
RCA (Feb 20)	5.6	5.7	16	25	1672	7.5
General Electric (Feb. 25)	5.6	6.4	16	30	1684	7.7
Lionel D Edie (Apr 23)	5.9	5.2	20	22	1671	7.5
C.J. Lawrence (Apr 1)	6.1	5.0L	20	26	1669	7.4
Dean Witter (Feb. 23)	5.4	5.6	12	23	1669	7.5
A.G. Becker * (Dec. 4)	5.3	5.4	8L	22	1641L	8.3H
First National City Bank (Feb. 23)	5.2	5.2	13	14L	1659	7.9
Harris Trust (Jan. 28)	5.1L	5.5	13	24	1662	7.8
Table Mean	5.9	5.7	15	26	1670	7.7
Table Mean last month	5.7	5.7	15	24	1648	7.8

*Based on unrevised GNP accounts data
[1]After tax, not included in table mean
[2]Federal Reserve Board, 170 large manufacturing companies, after tax, not included in table mean
NA: Not available
H: highest forecast in column
L: lowest forecast in column

SOURCE: published and personal communication from the Economics Departments of the firms listed.
RCA Forecast: RCA Economic Forecasting Model, 2/20/76.

Productivity — A key concept to progress. The last year and a half shows performance way below the 2.7% trend line; however, the gap is rapidly closing with the sharp upturn in 1975.



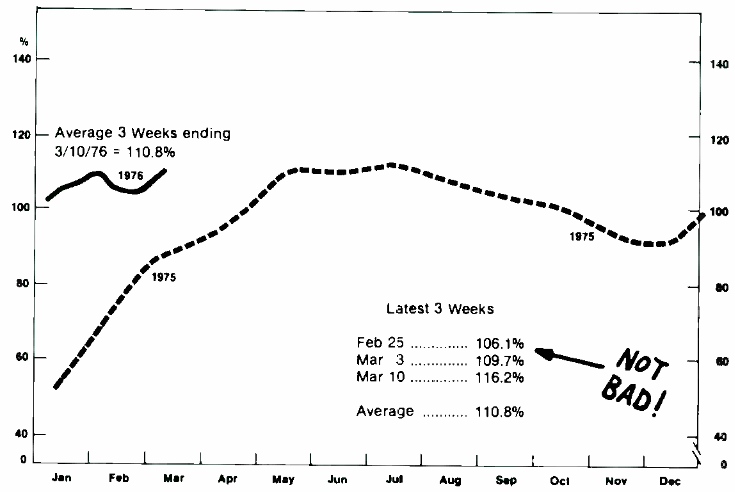
Consumer forecast confidence—An indicator of the consumer buying mood reached its lowest level since World War II in December 1974, then rose sharply, but declined somewhat in August 1975 due to high interest rates and concern about double-digit inflation. Since then, however, it has shown steady gains.

In the chart at the right, the index of 100 is the 1957-59 average, forecasted by consumer for 6 months ahead. The index is the average index of: a) expected household income, b) expected employment situation and c) expected local business for 6 months. Source: Singlinger & Company

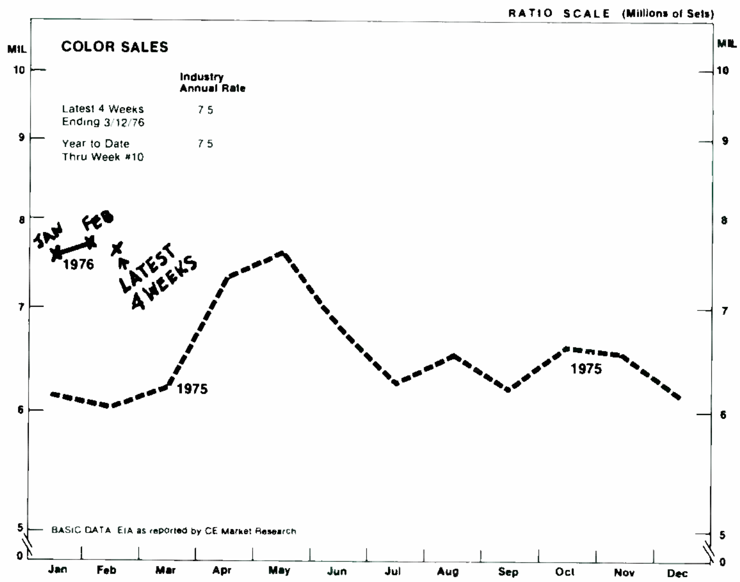
Customer appraisal of "value received"—This chart of "value received" for money spent, by product category, is related to customer confidence. Note the very high rating of tv and the very low rating of appliance repairs!

Consumption item	*Ranking 1974*	*1973*
Poultry	1	7
Black & White tv	2	1
Eggs	3	2
Color tv	4	5
Small appliances	5	4
Life insurance	6	12
Major appliances	7	6
Carpets	8	9
Fresh vegetables	9	16
Fish	10	11
Beef	11	33
Air fares (foreign)	12	10
Telephone	13	14
Air fares (domestic)	14	13
Magazines	15	18
Bank service charges	16	17
New cars (foreign)	17	15
Milk	18	3
Electricity	19	8
Auto insurance	20	31
Beauty shop service	21	21
Local transportation	22	28
Men's suits	23	19
New cars (domestic)	24	25
Used cars (domestic)	25	26
Wood furniture	26	22
Health insurance	27	29
Children's toys, games	28	24
Doctors' fees	29	30
Restaurant meals	30	20
Drugs (other than prescriptions)	31	32
Prescription drugs	34	39
Women's dresses	35	35
Shoes	36	34
Convenience foods	37	27
Credit charges	38	40
Moving expenses	39	38
Children's clothing	40	37
Heating oil	41	NA
Repairs on homes	43	42
Appliance repairs	44	43
Gasoline	45	NA

SOURCE: The Conference Board, National Family Opinion, Inc. — Nov. 1974.



Color tv — In line with the recoveries shown in consumer durables and automobiles, color television is expected to rise significantly over 1975 levels.



Encouraging developments

- *Industrial production continues to climb* — The Federal Reserve Board reported industrial production rose 0.7% in January, the ninth consecutive monthly increase. The January level was 4.9% above a year earlier. Further gains in this index of industrial output are expected in the coming months as economic activity continues to expand.
- *Wholesale prices unchanged* — Wholesale prices remained unchanged in January on a seasonally adjusted basis, as lower prices on farm products and processed foods and feed offset increases for industrial commodities. It is hoped that the tapering in wholesale price rises evident since October will be reflected in consumer prices in the months ahead.
- *Rise in consumer prices moderates* — Consumer prices rose at a seasonally adjusted annual pace of 4.8% in January, reflecting declines in food and fuel prices. The index was 6.8% higher than a year ago.
- *Real spendable earnings up* — Earnings of the typical worker after adjusting for inflation and payroll tax deductions was up 1.2% in January.
- *Index of leading indicators up* — The index of leading indicators, widely used to indicate the future direction of employment and production rose 0.4% in December and was virtually unchanged for the final quarter of 1975. Improved categories in December were a longer average workweek, fewer job layoffs, higher new orders for business goods, more money available.

- *Personal income moves higher*—Personal income rose 1% in January, or $4.7 billion, the largest monthly gain since September. Personal income from wages, salaries, investments and other sources increased $13.6 billion to a seasonally adjusted $1.3 trillion.
- *Durable goods orders up*—New factory orders for durable goods increased 2.3% to $43.8 billion in January, the biggest jump in five months. The increase was both a sign that consumers were digging into their pockets for major expenditures and an indication that business might be ready to begin the long awaited increased investment in the new productive facilities that permit more efficient output and create new jobs.

Discouraging developments

- *Jobless rate still high*—Although the unemployment rate declined in January to a seasonally adjusted 7.8% from 8.3% in December, the jobless level remained high.
- *Housing starts remain sluggish*—The Commerce Department reported housing starts declined 5% in January to a seasonally adjusted annual rate of 1.2 million units. During 1975, housing starts totaled 1.2 million, the lowest level in 30 years. However, an encouraging development was the report that permits were issued at a seasonally adjusted annual rate of 1.1 million units, up 11% from December, and 65% from the year earlier period.
- *Retail sales fall in January*—Retail sales fell 0.3% to a seasonally adjusted $51.5 billion in January, but were 12% ahead of last January's $46 billion level. Sales of durable goods declined to $16.7 billion from $16.8 billion in the previous month.

In conclusion, the key question is — how fast a recovery and how long will it last? The recovery during the first quarter of 1976 was much better than most economists — *including this one* — anticipated. An 8 1/2 "real" GNP growth was impressive. Evidence is now clear that there has been a solid year of improvement in both "real" income and in a lowered "rate" of inflation, and there is an excellent chance of continued recovery through the remainder of 1976. Also, a highly preliminary look suggests that 1977 will witness a performance in "real" incomes that is above the long-term historic 4% "real" growth average. The year in question is 1978, but it's *much* too early to lay bets this far out!

Specifically, we expect the growth in "real" GNP (with inflation removed) this year to wind up about 6% *above* 1975's depressed levels. Inflation news is also expected to be favorable — with the year in the 5%-plus area — less than half the "double digit" rate that prevailed during the peak levels of 1974 — but still too high for comfort!

a look at the world economy

We now examine some significant economic indicators in the world economy.

Inflation — World inflation is easing but still high—with many countries remaining in double-digit inflation. Note the relatively favorable U.S. position.

							Changes in Consumer Prices Percent chane in twelve months*										
	1971	*1972*	*1973*	*1974*	*1974 Dec.*	*1975 Jan*	*Feb*	*Mar*	*Apr*	*May*	*June*	*July*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
World	6	6	10	15	16	15	15	14	14	14	14	14	—	—	—	—	—
Industrial countries	5	5	8	13	14	13	12	12	12	11	11	11	10	10	9	9	9
U.S.	4	3	6	11	12	12	11	10	10	10	9	10	9	8	8	7	7
Canada	3	5	8	11	12	12	12	11	11	10	10	11	11	11	11	10	—
Japan	6	5	12	23	22	17	14	14	13	15	14	12	11	11	10	9	—
France	6	6	7	14	15	15	14	14	13	12	12	11	11	11	10	—	—
Germany	5	6	7	7	6	6	6	6	6	6	6	6	6	6	6	5	—
Italy	5	6	11	19	25	24	23	20	20	20	19	17	15	13	12	—	—
U.K.	10	7	9	16	19	20	20	21	22	25	26	26	27	28	26	—	—
Other Europe	10	10	14	19	18	19	20	19	19	19	19	19	18	17	—	—	—
Australia, N.Z., S. Africa	6	6	9	14	15	16	16	16	16	16	16	13	13	12	—	—	—
Less-developed areas	10	12	20	29	29	28	27	26	26	26	27	26	—	?	—	—	—
Oil-exporting countries	6	5	11	17	15	16	16	17	17	18	18	18	15	15	—	—	—
Other Middle East	6	6	12	20	25	23	20	20	20	21	19	17	—	—	—	—	—
Other Asia	5	8	16	30	25	22	19	15	14	12	10	8	—	—	—	—	—
Other Africa	4	5	9	19	21	20	19	19	18	17	18	—	—	—	—	—	—
Other western hemisphere	16	22	31	38	41	42	41	42	43	44	48	49	48	—	—	—	—
Argentina	35	58	62	23	40	53	57	69	80	81	111	—	—	—	—	?	—
Brazil	20	17	13	27	34	33	32	29	26	26	27	29	29	30	—	—	—
Mexico	6	5	11	22	21	19	18	18	17	18	19	17	18	17	—	—	—

*Computed over corresponding month of preceding year

SOURCE: Interantional Monetary Fund, January 1976; Bureau of Labor Statistics

Comparative growth in real gross national product — There is no room for complacency; the U.S. position has been eroding.

	1960—1966	*1966—1972*
Japan[1]	10.2%	10.9%
China[2]	4.9	4.9
U.S.S.R.[3]	5.9	4.9
Germany[4]	4.7	4.5
United States[5]	5.1	3.2

SOURCES:
[1]Agency for International Development, Statistics and Reports Division
[2]U.S. Department of State, U.S. Department of Commerce
[3]Central Intelligence Agency
[4]Agency for International Development, Statistics and Reports Division
[5]U.S. Department of Commerce

NOTE: Annual percent change in 1973 for real GNP were recorded as follows: Japan, 10.3%; China, 6.8%(p); U.S.S.R, 7.7%(p); Germany 5.3%; U.S., 5.9%; Germany, 0.4%; U.S., -2.2%; where p=preliminary.

In the world economy, a resumption of real growth and a decline in inflation is the prevalent forecast for 1976.

Encouraging developments

- *Inflation eases in most lands* — Statistics compiled by the International Monetary Fund (IMF) show that prices have recently been rising more slowly almost everywhere. On the basis of the most current data available, the IMF computed an average price gain of 13.5% over the previous year, the lowest rate in about two years. This compares with a 15.4% rate in January 1975, and rates of 16% plus during much of 1974. While inflation is expected to cool in the next few months, inflation could begin to worsen again late in 1976.
- *French production improves* — French industrial production increased an estimated 4 to 5% from June to November, according to a survey by the Official Statistics Institute. The Institute said the proportion of industrial concerns working below capacity declined to 6.6% in November, compared with 30.6% in June and 20.4% in November 1974.
- *Japan's jobless rate down* — The Japanese unemployment rate declined 0.1 percentage point during November to 1.8%, representing 980,000 jobless workers.
- *Japanese inflation picture improves* — Japan's wholesale prices were up only 1.1% in December from a year earlier.
- *Large trade surplus for 1975* — The U.S. trade surplus for 1975 is expected to approach a record $12 billion. In November, the latest month for which data are available, exports exceeded imports by a seasonally adjusted $1.1 billion. Contributing to the good trade performance is the fact that American exporters have scored high sales gains in the oil-rich nations, as well as increasing business in such diverse places as the Soviet Union, India, Korea and Canada.

Canadian inflation rate slows — Canada's consumer price index rose 0.1% in December, the smallest month-to-month increase since October 1972. Canada attributed this slowing in the inflation rate to a 0.7% drop in food costs. In December, consumer prices were 9.5% above the previous year's level.

German living costs rise moderately — The West German cost of living rose 0.3% in November, and was up 5.4% from the previous year.

Discouraging developments

- *West Germany's GNP off 3.6% in 1975* — West Germany's gross national product dropped 3.6% in real terms in 1975 after rising 0.4% in 1974. In current prices, GNP rose 4.4% to 1.038 trillion marks, compared with the previous year's 7.2% advance. The GNP deflator gained 8.3% in 1975, after a 6.8% rise a year earlier. The sharp drop in real GNP was attributed to a 9.1% fall in exports of goods and services, compared with a 13.3% increase in 1974, and to a 5.4% decline in private capital investment.
- *Latin America growth cut* — A recently issued study by the United Nations Economic Commission estimated that regional production grew 4% in 1975, compared with 7% in 1974, and 7.2% in 1973. Brazil, which had been achieving annual real GNP increases of 10%, achieved an estimated 6% growth in 1975.
- *Canada's jobless rate at 7.3%* —Canada's jobless rate rose 0.1% in November to 7.3%, matching the 14-year-record rate set last August. In seasonally adjusted terms, the number of workers without jobs rose by 9 thousand to 734 thousand people.

In general terms, with inflation cooling and real growth picking up steam, the world economy will be improved in 1976.

Microeconomics

This microeconomics discussion treats the effect of the economy on the performance of RCA industries. The material for this section is drawn from reports prepared by the Economic and Editorial Research Departments for use as background information for the annual report.

There are a number of important economic factors which influence all RCA industries. Some of the over-all facts which apply to virtually all components of RCA include:

- *Most RCA Industries did not escape the recession* — A hypothetical chart drawn for the past three years shows that 1972 and 1973 were relatively good years for the economy and that RCA industries, in general, shared in this growth period. In 1974, the effects of many external factors (oil embargo, crop failures, overheating inflation, and restrictive anti-inflation government policy) caused a flattening and then a steep and prolonged drop in the economy. By mid-1975, the economy struggled to recover from this and toward the end of the year, has staged a significant upturn. The outlook for 1976 is for moderate growth continuing quite steadily, barring new problems of an oil-embargo dimension. This pattern of response affects all our components, some more—some less.
- *Much of RCA's activity is in areas requiring improving discretionary, disposal income* — This means that a good portion of our divisions respond very sharply to the swings of the business cycle. Many of our products represent postponable purchases (color television, carpets, etc), and as a result they fall more steeply in bad times and rebound higher when the economy recovers, reflecting pent-up demand, more dollars left over from necessitities, and expanded use of credit. This behavior would apply to some extent to convenience items such as frozen foods as well (although demand for frozen food reflects other factors such as a growing change in food preparation techniques as more women enter the labor force and other family members enter the kitchen).

Even the RCA industries that are not so strongly consumer oriented remain sensitive to general economic conditions. For example, auto renting and truck leasing, business and commercial services and equipment, and goverment sales depend upon healthy budgets within both the private and public sectors in order to post expanding sales records.

Keeping these general influences in mind, the outlook for specific RCA industries follows.

Consumer Electronics (television set sales)

The television industry has been a disaster area for two years as far as sales figures for new sets are concerned; the rocky past includes this kind of picture:

- From the mid-60s to 1970, the compound annual growth rate for current dollar sales of color television was nearly 12%.
- It slipped down a steep hill to 8.6% from 1970 to 1975 as recession, energy crisis with higher gasoline prices, tax burdens soared and postponable purchases were, indeed, postponed!
- The outlook is for a flat 7% growth in color tv compound annual rates from now until 1980 — with over half of the growth represented by inflation.

The near-term outlook is a little better, though. With two bad years in a row, there is considerable pent-up demand in the industry; even a moderate economic recovery will mean more discretionary dollars, and if inflation is modified (as we expect), the large-scale purchase which a color tv set represents is expected to seem more manageable.

Black and white television has been a "maturing" industry for some time, and—generally speaking—industry figures (both dollars and units) have been on the minus side as far as growth is concerned.

Total tv is expected to rebound sharply in 1976, and a whopping 22% growth for total tv set sales is predicted for 1976. This growth projection assumes certain developments such as continued increases in discretionary income, multiple-wage-earner families, and large numbers of new households. Replacement demand will be strong; and the portability of black-and-white sets continues a big plus factor. Even the added attraction of the Bicentennial and the major election should be modest plus factors.

A potential 22% growth will be negatively affected, however, if high interest rates depress demand from these consumers who buy on credit and if alternative demands on the consumer dollar continue heavy in the area of taxes, gasoline prices, housing and food.

Broadcasting

The radio and television advertising industry seem near recession-proof if the figures for an entire decade are surveyed briefly. In the years 1965 to 1970, televison and radio revenues from advertising grew at a compound annual rate of 7.5%. In the next five years they grew 8%, and for the five years ending in 1980 they are projected to grow to an annual ocmpound rate of 10.2%.

The reasons for this steady upward trend include demographic factors, satellite development, and further penetration of color into the television market. For example, there are population shifts in both the young and old groups. Expected increases in the 25- to 35-year-old age segments mean high levels of discretionary income in a generation raised on television, while the elderly population, always heavy television viewers, is steadily increasing.

Records and tapes

Records and tapes represent an industry in which (given inflation) modest growth has been the rule for the past ten years. Pre-recorded music industry (includes tapes and records together) showed one large 'up' figure in the mid-60s when tape was first mass-marketed. Because of the introduction of this new technology and the first appearance of its statistics in data-gathering, the compound annual growth rate of the pre-recorded music industry registered a 14% gain from 1965 to 1970. This large new element was then integrated into more routine music sales, and showed only a 6.5% growth for the industry from 1970 to 1975. It is projected somewhat higher for the next five years—a compound annual growth rate of about 8% from now to 1980. If one continues to factor in the expected inflation figure, that growth picture is modest indeed.

There are a number of variables affecting tape and record sales that are difficult to weigh as either positive or negative. For example, the population age mix is changing rapidly as the postwar baby-boom children mature and form households. They are not quite the insatiable record buyers they were as teen-agers; still, the 20 to 24 year old group purchases much pre-recorded music. In addition, there are competing media forms, such as the upcoming video-disc systems, which will have some effect on music sales, but may also serve to stimulate tape and record purchases, simply because new technologies often just expand all consumption in these areas (television did not destroy movies, it changed them). In addition, pilferage, pirating, and counterfeiting cost the industry literally hundreds of millions of dollars a year in lost sales, and no effective way of blocking those losses has yet been developed. On the plus side, of course, is the always-improving technology for playing music and improving sound quality and portability of equipment. A growing interest in the widest possible diversity of music types—rock, folk rock, classical, country and western, blues and jazz—also aids in an optimistic forecast.

Solid State

The multibillion dollar semiconductor industry was in an almost continuous revenue uptrend from its birth twenty years ago—with only minor blips during earlier, briefer recessions. In the past ten years, semiconductors have shown the fastest growth of any segment of the electronic components industry, with sales quadrupling through the decade to reach $2.5 billion and penetrating into an enormous spectrum of consumer, communications, computer and industrial equipment.

However, the industry faced something like a catastrophe in 1974, as the recession hit all the appliance, auto, and related consumer fields, and many of the other commercial uses as well, in which semiconductors had been so active. Sales plummeted 17% between mid-1974 and mid-1975, with a concomitant price war that had seldon been seen in the industry before; one of the results of over capacity!

Industry observers are now predicting a 25 to 35% rebound for semiconductors for next year. There are some significant signs that this recovery is beginning: the price cutting is abating, some manufacturers are re-hiring substantially, and new plants are being completed around the world, to meet what is assumed to be strong pent-up demands. Signs of caution are also in evidence about the pace of the recovery, and the stock market is still bearish on semiconductor companies.

Global Communications

The upswing in global communications reflected, in part, the generally heightened volume of world trade and the increased contacts between the oil-producing and the oil-consuming nations. From 1965 to 1970, over-all global communications grew nearly 11%, and in the five years following that, it went up to 13.7%. The projection for compound annual growth for the five years ending in 1980 is for a healthy 22%. Although varying amounts of this growth are probably going to be inflationary to one degree or another, there are specific trends which tend to promote *real* (non-inflation) growth.

One of the prime examples of 'it's an ill wind, etc.' is the fact that the unsettled currency markets and the flow of 'petrodollars' for both short- and long-term investments push up the volume of required global communications; the world does seem to be learning that it cannot trade, invest, negotiate or market without a constantly increasing flow of message traffic which will certainly work to support communications. In addition, the active spread of satellites, both for domestic communications and for regional and worldwide systems, will increase revenues in this field. Technological advances in cable capacity may mean a trend toward declining rates, as well.

On the down side, one of the components in the global communications industry is telegrams, and this has been, worldwide, a declining industry with no, or flat, growth in the U.S. Despite the much greater popularity of other forms of global communication, however, it is expected that the telegraph component of the industry will show a modest 3% gain next year.

Commercial Electronic Products and Services

The pattern outlined above of the general economy certainly is reflected in this area, with 1973 having been a substantial sales and profit year; 1974 a loss year; and 1975 very uneven. A slackening in demand was noted strongly in those segments of the division which depend upon consumer uses. Some of the variables that affected the industry in the past and will influence it in 1976 include: broadcast equipment sales should respond to a more favorable outlook for radio and tv advertising revenues; closed circuit and cable tv continue to represent new growth possibilities; mobile radio enjoys new application, including FCC decisions which become operative in the next few years; larger planes with larger cockpits utilize more avionics per plane. On the negative side, government and private budgets are cautious, which means new purchases of equipment are lagging. In solid state, helpful trends continue strong—more electronic products of all kinds are using solid state technology, and computer-aided design and better process techniques are enhancing the manufacturing process.

The growth projection for 1976 for Commercial and Government Electronic *products* is 10%; for *services*, 10.5%.

U.S. defense spending trends

The U.S. defense budget has risen substanially over the past decade, but inflation has risen faster. Thus modernization and improvement of the forces were postponed, and there were cutbacks in the size of the military establishment. Despite this long-term effect of inflation, the outlook now is for a very gradual, very evolutionary rise in the budget for the coming fiscal year. The Defense Department projects further increases in spending, reaching about $148 billion by the end of this decade (or $116 billion in 1976 constant dollars).

Growth of RCA industries

The following table presents annual compound growth rates for business areas covered by RCA industries.

Industry (major)	Ranked by 1975-80 compound annual growth 1975 to 1980	1970 to 1975	1965 to 1970
Global Communications	21.9%	13.7%	10.9%
Auto & truck rental	15.4	11.9	18.0[1]
Commercial Electronic Products	10.9	5.0	13.5
TV & radio advertising	10.2	8.1	7.5
Total prepared frozen foods	9.4	8.8	8.9
Business & consumer services	9.4	8.7	7.5[1]
Pre-recorded music	7.9	6.5	14.0
Carpets & furniture	7.8	10.9	7.1
Total tv	6.5	6.3	3.3
Books	5.7	6.2	8.7
GNP — current $	9.0	8.9	7.4
GNP — constant $	4.4	2.0	3.2
GNP — deflator %	4.4	6.8	4.0

[1]1966-70

These growth rates range from the explosive 22% for international communications to the 5.7%-rate for book publishing. But the point to note is that growth is indicated in all of RCA's businesses. RCA's growth in many of these businesses has been at a better than the industry rate, and we expect it to continue to be better.

Healthy corporate growth is achieved not only through expansion; it is also accomplished by disposing of activities that fail to contribute to progress and actually hinder it. This is particularly true in technological businesses where new developments frequently crowd out and obsolete older products and services. Where these fading businesses linger beyond their useful span, they not only fail to contribute their share of profit, they immobilize capital that could be put to better use, and they divert skilled management and professional talent from more productive employment.

Outlook

Now that we have reviewed macro- and microeconomics, let's ask a couple more questions, and try to provide a few answers.

How can we be reasonably sure that consumers will spend more in 1976?

The following factors (many overlapping) will contribute to an upturn in consumer expenditures throughout 1976:

- Personal tax cuts — election years tend to be expansionary;
- Expanded money supply and improved velocity will provide support to spending programs;
- Real spendable pay of wage earners has advanced during recent months;
- Renewed expansion in the use of consumer credit — improved income and use of credit go hand-in-hand;
- Better food and feed-grain crops last year and improved productivity should help curb inflation this year;
- Backlog of consumer demand for durables after two years of slow growth;
- Consumer buying plans for most durables up over depressed levels of a year ago;
- Auto sales are expected to jump 17% from depressed 1975 levels—to a total of 10.2 million.

In our judgement all of these "short-term" factors will provide support to the expected 5% improvement in "real" consumer expenditures during 1976.

How can our business benefit from the improved economy ahead?

The *good* recovery expected this year and next suggests that alert marketers can improve profits by:

- Guarding against "over lean" inventories — don't get caught short on popular consumer items;
- Keeping a weathered eye on the *mix* of products demanded by customers — shifts will continue to be rapid in the 1976-77 economic climate;
- Stressing quality and dependability — customers are fed up with inconvenient and costly repairs;
- Searching for new items that are in the expanding phase of the sales curve, especially if production capabity is relatively limited; and
- Starting to plan *now* for more space (or new locations) to take care of the needs of the seven million new households expected to be formed throughout the last half of the 1970's.

For RCA, this means opportunity for 1976, and these are our goals:

- To seek expansion where we can reasonably expect to gain a substantial share of a sizable market, or where the market is going at a better-than-average rate.
- To strengthen those old businesses that hold promise of continued growth, and to build new businesses upon them.
- To attain stability through a balance between manufacturing and service, cyclical and noncyclical activities.
- To achieve strength through diversity in the total range of our operations.

We have a management that is dedicated to solid rather than spectacular accomplishment, to paying rigorous attention to the deployment of our resources, and to a close and constant awareness of profitability as the ultimate yardstick of business success.

Acknowledgment

Comments on RCA growth and goals were drawn from a presentation made by C.C. Ellis, Senior Vice President, Finance, on April 9, 1976.

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Design for production

R.H. Aires

To design products that are capable of high yield production, 20 guidelines have been outlined. These guidelines have been successfully implemented at Avionics Systems to increase production yields.

THE commercial marketplace of today is a world of intense competition. Managers responsible for the design and production of products for sale at a profit must be as concerned about producibility as they are about performance, reliability, and maintainability. A product that has not been designed for a high yield in production, regardless of its technological merit, will not be competitive.

Effective design for production must begin in the early phases of the product development cycle. From the outset, if a product is to be cost-effectively produced, consideration must be given to design factors that will allow manufacturing to perform its function in the most efficient manner possible.

Unfortunately, the producibility of a design cannot be confirmed until the product has started the production cycle and a pilot run of production units has been made. At this point, if significant producibility problems occur, the consequences can be disastrous. The options are very limited and are to either shut down the production line and go into a redesign phase, thus delaying the product's introduction into the marketplace; or continue production and incorporate design fixes as problems occur, hoping production yields will improve. Neither of these available options are conducive to efficient product management.

To avoid the unpleasant consequences of either of these alternatives, we at Avionics Systems have implemented a group of producibility design guidelines that have considerably improved production yields at our facility.

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Production yield

At each step of the production cycle where test or inspection occurs (i.e., purchase material inspection, subassembly inspection and test, unit test, and final system test) rejection fallout causes rework and the use of additional material. While it is neither economically feasible nor practical to assure a 100% yield at each step, failure to achieve a yield close to 100% will result in an unacceptable yield for the total production cycle.

Production yields are the consummate expression of the efficacy of the production cycle, revealing the care taken in selection and the quality of materials used, the adequacy of methods and procedures imposed, the standards of workmanship experienced on the production line, and ultimately the producibility of design itself. Good production yields mean lower manufacturing costs, which translate into higher gross margins, which allow lower, more competitive sales prices, and thus increase sales.

Since the total production yield is the product of the yields at each step, even an 80% yield at each of the steps results in a total production yield of only 41% (Fig. 1). A 60% yield at each step provides a total yield of only 13%. The desirability of yields approaching 100% becomes apparent. It is important to discover rejects or failures as early in the production cycle as possible since this simplifies the debug process and reduces the cost to locate and repair or replace the failure.

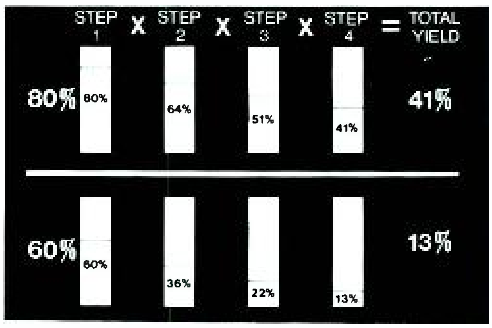

Fig. 1 — Total production yield.

Production guidelines and procedures

A set of guidelines, 20 rules in all, has been established; these guidelines are being imposed at the inception of all design programs. They have been divided into four major categories as follows:

1) Design rules.
2) Design practices.
3) Design reviews.
4) Design proof.

Each of the rules relates specifically to an aspect of producibility design. They have been evolved and formulated from past experiences and most are the results of corrections to previous problem areas.

Design rules

This category applies to the selection and use of vendor-supplied material and subassemblies. The first two rules relate to the selection of all semiconductors to be used in the product design. In the past, it had been observed that semiconductors represented the greatest percentage of field failures as well as the greatest number of in-process rejects in Avionics Systems equipments. A typical weather radar system contains approximately 400 semiconductors. Historically, 2 to 2-1/2% of these failed during production. This was equivalent to 10 failures per system. In addition, over 25% of radar equipments being returned from the field for warranty repair involved semiconductor failures.

It was decided to use a preconditioning regimen (frequently referred to as a screening program) in order to cause rejection fallout before these semiconductors reached the production line. A statistical summary of the results of our screening of over 2 million semiconductors is shown in Table I. More importantly, since we started the screening program, we have been able to reduce in-process semiconductor failures by a factor of 5.

Table I — Results of screening semiconductors.

	Screened	*Fallout*	*% fallout*
Diodes	872,101	59,449	6.8
Transistors	901,678	50,936	5.6
IC's	307,558	11,514	3.7
Total semiconductors	2,081,337	121,899	5.9

Rule 1. Establish the screening requirements for each type of semiconductor to be used in production and include these in the purchase specification of the part.

The second rule greatly assists us in accomplishing the first rule since it requires the use of standardized semiconductors in the design process. Prior to our standardization program there were 340 types of diodes and transistors and 281 types of IC's purchased from 55 vendors. We now use only 80 types of diodes and transistors and 40 types of IC's purchased from only seven different vendors. This has allowed us to purchase screened parts directly from semiconductor vendors and has significantly reduced the cost of our screening program.

Rule 2. Use only semiconductors in the standards book for general application.

In addition to limiting their use, it is also important to control the use of nonstandard parts. Their use requires prior approval from the Design Review Board, and procurement is controlled by a source control drawing. A minimum of two vendors should be qualified for each part and first production articles should be qualified during the preproduction run.

Rule 3. Prepare source control drawings for nonstandard parts which have been approved by Design Review.

Rule 4. Qualify first production articles from at least two vendors for all nonstandard parts and subassemblies in order to find problems before they impact the production line.

Marginal design problems are frequently caused by disparities between vendor ratings and actual use conditions. Derating is the best way to avoid such problems. To assure uniform derating in all designs, derating rules have been included in our Standards Manual. A typical example of minimum derating is shown in Table II.

Table II — Electronic part derating.

Capacitor type	*% rated voltage at worst case temperature*	*% rated ripple current at worst case temperature*
Aluminum electrolytic	80	70
Ceramic	50	70
CI	70	70
Mica	60	60
Mylar	60	60
Paper	60	80
Polycarbonate	60	70
Solid tantalum	70	70

Rule 5. Apply minimum derating rules for the use of all components.

It is usually true that the test equipment available in the factory is far superior to any available in the field. Therefore if there is a choice between a reliable part that will not drift and that can be selected in a factory test position, and an adjustable part that is likely to drift it is better to use the selected fixed part. When it is necessary to use an adjustable part it is very important to have a precise method to determine proper adjustment. This consideration applies equally to electrical and mechanical design.

Rule 6. Use adjustable parts only when absolutely necessary.

It has been obvious to us in Avionics Systems that purchased subassemblies supplied to us by vendors cause the most serious problems. To assure equal quality in our vendors' products we have formulated the next rule.

Rule 7. Impose a design review, use of standard parts and derating rules, and screening requirements on vendor-supplied subassemblies.

Design practices

This category of guidelines deals with a series of specific design practice requirements. One observation of the design review program was that it was almost impossible to design for the worst case tolerances with the standard carbon resistors, which were being used. In addition to the end-of-life tolerance problem, it is known that a serious production problem can result if carbon resistors are exposed to humidity prior to soldering. The RCA Corporate Standard recognizes that these resistors can change up to 25% when exposed to humidity and the effects of soldering. Even after a proper drying cycle, the specification permits a permanent change of 10%. As a result of these observations a decision was made to specify 2% metal film resistors wherever the values are available. For higher values of resistance where fixed film types are not available, type 3 resistors were specified by use of Corporate Purchase Specification 2015204-3 because these parts have the best temperature characteristics. By using corporate purchasing agreements it is possible for us to purchase metal film resistors at a lower cost than carbon composition resistors.

Rule 8. When possible use metal film rather than carbon composition resistors.

Another serious production yield problem resulted from lack of control of lead length on ceramic capacitors. With too long a lead length the capacitors appeared to be inductors at the frequency of operation. To highlight this problem to the design engineer, a graph of resonant frequency *vs.* capacitor value for various lead lengths is included in the capacitor section of the Standards Manual. An initial effort to control lead length required the ceramic capacitors to be placed as close as possible to the printed-circuit boards.

This exposed another serious problem in this type of capacitor supplied by several vendors. It was discovered that the melting temperature of the solder inside the capacitor was low enough to reflow during our flow solder operations. As a result, many capacitors had to be changed to pass the module board test. We have since specified high-temperature solder in our specification for this type of capacitor.

A combination of three vendors was required to provide a dual source of all values required, since the vendors are still in the process of converting to the higher temperature solder. In establishing the specific values, tolerances, and voltages of capacitors, which were chosen as standards, we found that it was possible to reduce by 5:1 the number of types of ceramic capacitors previously required.

Rule 9. Use high-temperature solder ceramic capacitors listed in the standards manual.

Rule 10. Observe resonant frequency rules for lead length and capacitor value.

Another major source of manufacturing defects is solder shorts on high-density printed-circuit boards when flow solder machines are used. To eliminate these defects a decision was made to use a solder resist on all printed-circuit boards.

Rule 11. Design all printed-circuit boards to include provisions for solder resist.

One of the most troublesome areas, which in turn results in producibility problems, is the design of power supplies. There is usually at least one serious problem in a newly designed power supply. Standardization of B+ voltages and the approach to generating and regulating them permits standardization of power-supply board layouts, of power distribution, and of components as well as reducing factory test position and equipment requirements. While this standardization will not guarantee that there will not be any design problems, it will at least isolate them to areas that deviated from the requirement for the standard design, such as peculiarities of load.

Rule 12. Standardize B+ voltages and power-supply design.

It is generally accepted that the yield will increase significantly as direct labor is reduced. Automatic insertion of components and use of prefabricated ribbon cables and interconnect boards drastically reduces human error and associated rework, as well as basic assembly time.

Automatic test can be used to reduce test time significantly; however, debug time may continue to be an appreciable percentage of the manufacturing labor. Proper partitioning of the design is required to simplify the isolation of bad parts, thereby reducing debug time.

At the system level, plug-in modules greatly simplify the isolation of faults and permit substitution of known good modules to keep production flowing. These observations lead to the following additional rules.

Rule 13. All module boards are to be laid out to permit automatic insertion.

Rule 14. Use ribbon cables and interconnect boards instead of hand-wired harnesses.

Rule 15. Partition circuits and use test points to facilitate debug of subassemblies.

Rule 16. Use plug-in modules to facilitate system test and repair.

Design review

A comprehensive Design Review Program has been established, which includes a System Concept Review, a Circuit Concept and Major Circuit Review, a Major Logic Review, a Mechanical Concept and Major Mechanical Review, a Prerelease and Producibility Review, a Review of Specification Control Drawings and Vendor Items, a Safety Review, and ECN Reviews (Fig. 2). These reviews are scheduled throughout the design phase of the program and continue into the production phase in the case of ECN reviews. The Design Review Program provides an opportunity to incorporate the suggestions of specialists in various disciplines including systems engineers, components engineers, methods and test engineers, and field engineers. Design reviewers should be free thinking, outspoken, constructively critical, intuitive, innovative, and well experienced in their respective areas of specialized discipline. It is important that the reviewers provide a perspective free from organizational conventions or existing product line dogmas.

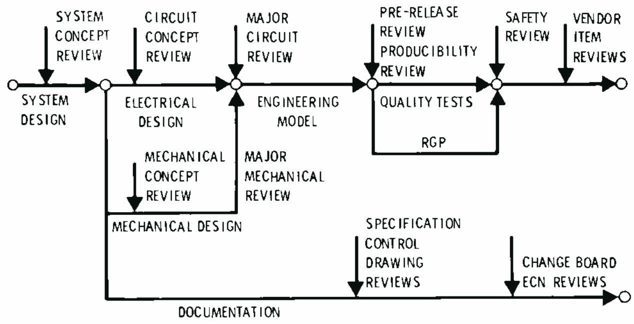

Fig. 2 — Design review program.

By pointing out potential problem areas early in the development cycle, it is possible to avoid problems that could require major redesign that would impact the release schedule. The Producibility Review will minimize problems related to manufacturing processing.

Rule 17. Conduct design reviews with engineers not involved in the design as participants.

Rule 18. Have methods, test, and field engineers review the design.

Design proof

The next major effort, which has resulted in improved yield, started as an effort to improve reliability. In addition to design reviews for producibility, a program known as the Reliability Growth Program (RGP) has been introduced. It is a controlled program of environmental testing of the preproduction units in which each failure is analyzed to determine the cause of failure and to allow incorporation by ECN of corrective action. The test consists of repetitive 8-hr cycles of which 2 hr are spent at -54° C with power *off* and 6 hr are spent at 55° C with power *on*. The equipment is vibrated the last 10 min of every hour that power is *on* (Fig. 3).

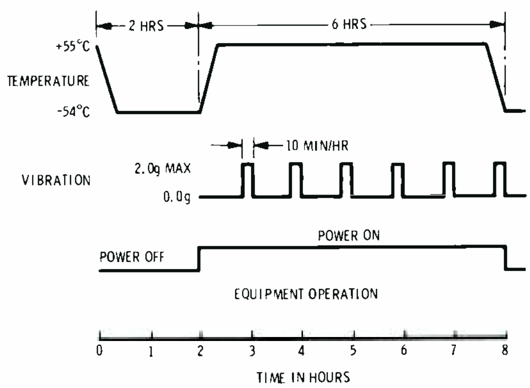

Fig. 3 — Reliability Growth Program test cycle.

Analysis of the cause of failures shows that approximately 1/3 of the failures are due to marginal design, 1/3 are due to inadequate performance of material supplied vendors, and 1/3 are due to manufacturing processes. The RGP pinpoints those areas that would reduce the yield during the production process if no corrective action were taken. If an RGP is not run, it will take a year or more of production problems and customer irritation before the necessary corrective action can be identified.

Rule 19. Specify a Reliability Growth Testing Program for each equipment to assure a satisfactory yield in production.

A commercial product division's lifeline is tied to its new product development and user acceptance. Timely introduction of new products and their likelihood of acceptance are related to the degree of change from successful predecessors.

Rule 20. Change only that aspect of the design of previously successful products that is actually required for the product to remain competitive in cost and performance.

This will reduce learning time in the factory, reduce nonrecurring costs, and result in fewer unknowns in design. The probability of providing a successful product within schedule requirements will be greatly improved.

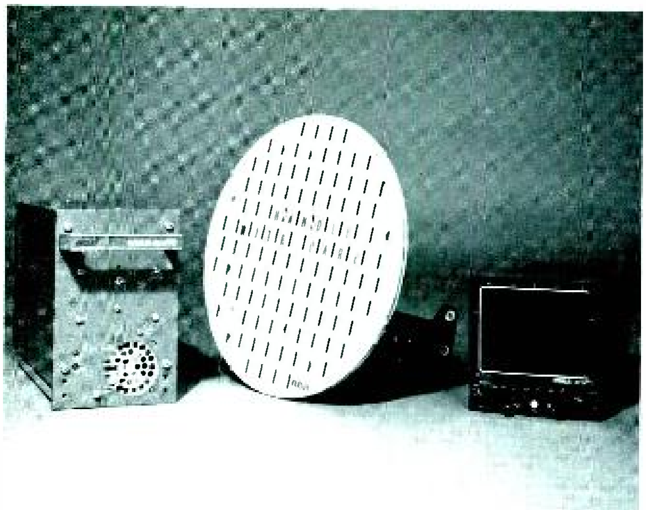

Fig. 4 — PriMUS-20 WXD, a lightweight digital weather radar used by light twin-engine aircraft in the general aviation market.

Fig. 5 — Six PriMUS-40 WXD digital weather radar systems are shown in the AGREE chamber. The PriMUS-40 WXD is the top of the line for the general aviation market and is used on heavy twins and business jets.

Fig. 6 — PriMUS-10 DME shown with dual and single indicator options.

Conclusions

We at Avionics Systems have been able to improve production yields dramatically as a result of our efforts. Figures 4 through 6 show several equipments currently in production at Avionics Systems. In a random sampling of production test yields, we found that the average yield of subassemblies from our older products (which did not have the benefit of our programmed emphasis on producibility) was only 63% while the average yield of our products that had received programmed producibility attention was 88%.

As stated previously, we have reduced by a factor of 5, semiconductor failures on the production floor. Further, there is a definite correlation between producibility and reliability. We have found that design changes that improve production yields also improve equipment reliability. As an example, the introduction and use of screened semiconductors and high-temperature capacitors improved one product's mean time between failure by 31%.

In summary, the goal of design for production is to improve profitability. In today's competitive environment, producibility of the product design is a prerequisite for success and must be a major consideration throughout the design and development phase.

Luminous flux standards for testing photosensitive products

Dr. R.W. Engstrom | O.J. Funke | L.P. Bundens

A new procedure for calibrating standard lamps based on objective instead of subjective techniques has been devised. The method uses photodetectors in place of the human eye. The equipment for studying the color temperature and luminous flux transfer is described.

THE RCA plant in Lancaster is a major producer of light- and radiation-sensing devices: phototubes, photomultiplier tubes, vidicons, silicon intensifier target (SIT) camera tubes, image orthicons, isocons, CCD's, and image-intensifier tubes. Thousands of photomultiplier tubes are sold annually for medical applications such as Gamma cameras, which image radioactive isotope locations in human subjects, thus helping to diagnose tumors and other problems. At the present time, tv cameras using vidicons at normal lighting levels or SIT tubes for low-light-level scenes are finding large markets in surveillance applications.

Although testing of these devices frequently involves semifunctional tests, which approximate users' applications, most of these products also require evaluation with standard radiant or luminous flux sources. Standards of radiation must be traceable to the National Bureau of Standards not only for military requirements (as is the case for low-light-level image-intensifier devices) but also to maintain credibility in a very competitive market. It is important to be able to define stringent test requirements and meet the stated specifications without unintentionally discarding a good product.

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L.P. Bundens, Foreman, Equipment Services, SSD, Lancaster, Pa., graduated from Rensselaer Polytechnic Institute in 1938 with a BS in Physics. After service as a Signal Corps radar officer, he joined RCA in Lancaster in 1946 as a Manufacturing Development Engineer. He later became foreman of Test Set Maintenance Activity, supervising maintenance, construction and calibration of kinescope and camera tube test equipment. In June of 1952 he became general foreman and later manager of Equipment Services Electricals, supervising and coordinating activities of the various electrical groups and gauge calibration laboratory. Since December 1974, he has been supervisor of the Instrument and Gauge Laboratories, overseeing procurement, maintenance, and calibration of all instruments and gauges.

O.J. Funke, Jr., Prototype Equipment, Color Picture Tube Development, Picture Tube Division, Lancaster, Pa., received the BSEE from Penn State in 1962. He joined the Special Equipment Engineering section of life test at Lancaster where he was involved with the design and construction of life racks and test equipment for small power tubes. He transferred to the phototube factory where he worked for three years as a Production Engineer. He returned to Special Equipment Engineering where he was assigned to the life test receiver area for color picture tubes. In 1972, he was given the additional assignment as engineer in the Instrument and Calibration Lab. Mr. Funke is a member of the IEEE and served as chairman of the Susquehanna Section.

Dr. Ralph W. Engstrom, Staff Consultant, Electro-Optics and Devices, Lancaster, Pa. completed his undergraduate work at St. Olaf College in 1935 and received the PhD in Physics from Northwestern University in 1939. Since joining RCA in 1941, he has been associated as an engineer, group leader, and engineering manager with various photosensitive devices, including photomultipliers, image tubes, and camera tubes. He has published numerous articles relating to these devices and their applications. At present Dr. Engstrom is a senior engineer serving as a staff consultant. He is a Fellow in the American Physical Society, a member of the Optical Society of America and of Sigma Xi.

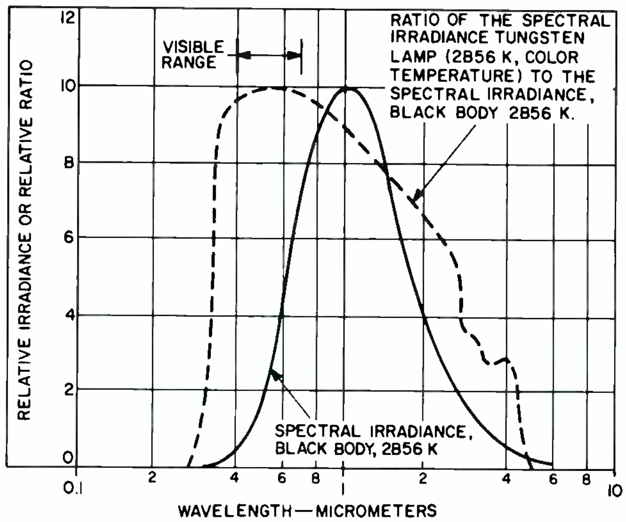

Fig. 1 — Relative spectral irradiance from a black body at 2856 K and the ratio of the spectral irradiance from a tungsten lamp operated at 2856-K color temperature to the spectral irradiance from a black body at 2856 K. Note that in the visible range, 0.4 to 0.7 micrometers, the spectral irradiance from the tungsten lamp closely matches that of a black body.

For many years the standard lamps at the Lancaster operation have been calibrated using visual photometric techniques. This paper describes a photometric procedure that is based on objective photoelectric measurements. The tungsten lamp has proven to be a suitable standard light source both because of its broad spectral emission and its stability over hundreds of hours of operation.

The tungsten lamp as a test standard

The radiation from a tungsten lamp approximates that of a black body in the visible and adjacent spectrum. A color temperature of 2856 K has been selected as an international standard. Fig. 1 shows the relative spectral irradiance from a black body at 2856 K. Also shown is the ratio of the irradiance from a tungsten lamp operated at 2856-K color temperature to the irradiance from a black body at 2856 K. Note that in the visible region, 0.4 - 0.7 μm, the ratio is essentially flat, with a broad maximum at 0.55 μm, the wavelength of maximum photopic response. Thus, in the visible spectrum, the spectral irradiance from the lamp almost exactly matches that of a black body. The useful overall spectral range for the tungsten lamp is from about 0.4 to 2.5 μm. Except for ultraviolet detectors, which may require sources such as mercury lamps, xenon lamps, or deuterium lamps, the tungsten lamp provides an excellent standard for all photoemitters and most photoconductors.

Standard lamps are calibrated in luminous terms for historical reasons and because it is very difficult to provide an accurate measure of the total irradiance from a tungsten lamp. Even though the lamp may be characterized by luminous units which imply the wavelength band of the photopic eye, it is possible by means of data such as shown in Fig. 1, to provide absolute spectral radiant calibration of photosensitive devices.[1] Conversion from a luminous specification to a (total) radiant specification can also be made on the basis of an estimate that the ratio of illuminance (lm/m^2) at some specified distance from the lamp to the total irradiance (W/m^2) at the same distance is 20.0 lm/W for a standard tungsten lamp operated at a 2856-K color temperature.

Visual calibration technique

In calibrating a tungsten lamp for use as a luminous standard, two parameters are important: the spectral distribution of the emission as characterized by the color temperature of the lamp and the luminous flux from the lamp.

For many years, secondary lamp standards were provided by visual comparison with an NBS standard lamp (primary). This was done on an optical bench well shielded to prevent scattered and reflected light from interfering with the comparison. Color temperature was judged by direct visual means using a Lummer-Brodhun contrast head.[2] Thus if the secondary lamp was too low in temperature, the associated pattern appeared slightly red in contrast with the pattern illuminated by the primary lamp; and similarly, if too high in temperature, the pattern appeared slightly blue in contrast with the primary illuminated target. When the two lamps were at the same temperature, candle power of the unknown lamp could be determined by application of the inverse square law.

Because both the color temperature of the lamp and its candle power were determined by visual comparisons, errors resulted from the eye's relatively modest sensitivity to color and contrast differences. There were also errors that arose from subjective bias. The data of Table I illustrate the typical precision achievable by the visual technique.

The tabulated current settings for the working standard are those required to match the color temperature of the NBS standard. Of the three observers, *K* was most experienced, having done calibrations for a number of years. *E* and *F* were knowledgeable, but not practiced in the technique.

Our goal for color temperature accuracy is ±8 K. For the type of lamp used as a working standard, this temperature variation corresponds to a lamp current difference of about 0.020 A. It may be seen in Table I that the precision of each individual's measurement is of this order, but that there are discrepancies between observers.

In order to check whether there was a fixed-type error difference between left and right on the optical bench, as observed in the Lummer-Brodhun head,

Table I — Current setting in amperes for working standard lamp to match an NBS standard lamp operating at 2856-K color temperature, using the Lummer-Brodhun photometer.

Reading	*Observer* *K*	*E*	*F*
1	4.27	4.35	4.35
2	4.30	4.35	4.34
3	4.30	4.40	4.38
4	4.29	4.38	—
Averages	4.29	4.37	4.36

Table II — Current setting in amperes for working standard lamp to match an NBS standard lamp operating at 2856-K color temperature, using the Lummer-Brodhun photometer, but with lamp positions interchanged.

	Observer		
Reading	*K*	*E*	*F*
1	4.47	4.38	4.33
2	4.47	4.33	4.38
3	4.51	4.39	4.36
Averages	4.48	4.37	4.36

the positions of the primary standard and the working standard were interchanged. The data in Table II resulted.

Again, the individual's precision was about the same, but a bias is observed in K's results. For some reason, he set the lamp to his left at too low a temperature. The bias error is of the order of 40 K.

Once the color temperature is properly adjusted, the candle power measurement is relatively easy. Precision with the visual techniyse s on th o on m l%. But larger errors can result from improper color temperature setting and fixed bias errors.

Photoelectric calibration technique

The use of subjective visual techniques in the calibration procedure may be completely eliminated by substituting a photodetector for the eye. Candle power measurements may be made by comparing photocurrents. Color temperature may be judged by using blue and red color filters to separate regions of the tungsten spectrum. Higher lamp color temperature results in a higher ratio of the blue-to-red photocurrent readings.

Two photodetectors were investigated: a photocathode of a photomultiplier tube having an S-20 spectral response, and a silicon PIN photodiode. Either type detector may be used in this application. The photomultiplier tube (operated as a photodiode) is linear in its photoelectric response, but it is not perfectly stable and is rather bulky for the development of a portable standard transfer equipment. The silicon cell is more stable than the phototube and much more portable. Linearity was adequate for our purpose in the visible spectrum, although an interesting nonlinear effect was observed in the near infrared spectrum. The silicon cell was selected for the development of a photoelectric photometer for tungsten-lamp calibration.

Transfer equipment

An experimental equipment was designed and fabricated for the study of the color temperature and luminous flux transfer. This equipment (Fig. 2) consisted of a housing for the photocell, color filter sliders, and measurement circuitry. A schematic of the measurement circuitry is shown in Fig. 3. The basic function of the circuit is to convert the current generated by the silicon detector to voltage, which is read on a digital panel meter.

The digital panel meter was calibrated as a separate device. The three-stage amplifier was calibrated by removing the silicon detector and inserting known currents into the input connection. On the most sensitive range and with a full display, the noise of the system was 0.1% of reading.

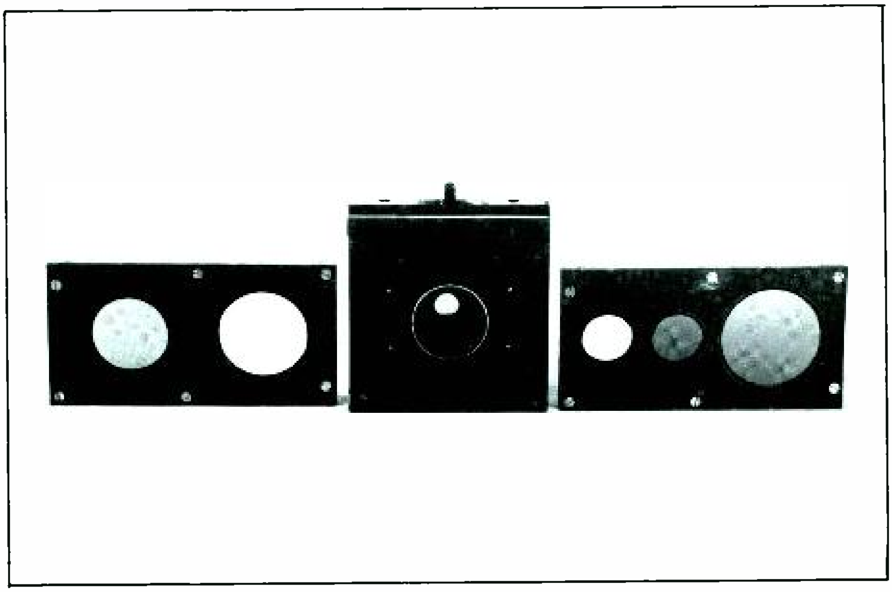

Fig. 2 — Silicon photocell housing and the sliders with color filters used in the tungsten lamp calibration. From the left, the filters shown are: green (photopic match), infrared absorbing, open aperture, red, and blue. The small light circle which may be observed in the center of the housing is the front surface of the silicon cell shown through a 1/2 in. aperture.

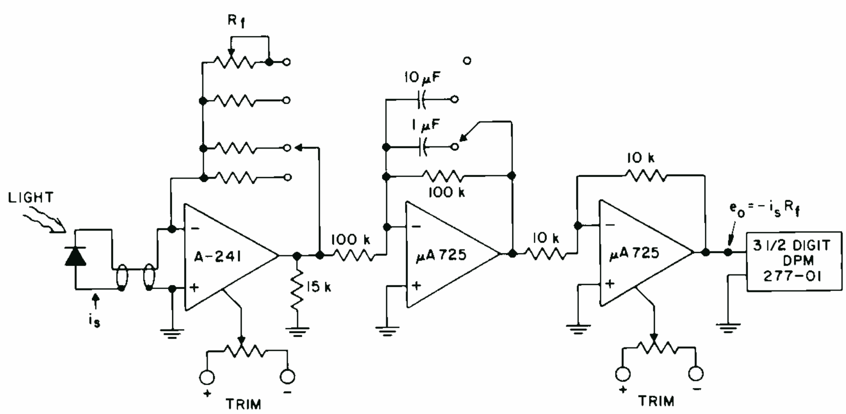

Fig. 3 — Schematic of the silicon-cell photometer circuit. The input operational amplifier is a high-quality chopper-stabilized unit using the silicon detector in the photovoltaic mode to eliminate the effects of thermally induced dark currents. Currents from 0.005 to 50 microamperes are resolved with linearity errors of less than 1%. The second stage operational amplifier is a unity-gain inverting amplifier. The third stage serves as a buffer to drive the 200-mV full-scale digital panel meter. The digital panel meter is a commercial item with 3 1/2 digits of display and an accuracy of 0.05% of reading and 0.05% of full scale.

Blue-red ratio characterization of color temperature

The blue and red filters were selected to obtain as much spectral "leverage" as possible while maintaining the test essentially in the visible region in order to provide consistency with the fundamental definition of color temperature. For the blue, a Corning blue filter CS 4-96 was used with an infrared absorbing filter HA-11. (Actually the latter was not necessary because the CS 4-96 does have good infrared exclusion.) For the red, a Corning CS 2-63 filter was used, again with the HA-11. The combination of the red and blue was also selected to provide a reasonable balance in the blue-red readings. Fig. 4 shows the spectral responses of the silicon cell to the tungsten lamp at 2856-K color temperature through the blue and through the red filters.

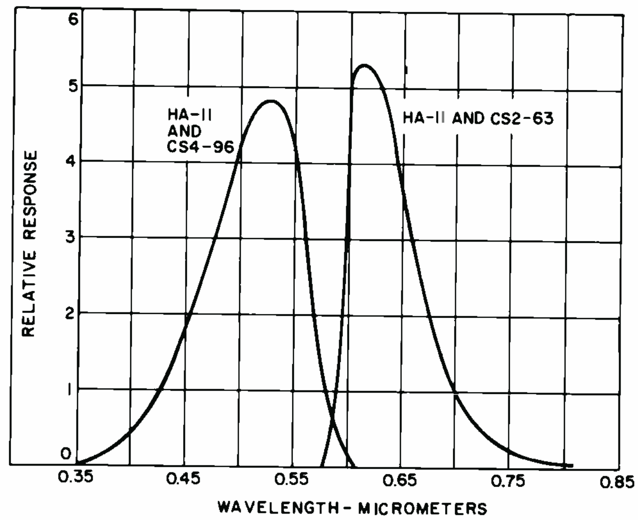

Fig. 4 — The relative spectral output of the silicon cell excited by tungsten-lamp radiation through the blue and through the red filters.

The data presented in Fig. 5 were taken to demonstrate the color temperature discrimination achievable with the blue-red ratio as discussed above. It may be observed that a 1% change in blue-red ratio is equivalent to about a 14-K difference in color temperature. The required 8-K precision in color-temperature measurement was readily obtained.

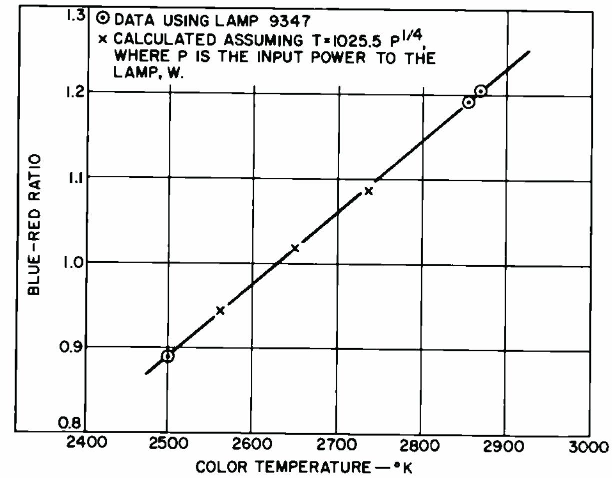

Fig. 5 — Blue-red ratio as a function of the lamp (NBS 9347) color temperature. The circled points are the blue-red value for NBS calibration temperatures. The crossed points were measured blue-red for temperature calculated from the input power to the lamp, assuming that $T = 102.5 P^{1/4}$, where P is the input power to the lamp, and the constant was selected for agreement with the NBS data at 2856 K.

Incidentally, once the blue-red ratio characteristic has been established as in Fig. 5, the data may be used to set lamps up at other than standard temperatures, or even to extrapolate beyond the ranges shown using a T^4 type approximation.*

Linearity of the silicon cell

The manufacturer of the silicon cell advertises a linearity of an operational amplifier photodiode of 1% over nine decades of input light intensity extending to photocurrents of 1 mA. Our measurements made in the visible part of the spectrum using an inverse square test on an optical bench demonstrated deviations from linearity of less than 0.1% per decade of light flux. This

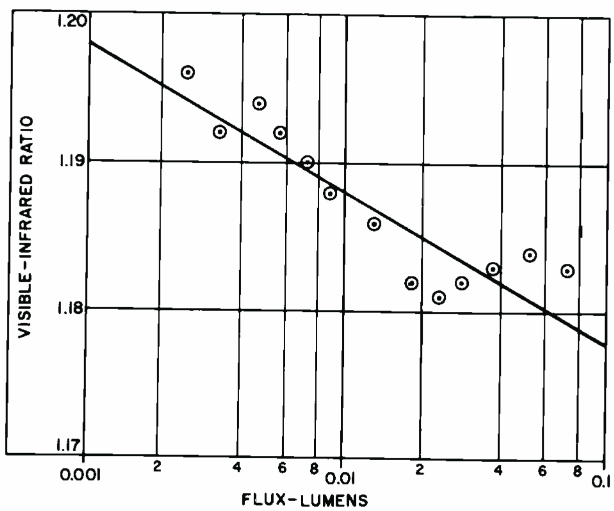

Fig. 6 — Ratio of the silicon photocell current for the visible (HA-11 filter) to the photocurrent for the infrared (a pair of CS 7-56 filters) as a function of the flux in lumens. Light source was a tungsten standard lamp. Note that the ratio decreases about 1% per decade as a result of the supralinearity characteristic of the silicon cell in the near infrared.

*One might expect the Stefan-Boltzmann law to be exact, except that the emissivity of tungsten is wavelength dependent, and optical properties of the lamp envelope complicate the relationship.

deviation was within the magnitude of our experimental error.

We did, however, discover a peculiar nonlinearity for near infrared irradiation. A ratio measurement was made on the optical bench using the HA-11 infrared absorbing filter for a *visible* reading and a pair of Corning CS 7-56 (2540 glass) infrared transmitting filters for the *infrared* reading. The data were developed in ratio form in order to avoid any question of inverse-square-law deviations on the optical bench. Fig. 6 shows that the ratio of visible to infrared readings decreased about 1% per decade of light flux. The decrease in this ratio is largely if not entirely the result of a relatively large infrared supralinearity effect in the silicon cell.

A possible explanation for the supralinearity relates to the absorption coefficient for silicon, which is much lower for long wavelengths than for short. For blue light, the $1/e$ absorption distance is about 0.5 μm, whereas for radiation at 1 μm, the $1/e$ distance is 100 μm. Thus, some of the near infrared radiation is absorbed beyond the depletion region of the silicon cell. Of the excitation beyond the depletion region, only those holes that diffuse back to the depletion region are collected. The remainder recombine in the n region. As the radiation flux is increased, however, the lifetime of the holes in the n region is increased because of the filling of recombination centers. In this case a greater fraction of these holes diffuses to the depletion region, accounting for the supralinear behavior for long-wavelength radiation.

Stability of the silicon cell and transfer accuracy

Some measure of the stability of the silicon cell during the calibration may be obtained by the repeatability of flux measurements. For a period of about one month, the responsivity of the silicon cell was measured using the photopic filter, and NBS Standard Lamp 5916. Luminous flux was calculated from the NBS candle power data together with the inverse square law applied to the optical bench setup. The data for this period indicated that deviations were within ±0.5%. During this period, the silicon-cell transfer equipment was in almost daily use for various other tests. We consider this stability to be quite adequate because transfer operation requires stability for only a few hours.

Table III — Consistency of the Lancaster Group of NBS standard lamps for color temperature and luminous flux.

Lamp	*Blue-red ratio*	ΔT, K	*Si Cell responsivity using photopic filter and* 0.1 *lm*, $\mu A/lm$	*Responsivity deviation*
9473	1.2018	−2.1	198.6	−0.3
9947	1.2033	−0.3	198.4	−0.6
5916	1.2056	+2.3	200.7	+0.8
Average	1.2036		199.2	

Temperature sensitivity

The silicon-cell manufacturer reports that the cell has a negative temperature coefficient of responsivity of 0.3%/°F. But if the ambient temperature does not vary more than 5°F from the calibration temperature, the error in luminous flux resulting from temperature variation should be less than 1.5%.

Visible-infrared type data taken in the range 25 - 50°C showed that the spectral response may be considered independent of temperature for our purpose, and thus the only consideration regarding temperature change is a possible small shift in the luminous flux calibration.

Calibration procedure

The RCA Lancaster Standards laboratory maintains four NBS lamps. Transfer of color temperature and luminous flux is done on the basis of the average of the four lamps. Each year one new lamp is purchased from NBS and one lamp is retired. The averaging process provides an additional degree of consistency and provides a flag against errors.

The degree of consistency among the NBS lamps* is illustrated in Table III. The variation from the standard temperature was obtained by measuring the blue-red ratio for each lamp with the silicon-cell photometer, assuming that the average blue-red ratio corresponds to 2856 K and estimating the temperature deviations in temperature may be compared with our ±8-K objective. Also shown is the measured responsivity of the silicon cell with the photopic filter, using each lamp in turn with the candle power calibration. The precision of the flux adjustment is also quite adequate, being of the order of a few tenths of a percent.

Once the responsivity and the blue-red ratio have been established for the silicon transfer cell, the transfer is made as follows. The temperature of a lamp in a working test set is adjusted by varying the lamp current. The blue-red ratio of the working lamp is observed with the silicon-cell photometer and the lamp current adjusted until the color-temperature standard is met. After the proper lamp current is determined, the photopic filter is introduced with the proper aperture, and the position of the lamp is adjusted until the output of the silicon cell indicates the proper flux.

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*We are temporarily only using three NBS standard lamps because our fourth is considered to be obsolete and somewhat in error.

Design automation for complex CMOS/SOS LSI hybrid substrates

P.W. Ramondetta | J.W. Smiley

The AUTODRAFT design automation system—developed by the Missile and Surface Radar Division—has been used to produce a complex thick-film hybrid substrate. The performance of this substrate, compared with that of a manually-produced device, demonstrates that design automation can be applied to produce high-density low-capacitance, high-speed CMOS/SOS arrays within a short development cycle.

THE advantages of CMOS/SOS devices as basic elements in LSI digital arrays are well known. Chief among these are high packing density, low power dissipation, and high on-chip operating speed. The SOS technology has achieved these features by virtually eliminating the on-chip parasitic capacitance that degrades the performance of MOS devices. Once the signal passes off-chip, however, the parasitic capacitance problems associated with chip packaging, interchip wiring, etc. still remain.

A packaging approach that maintains the on-chip performance of SOS at the next higher packing level has been developed by using low capacitance, multilevel ceramic-substrate hybrids. In essence, this approach extends the advantages of SOS beyond the individual SOS chip boundaries. Interchip wiring capacitance is kept low while packing densities are improved by a factor of eight over ceramic dual in-line packing.

Using this approach, two large multilevel, thick-film hybrid packages of equalivent complexity were designed and fabricated. One package, the Data Path hybrid, was designed using customized manual layout methods while the other, the Adder hybrid, used design automation throughout. Each hybrid contained eleven digital CMOS/SOS LSI arrays and several decoupling capacitors. (Table I). The hybrid substrates measured 1.8 x 4.2 in. and had 170 I/O pins. To minimize interchip capacitance, the LSI arrays were mounted directly to the substrates—individually sealed chip carriers were not used. Each LSI chip was mechanically attached to the substrate with an epoxy adhesive and electrically connected to the substrate wiring with 1-mil bonding wires. The substrates, in turn, were mounted in "butterfly" lead cases for mechanical protection.

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Table I — Summary of Adder hybrid component complement.

Component name	*Component type*	*I/O pins/ chip*	*Component size (mils)*	*Quantity*	*Total No. of logic gates*	*Total No. of devices*
8-bit adder chip (ATL-030)	CMOS/SOS LSI	65	229 × 229	6	2,750	9,624
8-bit MUX chip (ATL-031)	CMOS/SOS LSI	64	172 × 175	3	460	1,608
Add Con. chip (ATL-032)	CMOS/SOS LSI	48	139 × 154	2	331	1,160
Decoupling cap	0.10		150 × 100	2	—	—
Hybrid totals				11 CMOS/SOS LSI arrays	3,541	12,392

John W. Smiley, Advanced Technology Engineering, MSRD, Moorestown, New Jersey received the BSEE from Lafayette College in 1952. After a tour in the U.S. Army as a Signal Corps Officer, he joined the Communications Systems Division at RCA in Camden in 1953, involved with military television applications. Then, in Digital Applications Engineering, he was active in the design, development, fabrication, and test of the AN/GRA-5 digital communication system, part of the Sage system. In 1961 he was assigned to the Micropac computer program which was to be a test vehicle for the newly developed micromodules. In 1964 he was assigned computer programming tasks and developed a memory diagnostic program for fault isolation to the component level for the MICRORAC computer system. From 1967 to present, he has been responsible for program development, maintenance and operation of design automation programming systems. At present, he is engaged in upgrading the AEGIS-EDM-1 system, revamping some programs, and replacing others with more cost effective software.

Paul Ramondetta, Computer Systems Research and Applications, Advanced Technology Laboratories, Camden, N.J., received the BSEE from the City College of New York in 1966 and the MSEE from the University of Pennsylvania in 1970. In 1966, he joined the Advanced Technology Laboratories, becoming involved in the design and development of communication devices employing solid state microwave sources and microwave pumped photoconductors. In 1969, he joined the Computer Systems Research and Applications group where he has been responsible for the design, computer simulation, and evaluation of the (standard) CMOS circuit library portion of the "APAR" design automation system. More recently his work has included responsibility for the design and evaluation of new MOS families of standardized circuits for other LSI DA systems employing the developmental silicon-gate/beam-lead and the silicon on sapphire technologies. His work has included the responsibility for the development and testing of SUMC's complex Adder Hybrid—a 13,000 device CPU subsystem. Mr. Ramondetta is a member of Eta Kappa Nu and the IEEE.

Basic design considerations

Materials selection

During the early design and layout of the substrates, two possible performance-related problems concerning materials selection were examined: First, a metalization material that would introduce high interconnect resistance on the power and ground lines of the substrate could degrade performance. (Although CMOS is a low-power technology, high transient charging currents associated with output buffers could conceivably reduce localized V_{dd} bus potentials and thereby increase stage delays.) The problem of line resistivities for CMOS systems is much less severe than for T^2L systems. However, the problem was examined in the interests of a sound design. Second, insulating materials with high relative dielectric constants would introduce unnecessary parasitic capacitance on the signal lines, and this would also be reflected as increased stage delays for the SOS output buffers. To optimize performance, therefore, a low-K dielectric material* and a low-glass (low-resistivity) gold conductor material** were chosen for the design.

Line widths, spacings, and levels of interconnect

The widths and spacings of the substrate's routing wires had to be chosen before the actual layout of the substrate could begin. These dimensions had to be consistent with the capabilities of the fabrication techniques and materials chosen earlier. In addition, they had to be chosen to minimize parasitics if performance was to be optimized. By designing the substrate with as much of the routing as possible on the uppermost interconnect level, wiring capacitance was minimized, since much of the routing was now surrounded by air (a "low-K material"). The remainder of the signal-line routing was placed on the next lower level. Whether or not more levels of interconnect would be required was a function of only the complexity of the design's netlist. To ensure firm power and ground potentials at each of the LSI arrays, wide bus lines on other levels of interconnect were used.

*Electro Oxide Co. EO-6209 Dielectric Insulation (measured K = 7.0)
**Electro Science Labs ESL-8835-B Low Glass Gold (measured resistivity = 0.003 ohms/□).

Table II — Adder hybrid design rules.

Metalization levels	2 signal 2 power/ground
Metalization widths	5 mils: signal 15 mils: power/ground
Metalization (channel spacing)	15 mils
Via hole diameter	11 mils
Substrate size	1.8 × 4.2 in.

For a 1.8 x 4.2 in. substrate of the Adder hybrid's complexity, two levels of signal interconnect were sufficient when 15-mil center-to-center channel spacing was maintained. Table II summarizes the layout rules used for the Adder hybrid. Four levels of metalization were utilized. The signal lines were routed only on the top two levels. Power and ground bus lines were routed entirely on the bottom two levels, (Only three levels could have been used, but this would have introduced twice the parasitic capacitance as the approach taken.) The extremely low wiring density on the bottom two levels permitted 15-mil-wide low resistance bus lines to be used; while the high wiring density on the top two levels required 5-mil-wide lines.

Because the automatic routing program did not make allowances for extra spacing between via holes and adjacent channels, relatively small-diameter (11 mil) via holes and backfills were used.

Design automated approach

AUTOROUTE—a subset of the AUTODRAFT system—is a two-level automatic routing program, where adjacent levels are orthogonal and direction changes are accomplished by changing levels. The program requires point-to-point netlist information and the positional coordinates of all points to be interconnected. In essence, the user must supply both a formated netlist and component placement data to run the program. The program output can be edited on the Applicon interactive graphic terminal, whereby additional levels may be added, modifications made, and excess via holes removed.

The approach taken with the Adder hybrid made use of AUTOROUTE for all signal-line routing. (The program excels at routing "random" interconnections.) The more regular power-ground nets were routed "by hand" on the Applicon terminal. This avoided the possibility of the program creating an unnecessarily complicated bus structure that might have introduced excessive amounts of resistance.

Although a portion of the hybrid's routing was done "by hand", the obvious advantages of using design automation were not lost since the power-ground nets were sufficiently regular in distribution to be easily added after running the program.

Fig. 1 outlines the basic steps in the tasks of component placement and interconnection routing for both the design-automated approach taken with the Adder hybrid and the traditional approach used with the Data Path hybrid. The significant features of the design automation approach are:

- Netlists are generated in an AUTOROUTE format from documented master netlists totally under program control.
- Greater than 98% of all interconnections are successfully routed under program control.
- All modifications are made on the Applicon system.
- New hybrid designs benefit by using existing library elements with a minimum of redesign effort.

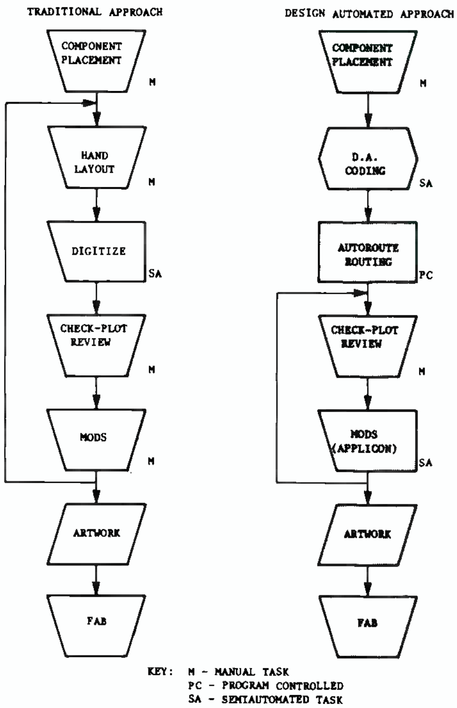
All of these steps served to minimize human intervention in the design process. Because of this, very few iterations were needed on the feedback loop, manually generated errors were minimized, and the interactive terminal allowed minor modifications to be made in the layout to enhance producibility.

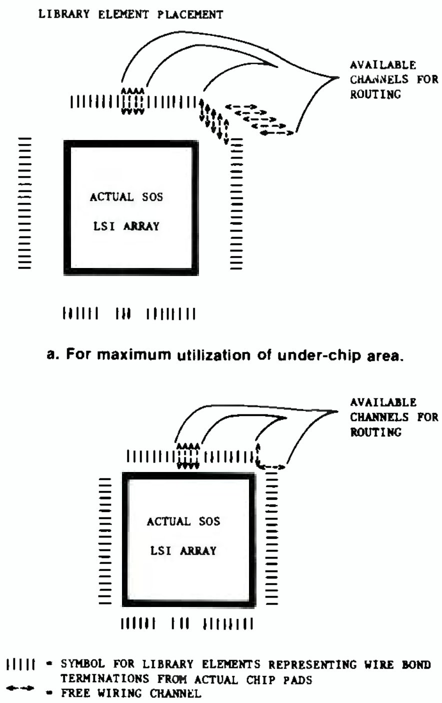
A copy of the Gerber-generated artwork for top-level metalization of the Adder hybrid is shown in Fig. 5a. The regularity of the wiring is a direct consequence of the orthogonal nature of the AUTOROUTE program—while the even distribution of the wiring is a result of the chip placement. This can be compared with the top level of metalization of the manually laid out Data Path Hybrid substrate shown in Fig. 5b. Figure 6 is a photograph of a populated Added hybrid before its insertion into the custom-designed package.

Hybrid performance

All SOS LSI chips were tested and screened for functional performance,

Fig. 1 — Hybrid design tasks for the design-automation approach used for the Adder hybrid (right) and the traditional approach used with the Data Path hybrid (left). Both charts assume that design rules and materials have been decided upon previously. Manual operations, semiautomated operations, and program-controlled operations are called out for comparison. In both charts, feedback loops are illustrated. Although other loops are possible, those illustrated were the ones actually used. Further to the right, the steps in the design automation approach are explained in some depth.





b. For minimum utilization of under-chip area.

Fig. 2 — Library element placement.

COMPONENT PLACEMENT: To minimize interwire capacitance and to keep wiring build-ups from occurring, strict attention was paid to the SOS LSI chip placement. Chips with a large number of off-hybrid connections were positioned near the hybrid edges, while chips having a large number of common connections were positioned close to each other. Possible wiring congestion was anticipated based on a knowledge of the required data flow. It was possible to position and reposition chips by increments of the basic wiring grid spacing (in this case 15 mils) and it was possible to rotate components in increments of 90°.

D.A. CODING: An important part of the design-automation coding task was the definition of those library elements used to represent the LSI chips and the hybrid I/O pins. A library element configuration, similar to that shown in Fig. 2, was generated for each chip type. Because the design called for thermal-compression wire-bond connections between chips and hybrid wiring, the libarary elements could be designed in such a way as to permit extensive use of the areas under the chips for routing purposes. Netlist preparation consisted of reformating existing documentation to adhere to the syntax requirements of the AUTODRAFT system. This latter procedure was performed totally under program control to minimize the possibility of human error. The coding effort was about 58 manhours, and included some analysis and updating.

AUTOROUTE ROUTING: Before running AUTOROUTE, the power (+V) and ground nets were removed from the netlist. They were added later on the interactive graphic terminal on two separate levels. The computer program required several input-data validation runs before the nets were routed automatically. The computer cost was $630. Since the output of the AUTOROUTE program was in the form of fully digitized routing data, this $630 cost may be compared in a favorable light with the $1200 digitizing costs incurred during the manual digitizing effort required for the Data Path hybrid.

CHECK-PLOT REVIEW: The AUTODRAFT-generated check-plot of the Adder hybrid is shown in Fig. 3. The library elements representing the 170 hybrid I/O pins (along the periphery) and the 11 LSI arrays (inside the hybrid's border) have been darkened for clarity. Their locations define the substrate's outer dimensions and the chip positions. The routing shown connecting the library elements was all program generated. Because the program routing is orthogonal for adjacent layers, every change in line direction required a via hole. The program has the ability to route in-between connectors (or under chips) to save wiring channels. Fig. 4 is a CalComp checkplot of the Adder hybrid after the power/ground buses were added and the excess via holes were removed. The review of the checkplot included a comprehensive study of the net connections made and determination of where to install the remaining connections. At the completion of each editing session, a new checkplot was generated for further analysis.

MODS (APPLICON): Routing and via modifications resulting from reviews of the checkplots were made using the Applicon interactive graphic terminal. Applicon allows the operator to zoom in and out of areas of the hybrid and edit a selected area in detail. Total editing time for the Adder hybrid was 75 hours. During some of the editing process, the design engineer was assisting with on-the-spot review and analysis. The editing time also included development of an input tape for the Gerber Artwork program.

ARTWORK: Artwork was developed on the Gerber plotter. The output, plotted at a scale of 10X, was in the form of film negatives and positives. They were later reduced to a scale of 1X for screen fabrication.

Fig. 3 — Checkplot of AUTODRAFT output for Adder hybrid.

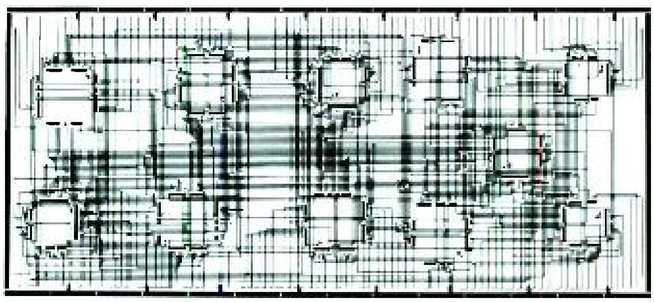
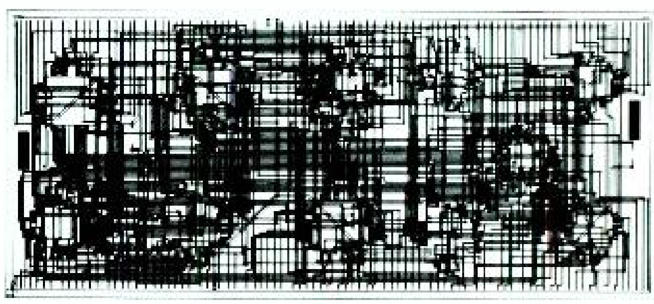


Fig. 4 — CalComp checkplot of Adder hybrid.



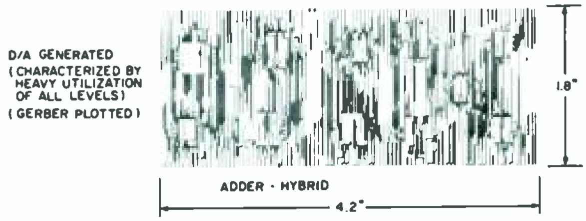


Fig. 5a — Top level metalization for Adder hybrid.

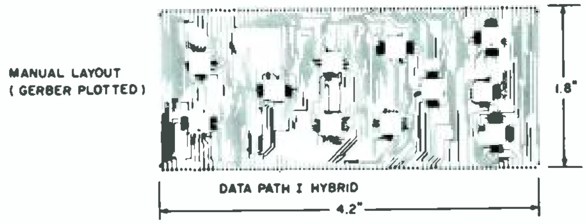


Fig. 5b — Top level metallization for Data Path hybrid.

leakage, and dynamic performance prior to substrate mounting. The assembled hybrid substrates were tested from a system-function point of view. That is, the microprogram coding table of the intended logic design was used to assure that all funcitons were operational.

Capacitance measurements on the unpopulated Added hybrid substrates were made with all 170 I/O lines tied to ground. The highest capacitance measured was 27 pF, which was within 10% of the highest measured capacitance of the manually laid out version. Essentially, then, there was no difference between the two designs in this area. Values in this range are too small to adversely affect off-chip SOS performance.

The dynamic performance of the SOS chips in the hybrid package was examined for several paths. Fig. 7 illustrates one such path on the Adder hybrid. It traverses three LSI arrays, or 22 stages of logic from input to output. The average measured delay was 4.3 ns/stage. This value, although measured over three on-chip/off-chip excursions, is typical of on-chip SOS performance levels. A similar measurement, taken over 21 stages on the Data Path hybrid, resulted in an average on-hybrid delay of 7.6 ns/stage. (Since capacitance measurements for the two hybrid designs were essentially equivalent, any differences in performance between the two would have to be attributed to the performance differences of the LSI chips, rather than to the hybrid substrates themselves.) In short, the thick-film substrate interconnection scheme can be counted on to remove many of these unexpectedly large delays associated with large amounts of interchip wiring capacitance.

Conclusions

In the development of the Adder and Data Path hybrid packages, thick-film and SOS LSI technologies have been combined to extend the on-chip performance levels of SOS to the subsystem level. Packaging density improvements of 8:1 have been achieved over standard DIP packaging schemes.

The development of the Adder hybrid using design automation shows that the MSRD-developed AUTODRAFT system can be used for complex digital thick-film hybrid designs. Furthermore, substrate performance characteristics identical to manually laid out designs can be achieved in shorter development times — particularly when several complex hybrid types are to be designed that can utilize existing library components.

The Design Automated approach—with the reduced turnaround time, the availability of the Design Automation programs, and the editing capabilities of the terminal—can be expected to result in a 3:1 reduction in cost over the use of manual methods for the initial design of a hybrid.

Acknowledgments

The authors acknowledge the contributions of the following members of the Missile and Surface Radar Division: J.W. Douglas and W.M. Morsell for their assistance in running the AUTODRAFT programs; and H.F. Sammeth for his assistance during the Applicon phase of the Adder hybrid substrate development. The authors also thank S. Steriotis and P. Mendicino of the GCSD Hybrid Laboratory for fabrication and assembly of both the Data Path and Adder hybrids.

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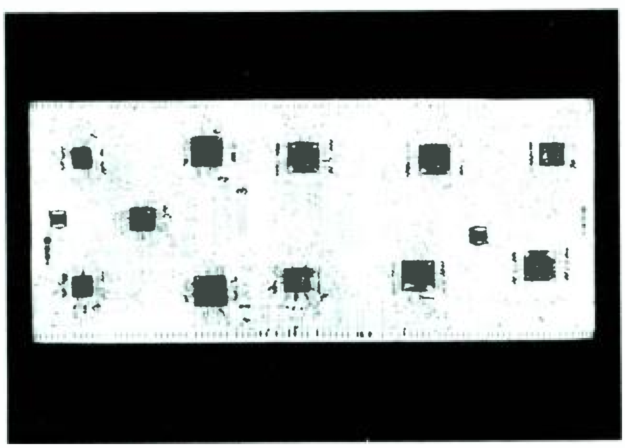


Fig. 6 — An assembled Adder hybrid.

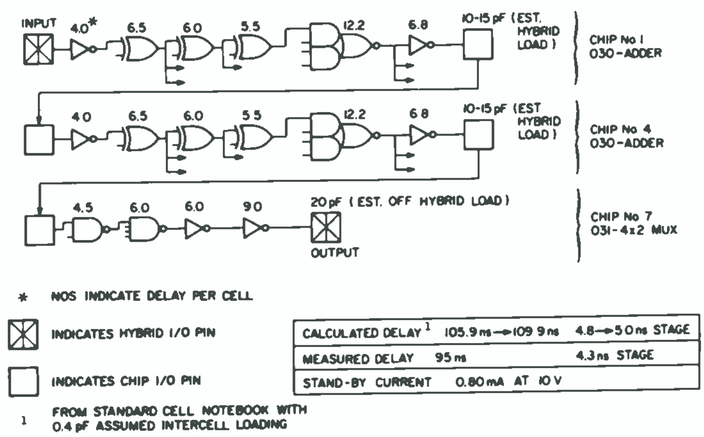
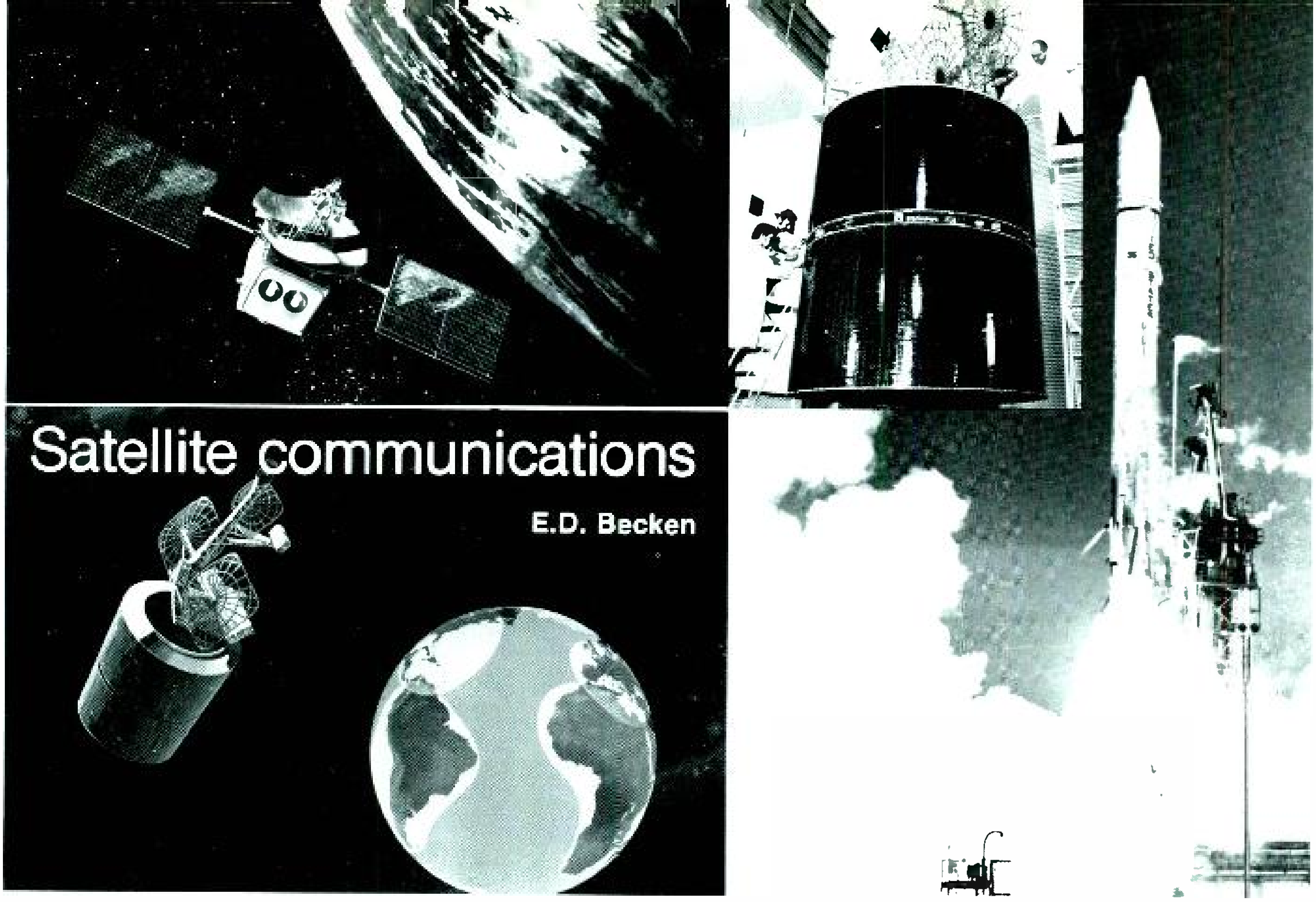


Fig. 7 — Adder hybrid measured performance.



Satellite communications

E.D. Becken

Satellite communication technology is providing opportunities for profound changes in accomodating the world's requirements for international and domestic communications. The latest technology used for these satellites and their launch vehicles, and for the recent RCA Satcom I satellite launch is described. The satellite technology and service opportunities of the future are briefly reviewed.

SATELLITE communication technology—accomodating the world's commercial, governmental, social, and other communication requirements—gives a new dimension to the telecommunications industry. Three equidistant synchronous satellites, located on the 165,000-mi circumference of a circle in the equatorial plane, make it possible for all points of the world to communicate with each other on a one-hop (or at the most a two-hop) communications basis. Furthermore, this new technology, with appropriate facilities at the earth stations, can operate as a demand switch for all types of communications. The potential of housetop-to-housetop communications with demand switch capability via satellite is stimulating to the long-range communications planner. Two-way satellite communications are now in operation between most nations of the world.

In connection with potential communication volume via this new technology, more people are alive now than the total number who have lived up to 1900. Furthermore, scientists and engineers are usually quite communicative, and since approximately 90% of them who have ever lived are alive now, almost all of the scientists and engineers who have ever lived can now communicate via satellite relay systems.

More prosaically the satellite communications system is a one-hop microwave system with great flexibility and no geographical boundaries. Satellites are not currently maintainable in space but this will undoubtedly be possible at some time in the future. On the other hand, perhaps the throwaway philosophy of our current society is warranted, since the particular satellites involved will be technically obsolete before the expiration of their normal 7- to 8-year anticipated life.

The great potential and anticipated strong growth of the satellite industry, and the potential geographical coverage of satellite communications, make the development of international rules and regulations pertaining to its utilization highly essential. The ability to cross political boundaries at will requires control of broadcast service for propaganda, educational, cultural, and advertising uses.

We shall now examine this new technology and its uses in greater detail. This review will examine international and domestic satellite communications, and will cover the nature, current levels, and future growth opportunities of the field.

International and domestic systems

The satellites used in international commercial systems are owned by the International Telecommunications Satellite Organization (Intelsat), which is a partnership of telecommunications organizations from more than 90 nations around the world. The Communications Satellite Corporation (Comsat) represents the United States in Intelsat. Cosmat serves as owner of the U.S. share of these satellites, and also serves as manager of all of the international satellites on behalf of all owners. Comsat and the various international com-

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munication companies in the United States including RCA Global Communications, Inc., share ownership in the U.S.-based earth stations for this international system, with Comsat acting as the manager and operator in most cases. Earth stations in foreign countries are owned by the communication organizations in the countries where they are located.

Russia orbited its first satellite over the earth on October 4, 1957 and the first operational communication satellite was launched by the United States on December 13, 1962 followed by the launch of the first Intelsat I, (Early Bird) on April 1965. There have been great strides in all aspects of this field since then. A brief description of the latest of these international synchronous satellite families, Intelsat IV and IV-A, is shown in Table I. The last Intelsat IV launch from Kennedy Space Center was on May 22, 1975 and the first Intelsat IV-A was on September 2, 1975. Details of the launch vehicle are given in Table II.

Table I — Technical description of Intelsat IV international satellite.*

Size
7'10" in diameter
17'4" in length
Weight
3058 lb at launch
1544 lb in orbit after apogee motor fire
Characteristics
12 transponders, each with 36-MHz bandwidth
Capacity available: 3750 two-way voice-grade circuits plus 2 color tv channels
2 transmitting antennas
2 receiving antennas
2 steerable spot-beam transmit antennas
Frequency
6-GHz up-link frequency band
4-GHz down-link frequency band
Design life: 7 years
Spinner/type: approximately 50 r/min
Launch vehicle: General Dynamics Convair division, Atlas Centaur
Space contractor: Hughes Aircraft Company

*Intelsat IV-A differs in the following respects. It has 20 transponders, capacity is 6250 two-way voice-grade circuits plus 2 tv channels, and weight is 1732 lb in orbit after apogee motor fire. It also utilizes four spot-beam antennas in order to use the same frequencies in the east and west directions for this increasing satellite communication capability.

Table II — Technical description of Atlas Centaur launch vehicle for Intelsat IV international satellite.

Size
130' in length
10' in diameter
Weight
326,000 lb on launch pad
Engines
Main: liquid propellant
Payload: solid propellant
Thrust in lb
370,000/booster
60,000/sustainer
30,000/upper stage
370,000/at lift-off

The second major area of interest in satellite communication lies in the domestic field, particularly in the United States. This development in our country has been opened to competition in the private line field by the FCC decision of June 16, 1972. U.S. domestic satellite communications first began on December 21, 1973, when RCA Globcom initiated communication services between its earth stations in Valley Forge, Pa. and Pt. Reyes, Calif., and RCA Alascom between its earth stations in Talkeetna, Alas. and Pt. Reyes, utilizing transponder space on the ANIK satellite owned by Canada's Telesat organization.

Western Union began operation of its domestic satellite system between New York, Los Angeles, Dallas, Chicago, and Atlanta on July 10, 1974 using its own Westar satellite. On May 31, 1975, as required by FCC decision, RCA Globcom transferred its satellite operations from the Canadian ANIK to Western Union's Westar II. On December 12, 1975, RCA Globcom and RCA Alascom launched their first satellite, RCA Satcom 1, which began commercial service on February 28, 1976. The ATT Company, IBM, and possibly others are proceeding with plans to launch additional domestic satellite systems.

Until the recent launch of the RCA Satcom 1 satellite, all of the commercial communication satellites were built by the Hughes Aircraft Company in California and were of the so-called spinner type. The competitive opportunity afforded by the FCC decision in the domestic field gave rise to new innovations in the technology and there will be more to come. The innovations in the RCA Satcom I satellite are shown below.

- A cross-polarized antenna with overlapping gridded reflectors fabricated from lightweight Kevlar material, which increases the satellite capacity from 12 to 24 simultaneous color tv channels. Each of these channels also is capable of carrying approximately 1000 one-way telephone conversations or 64 million bits per second of computer data.
- The use of graphite fibre epoxy composite materials to achieve a 2:1 weight reduction over customary invar material for the complex frequency filtering elements in the spacecraft.
- Use of a traveling-wave-tube driver amplifier with an all solid-state device that decreased weight and improved reliability.

The American free enterprise system resulted in development being telescoped in time for the benefit of all. The RCA Satcom 1 satellite is a three-axis stabilized bird with the solar panels on extended arms, which are directed continuously on the sun.*

In addition, substantial improvements in thrust capabilities were made on the Delta line of launch vehicles by the McDonnell Douglas Corporation. Under contract with RCA Globcom, they produced the augmented Thor-Delta launch vehicle 3914, which permitted the launch of a 24-transponder, 2000-lb satellite at a cost per transponder substantially less than that of the 12-transponder, spinning satellites previously launched.**

The launch

Witnessing the launch of a communications satellite and the subsequent events leading to its final positioning and commercial operation is both instructive and exciting. It permits close-hand observation of the complex range of this new technology and helps place it in proper perspective with older developments of our modern society.

At 8:56 p.m., December 12, 1975, at the culmination of a long automatic computer-controlled check-out, the launch of the RCA Satcom I began. The final computer command—firing of a launch vehicle motor—was given. At night, this moment was spectacularly visible, illuminated by the glowing red exhaust of powerful launch motors. The huge rocket began its ascent, internally guided on its first movements by its own computer controls. Sixty-four seconds after the firing of the liquid propellant

*For a technical description of the RCA Satcom I satellite, see the paper in this issue by Kiegler.

**For information on the McDonnell Douglas 3914 launch vehicle see the paper in this issue by Christopher, Plush, and Greenspan.

main engine and five of the strap-on solid propellant booster engines, these spent boosters were jettisoned and seen toppling end-over-end back into the ocean from a height of about 7 mi. The remaining four strap-on solid propellant boosters were also jettisoned 128 s after lift-off at a height of about 28 mi following a similar tumbling path. At 3 min 56 s after lift-off, the main engine separated and the second stage ignited, for a burn cycle of 4 min 17 s and then reignited for a second burn cycle of 41 s, after which time the vehicle was at an elevation of about 110 mi. The protective shroud, which housed the spacecraft, was then shed (fairing jettison). This was followed by the ignition of the third and final stage of the launch vehicle for a 43-s firing. At 24 min 46 s after lift-off and at a height of about 140 mi, this final third stage and adapter were separated from the satellite.

At this time, when the satellite was in an elliptical orbit with a perigee altitude of about 113 mi and an apogee of 22,358 mi, NASA's obligations and responsibilities to RCA were terminated. Under RCA control during the seventh apogee, the kick motor was fired, placing the satellite in its synchronous orbit at 5:41 p.m., December 15, 1975, at a height of about 22,300 mi above the equator. This was followed with a series of intricate command maneuvers and events all controlled from the earth station operated by RCA Globcom at its Telemetry and Control Center at Vernon Valley, N.J. These commands included despinning, orientation of the spin axis, energizing the fly wheel, deployment of the solar-array panels, and sun capture by the solar panels' command sensors, the latter occurring at 5:45 p.m., December 18, 1975.

The process of placing the satellite in its approved longitudinal position of 119° west longitude and the exercising and testing of its communication capabilities began next. Since it was located approximately 137° west longitude, the east/west positoning hydrazine thrusters had to be activated under computer control from the earth station. The satellite was sped up a bit in order to drift gradually at about 1.25° per day to its position at 119° west longitude. This path took it within 88 mi of another active communications satellite, which meant that for a short time these two satellites, under different command control from the ground, were in the spot beams from RCA Globcom's and Western Union's earth stations. Great care was required to insure that these satellites passed each other successfully. The testing of the communication transponders and associated satellite facilities began in earnest, finally culminating in the availability of this new satellite for commercial service in the domestic communication field on the anticipated date of February 28, 1976.

The future

It is quite clear when one examines the capacities of the latest satellites that the growth in capacity with each generation is picking up speed. The RCA Satcom 1 capacity is 12,000 two-way voice-grade circuits or 4 color tv circuits and the Intelsat IV-A satellite has 6250 voice-grade circuits plus two color tv circuits, compared with the first Intelsat 1 (early Bird) satellite with 240 two-way voice-grade circuits or one color tv circuit. In addition, there are many foreseeable changes ahead in the technology, some immediate and others long ranged. These include increasingly high frequencies, greater power, more intricate and effective antenna arrays, and possible space maintainability using the space shuttle.

Associated with these advances in satellite technology will be ever increasing improvements in speed and capabilities not only at the earth stations but for all the associated computer-controlled communications switching facilities, demand assignment multiple-access switching systems, and advanced digital equipments.

Concurrent with the increasing capacities will be a reduction in satellite circuit costs. Already we have seen coast-to-coast satellite service rates for private-line point-to-point voice-grade service reduced by as much as 50% over land-based facilities.

Satellite communications provide new opportunities for commercial, governmental, educational, political, medical, cultural, news, marine, mobile, and other users. It lends intself to automatic operation, video, low- and high-speed data, record and voice, and a multitude of miscellaneous services. It has enormous time-saving potential for mankind in the conduct of its business and services.

Eugene D. Becken,* Chairman, Executive Committee, Board of Directors, RCA Globcom, New York received a BSEE from the University of North Dakota, an MSEE from the University of Minnesota, and an MS in industrial management from the Massachusetts Institute of Technology. He has been associated with RCA Global Communications, Inc. for more than 40 years He previously held assignments as Transmission Engineer; Plant Operations Engineer; Vice President, Chief Engineer; Executive Vice President Operations; and President. He has been active in the computer switching and satellite engineering fields. Mr. Becken is a Fellow of the IEEE and a Sloan Fellow of MIT. He is a member of the Board of Governor's of the Communication Society of the IEEE and the Junior Achievement of New York. He also hold membership in the American Association for the Advancement of Science, the New York Academy of Sciences, the Armed Forces Communication and Electronic Association, Sigma Xi, and Sigma Tau. He is a registered Professional Engineer in the States of New York and New Jersey. He received the 1975 DeForest Andion Award from the Veteran Wireless Operators Association and the Sioux Award from the University of North Dakota.

*Mr. Becken retired May 1, 1976.

The engineers and scientists are giving us a continuously improving unparalleled global communication service for point-to-point service as well as voice and tv broadcasting. Transponders and earth stations can be dedicated to specific users. Altogether, satellite communications represent a massive opportunity for peaceful improvement of mankind's existence.

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RCA Satcom system

A.W. Brook

The RCA Satcom system is really many systems which share common facilities where possible, with special-purpose facilities tailored to specific services. This paper describes how the 24-channel RCA Satcom satellites have been used to provide many services and also describes the different ground segments associated with each of those services.

THE RCA Satcom system was conceived in 1970, and RCA Alaska Communications and RCA Global Communications jointly filed with the Federal Communications Commission in March 1971, requesting authority to own and operate the system. The application contained detailed descriptions of the services which would be provided by the system and also proposed a space and ground segment design for the facilities to be used. The proposal also contained an alternate space segment design using the 12- and 14-GHz band of frequencies. The application was subsequently amended when assurances were obtained that the Thor-Delta launch vehicle, on which the space segment was based, could be augmented to have the capability to place 2000 lbs. into the synchronous transfer orbit. It was at this point that a 24-channel satellite could be considered to be practical on a Thor-Delta launch.

The services proposed in the original application have all since been implemented or, to some extent, demonstrated, except for motion picture distribution. The services are:

- Message toll telephone service and bush service for RCA Alascom
- Private leased-channel service for RCA Alascom and RCA Globcom.
- Digital data service.
- Private-line services to government agencies.
- Commercial television and radio services.
- Cable television services.
- Motion picture distribution service.
- Private switched-network services.

In the following paragraphs, the facilities that are constructed or planned for each of these services are described and the transmission performance of each is summarized.

Message toll telephone service for RCA Alascom

RCA Alascom provides long-distance telephone facilities and services within the State of Alaska and between Alaska and the lower 48 states. RCA Alascom also provides private-line services throughout the State of Alaska, and in some instances where local operating companies do not exist, RCA Alascom provides some essential services directly to the public. The service provided to many of the rural communities in Alaska—described generally as bush service—is one example. Bush service will be described separately.

The present Alaska Communications Plan contemplates about twelve large and midroute earth stations by the end of the 1976. These are listed in Table I together with their characteristics. All the stations listed, except Barrow, Kotzebue, Adak, and Dillingham, are presently operational; these four will be operational by the end of 1976. These earth stations are used in combination with terrestrial microwave and cable facilities to provide the toll network in Alaska. Figs. 1, 2 and 3 show three of these earth stations.

Table I — Major earth stations operational or under construction.

Earth station	*G/T (dB/K)*	*Antenna size (m)*
Bartlett	40.7	30
Lena Point	31.7	10
Yakutat	29.8	10
Nome	29.0	10
Bethel	29.0	10
Valdez	29.0	10
Put River	29.0	10
Cordova	29.8	10
Barrow	27.8	8
Kotzebue	29.8	10
Adak	29.8	10
Dillingham	23.2	4.5

Approximately 70% of all circuits are carried for some portion of their length by satellite, while 30% of all circuits are not routed by satellite. The performance presented here is only for the satellite portion of a circuit. Three different types of circuits are used with three different modulation schemes:

- Toll connecting midroute to Juneau (frequency-division multiplexed—frequency modulation (FDM—fm).
- Intrastate Intertoll single-channel per carrier (SCPC), Juneau to Anchorage (Narrow-band fm and delta modulation).

A. William Brook, Chief Engineer, RCA Americom, Piscataway, N.J. received the BS (tech) from Manchester University, England, in 1955. He has more than 20 years experience in electronics and communications in England, Canada, and the Unites States. In the U.S., prior to joining RCA, Mr. Brook worked with General Electrical where he participated in the ATS-F and G, phase BC Program, the ERTS Program, and the conception of communications systems employing small earth stations for national switched networks. With IT&T, he was with the International Electric Corporation working on the 465L Command Control Network and with the Federal Electric Company, working on the European, Mediterranean Trospospheric Scatter Communications Network. With Adler Electronics (later to become the Adler-Westrex of Litton Industries), Mr. Brook worked on a number of military line-of-sight and tropospheric scatter transmission systems and the AUTOVON 4-wire switching network. Since joining RCA Global Communications, Inc., in 1970, Mr. Brook has worked on the design and implementation of satellite communications systems for use in Alaska, Hawaii and the contiguous states. In Mr. Brook's previous position of Director of Systems Engineering and Facilities Planning, he directed the Plant Extension; Transmission; Traffic and Switching Engineering Sections of the RCA Satcom Project. He was appointed to his present position in April of this year.

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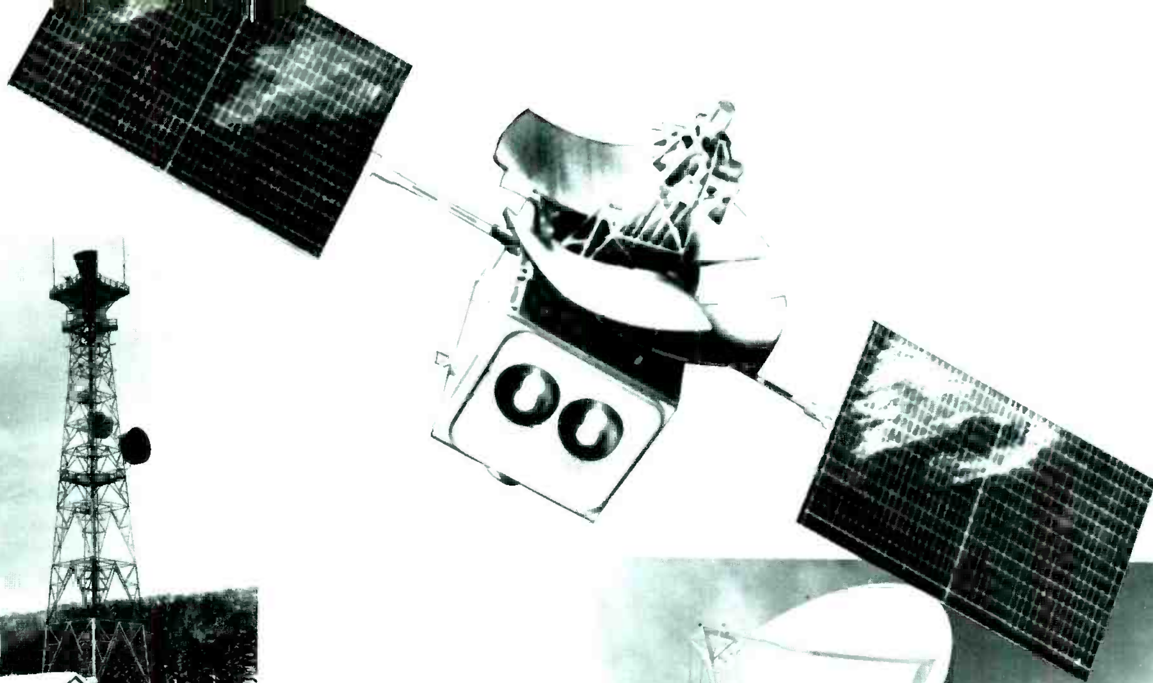


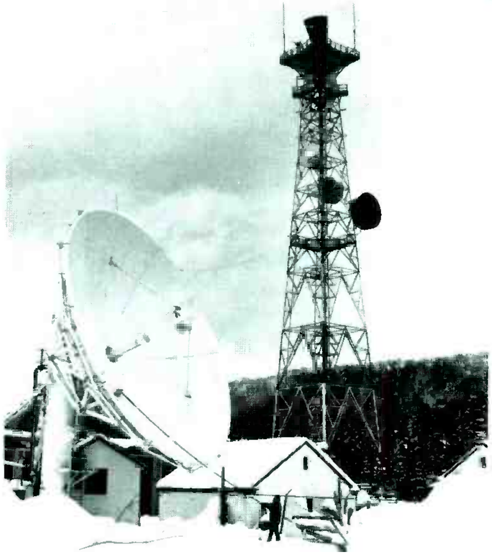


Fig. 1 — 33-foot earth station at Juneau.

Fig. 3 — 98-foot earth station in Bartlett.

Fig. 2 — 33-foot earth station at Valley Forge.

- Interstate Intertoll FDM-fm, Pt. Reyes to Anchorage

The associated link budget and the performance summary are shown in Tables II and III. The transmission performance here is characterized in a single parameter; namely, the noise level in a voice circuit when measured at the zero Toll Level Position (0TLP). RCA Alascom has selected as its goal, for both toll connecting and intertoll circuits, 7500 pWpo. This goal is 2500 pW lower than the noise level established for intercontinental circuits using the Intelsat series of satellites. It should be noted that where a single-channel-per-carrier (SCPC) scheme has been employed, the use of a compander is implied. Care has been taken, however, to avoid the use of companders on the satellite portions of circuits, which may, in turn, be connected to terrestrial links that might also employ companders (*N* carrier systems, for example). Thus, companders are not used on intertoll circuits either for intrastate or interstate service.

Present plans call for some 2670 interstate circuits and 3360 intrastate circuits in 1976, growing to 5780 interstate and 8100 intrastate circuits in 1980. In 1976, five equivalent transponders will be used and in 1980, this will grow to thirteen. [An equivalent transponder is defined as a measure of satellite capacity and represents the sum of a number of fractions of the capacity of whole transponders which together equal unity.]

Bush service

At the time of the acquisition of the Alaska Communications System by RCA, there were over 200 communities in Alaska with 25 or more people who did not have telephone service. Some had access to hf radio, but many had no means of electronic communication. The initial approach to providing service to these communities was to use thin-route

Definitions of important communication system parameters

C/N (carrier-to-noise ratio): The ratio of specified measures of the carrier and the noise after specified band limiting and before any nonlinear process such as amplitude limiting and detection.

G/T (figure of merit): This is a very useful indication of the performance of an earth station, defined as:

$$10 \log_{10} \left[\frac{\text{antenna power gain}}{\text{system noise temperature (K)}} \right]$$

S/N (signal-to-noise ratio): The ratio of the value of the signal to that of the noise, usually expressed in decibels. Suitable definitions of the signal and noise should be associated with the term: as, for example: peak-signal to peak-noise ratio; rms signal to rms noise ratio; peak-to-peak signal to peak-to-peak noise ratio; peak-to-peak signal to rms noise ratio, etc.

RTC (receiver transfer constant): The receiver transfer function relates the predetection *C/N* to the post detection *S/N* for given modulation parameters. It is the signal-to-noise improvement ratio in fm systems. Mathematically, it is expressed as: $S/N = C/N + RTC$.

microwave and vhf radio. However, as satellite communication facilities became lower in cost, it was apparent that small earth stations could be used to provide circuits to a community. Until the community developed its own exchange, the circuits could be terminated with telephone instruments. The circuits are, in effect, long subscriber loops connected to a switch in Anchorage, which automatically connects the bush subcriber to his calling party. Virtually all traffic from the bush either terminates in Anchorage or the nearest large community to the bush village. Bush-to-bush calls are expected to represent no more than 6% of all calls. The transmission performance associated with these subscriber loops has been specified in terms of satellite link parameters. This is a convenient method in view of the equipment that has been selected, which makes use of compandors and, consequently, the performance of the circuit would be difficult to specify, even in subjective terms.

The use of high-gain transponders 1 and 3 (in the satellite) will result in a substantial power saving at the Bush stations where electrical power is scarce and costly. The frequency plan of approximately 877 channel-assignment slots for the 130 voice-activated circuits on transponder 1 and for the 276 voice-activated circuits on transponder 3 were implemented in order to meet a performance objective of a S/N of 33 dB plus 17 dB of companding gain for a total subjective test-tone signal-to-noise ratio of at least 50 dB. The G/Ts of the bush stations are of the order of 19.2 dB/K.

Private leased-channel services for Alaska and the lower 48 states

This category of service, in its broadest sense, covers many different service offerings; however, what is meant here is a point-to-point voice-bandwidth service available to a customer on a dedicated basis, 24 hours a day. Such circuits are capable of voice and data transmission up to 9600 bits/s. This service is offered between all of the major cities served by the Satcom system.

Fig. 4 shows the routing of a circuit through the space and ground segments. Circuits from a customer's location are

Table II — Link budget.

	Toll connecting midroute to Juneau (FDM-fm)	*Interstate intertoll Pt. Reyes to Anchorage (FDM-fm)*
Up-link thermal noise	741 pWpo	741 pWpo
Down-link thermal noise	2512	4571
Satellite intermodulation, earth station out-of-band intermodulation noise	570	570
Adjacent and crosspolarized transponder intermodulation	1259	661
Earth station equipment noise	500	500
Interference noise (includes interference from terrestrial and adjacent satellite sources)	457	457
	6,039 pWpo (a margin of 1461 pWpo)	7,500 pWpo

Table III — Intrastate intertoll single-channel-per-carrier (SCPC) performance summary.

	Narrowband fm	*Δ mod.*
Up-link thermal $(C/N)_{up,th}$	25.5 dB	23.6 dB
Down-link thermal $(C/N)_{dn,th}$	15.3 dB	13.4 dB
Intermodulation $(C/N)_{IM}$	20.5 dB	18.6 dB
Internal interference $(C/I)_{INT}$	19.5 dB	19.5 dB
External interference $(C/I)_{EXT}$	31.4 dB	31.4 dB

System C/N*	12.7 dB	System C/N	11.2 dB
S/N (without companding)	34.8 dB	BER	7×10^{-5}
Companding improvement	17.0 dB	Equivalent S/N	>50 dB
Total (subjective S/N)	51.8 dB		

*For a SCPC circuit between midroute earth stations, the required carrier-to-noise ratio is 5 dB above threshold, which results in $C/N = 12.6$, i.e., $C/N_o = 56.7$ dB · Hz.

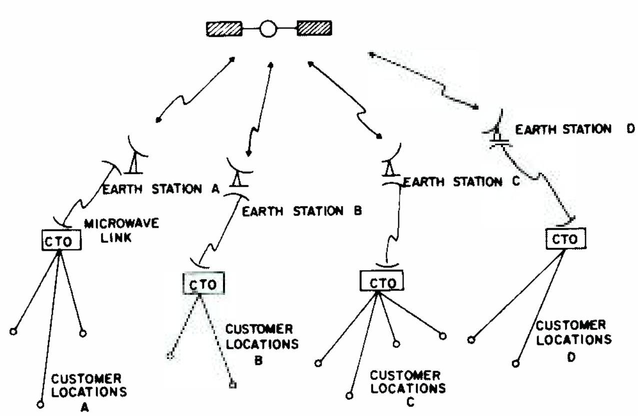


Fig. 4 — Network configuration for private leased-channel service.

Table IV — Major cities served by RCA Satcom system and earth stations serving these cities.

City	*Served by*	*Antenna diameter (m)*
New York City, Boston, Newark	Vernon Valley	13
San Francisco, Oakland,	Pt. Reyes	13
Camden, Philadelphia, Wilmington	Valley Forge	10
Los Angeles, San Diego, Hollywood, Milwaukee	South Mountain	13
Washington, Baltimore, Norfolk	Benedict	13
Chicago, Detroit, Minneapolis, St. Paul	Lake Geneva	13
Dallas, Houston, New Orleans	Rayburn	13
Indianapolis, Cleveland, St. Louis	Indianapolis	10 or 13
Atlanta, Miami, Nashville	Atlanta	10
Kansas City, Kansas City Oklahoma	Kansas City	10 or 13
Seattle, Portland, Boise	Seattle	13
Honolulu	Paumalu	16

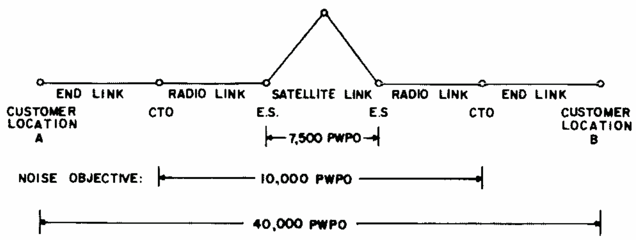


Fig. 5 — Reference circuit for private-line leased-channel service.

carried to a CTO (central terminal office) over lines leased from local carriers. The circuits are then multiplexed in the CTO using single sideband—frequency division multiplexing. The multiplexed signal is then carried by microwave to the earth station serving that city. A multi-destination frequency-modulated carrier is transmitted to all other earth stations in the system. At each earth station, the entire signal is demodulated but only the voice channels destined for that city are demultiplexed. This demultiplexing is arranged so that either a group or supergroup interconnect is made between the receiving earth station and the microwave relay to the receiving CTO. At the receiving CTO, the groups or supergroups are demodulated to the voice-frequency band for interconnection with a local carrier and delivery to the customers' facility.

The cities between which this service is planned are listed in Table IV. The service is provided through the general purpose earth stations (Fig. 2, for example) which have a G/Ts of 32.4 dB/K. The transmission standard is illustrated in Fig. 5 and shows that, from CTO to CTO, the circuit is engineered to meet a 10,000 pWpo standard.

Digital data service

The Satcom system has been designed to provide digital transmission service for low and high speed data. This service is separate and distinct from the analog transmission services, which may be used for data transmission if the customer wishes; that is, customers who lease voice circuits are able to use those circuits for transmission of data, up to 9600 b/s. In a similar manner, a 48-kHz group transmission path may be used for the transmission of data up to a speed of 56 kb/s.

The digital data transmission service which was proposed in 1971 has so far attracted the interest of only very few commercial users and none have so far taken this service. However, a number of government agencies have recently started to order this type of service between specific government installations. The 1971 proposal was for high speed data between the New York, San Francisco, Los Angeles, Chicago, and Denver earth stations using a time-division multiple-access (TDMA) system. The earth station microwave and CTO network was exactly the same as that described above in the section on point-to-point private leased channel service and illustrated in Fig. 4.

The service contemplated the use of two transponder channels with approximately 44 Mb throughput for each. The channels were time shared between the five earth stations and customers were offered standard interfaces at the CTO locations for 19.2, 38.4, 48, 50, 56, 64, 256, and 1544 kb/s.

Government private-line service

The government private-line services which are being, or have been, implemented are the data services between:

- Pt. Reyes, Cal. and an offshore point,
- Kokee Park and Maryland (duplex 56 kb/s),
- JPL, Cal. and Goddard Space Flight Center (duplex 56 kb/s),
- Camp Roberts, Cal. and Washington D.C. (3.08 Mb/s to Washington, D.C., 64 kb/s to Camp Roberts), and
- Edwards AFB, Cal. and Houston, Texas (simplex, 168 kb/s to Houston).

All the earth stations are equipped with a 10-m antenna (G/T = 32.4 dB/K) except at the offshore point. A 28-foot antenna is being used there with G/T of 31.4 dB/K. A block diagram of one of the data circuits is shown in Fig. 6.

The 56 kb/s full-duplex (simultaneous, two-way) data services between Jet Propulsion Laboratory and the Goddard Space Flight Center are being provided by the RCA Satcom F-1 spacecraft with performance at a BER less than 10^{-6} which is compatible with the NASA performance requirements. The remaining data circuits are being implemented via the facilities of our domestic communications satellite systems to meet the performance objective of a BER no worse than 10^{-7} end-to-end. The transponder utilization for the above data services in terms of the available power radiated from the satellite varies from 1% to about 18%, depending on the data rate and the number of voice circuits.

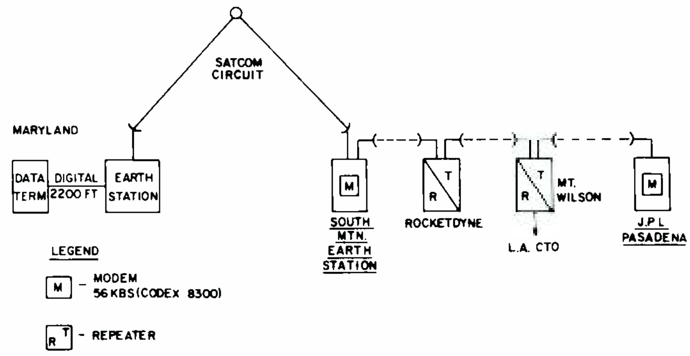


Fig. 6 — RCA Satcom data circuit, Maryland to JPL.

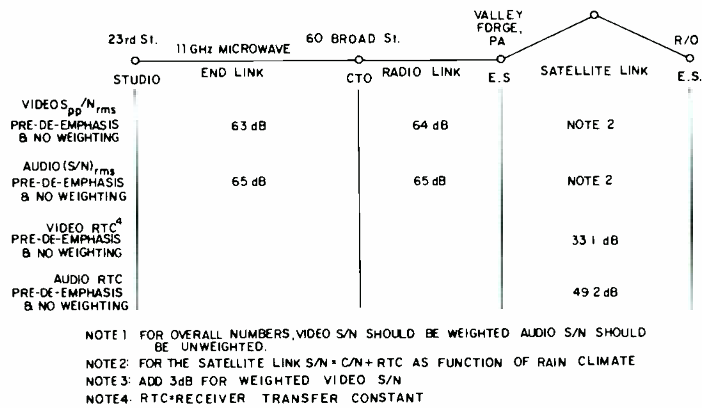


Fig. 7 — CATV television service. Hypothetical reference circuit for video and audio signal to noise ratio.

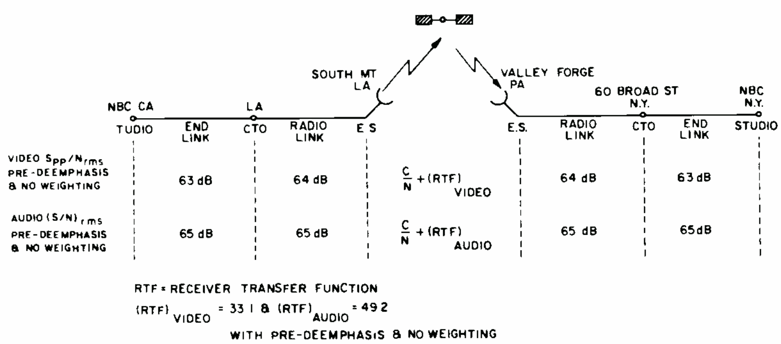


Fig. 8 — Commercial television service.

Television distribution services

Single-point to multipoint service to the catv industry

One innovative service that is being offered by RCA is television distribution to catv head-ends. Fig. 9 is the reference circuit describing the RCA system between a major cable-program packager in the Northeast and the RCA satellite earth station at Valley Forge, Pa. The RCA domestic satellite system has been designed to be transparent to video and audio parameters such as frequency response, harmonic distortion, differential gain, etc. provided that the receiver noise level of the satellite earth station (receive-only station in the reference circuit) is below the tv signal level. This noise level relative to the signal level is determined by the system carrier-to-noise ratio (C/N), which in turn is determined by the level of the radiated power from the satellite, by the earth station figure of merit (G/T), by atmospheric or rain characteristics in the transmission path, by interference from the adjacent co- and cross-polarized transponder channels, by interference from the other satellite systems.

The end link (which is an 11-GHz microwave link, or an fm cable link) and the radio link (which is a 6-GHz microwave link) are common elements in the transmission path and have been designed to achieve the stated performance (see Fig. 7) for 100% of the time in order to minimize the receive-only earth station cost for a given level of performance.

As a numerical example, the video peak-to-peak signal-to-rms noise ratio achievable for the circuit from the N.Y. studio to a receive-only earth station located in San Francisco is 51.3 dB for a system availability of 99.9% where an earth station G/T of 27 dB/K is used. The associated audio rms signal-to-rms noise ratio is 52.4 dB.

Point-to-point television leased-channel service

While catv service is for distribution from the studio to many catv head ends where the receive-only stations are located, the point-to-point leased-channel service provides sutdio-to-studio circuits as shown in Fig. 8. This figure describes the reference circuits from the NBC studio in California to the New York Studio. In this case, both the transmitting and the receiving stations are connected to their respective studios through the radio link and the end link. The G/T of the Valley Forge earth station is 32.4 dB/K and this

Table V — Television performance parameters for service to Alaska. Highest video frequency is 4.2 MHz; highest audio frequency is 15.0 kHz; and transponder bandwidth is 34.0 MHz.

Link type	*C/N (dB)*	*I.F. bandwidth (MHz)*	$(RTC)_a$ *(dB)*	$(RTC)_v$ *(dB)*	$(S_{pp}/N)_v$* *(dB)*	$(S/N)_a$ *(dB)*
Lower 48 to midroute using full transponder	17-20	34.0	41.0	39.0	56-59	58-61
Lower 48 to idroute using half transponder	20.0	17.5	30.0	30.0	50.0	50.0
Midroute to bush using full transponder	10.0	34.0	41.0	39.0	49.0	51.0

*Including CCIR noise weighting.
$(RTC)_a$ and $(RTC)_v$ are the receiver transfer constants for the audio and video signals, respectively.

yields a video signal-to-noise ratio of 52.5 dB for a system availability of 99.9%.

Television services for Alaska

The RCA Satcom system is specifically designed to provide excellent television service in Alaska—even to earth stations with *G/Ts* of 19 to 20 dB/K. This was achieved by making all 24 channels available in the State and, in addition, tilting one reflector on the spacecraft so that six of the channels have their beam centers in Alaska.

The forecasted requirements for televisi in 1976 are for one full-time channel and one part-time channel from the lower 48 states to midroute stations in Alaska. In 1980, the traffic is expected to increase to two full-time channels and one part-time channel from the lower 48 to midroute stations, one full-time channel from midroute to bush stations, and one part-time channel from midroute to the lower 48. The noise performance of the ground-to-spacecraft-to-ground links is shown below as peak-to-peak signal-to-rms noise for the video and as rms signal-to-rms noise for the audio. The link budgets for the various routes show that 37.1 dBW EIRP (effective isotropic radiated power) is available on six channels in Alaska on the F-2 satellite and 31 dBW is available on 12 other channels. This makes a TASO 1, or better, signal available to the bush stations using a full transponder and permits two television channels/transponder between larger stations.

	Space segment S/N	
	Video	*Audio*
Location	*(weighted)*	*(unweighted)*
Lower 48 to midroute using full transponder	>56.0 dB	>58.0 dB
Midroute to bush using full transponder	>45.6 dB	>40.6 dB

The calculated performance for given modulation parameters is shown in Table V for the different types of links considered.

Commercial broadcast service for network radio

Audio signals intended for use by broadcasters—generally known as program audio—may be distributed between originating studios and remote stations of a network, over satellite transmission systems. One such system is currently in use between New York City and Burbank, California, by the NBC Radio network.

The program audio is transmitted from the New York studio to the RCA Central Terminal Office (CTO) over lines leased from the local telephone company. These lines will eventaully be replaced by 11-GHz radio to provide the frequency response shown in Fig. 9. At the CTO, the incoming signal is monitored and routed to the appropriate equipment for further transmission. The signal is then converted in level and frequency to a signal which is the equivalent of six voice channels when included in a normal FDM-fm composite signal. This signal is combined with voice channels and other program channels using ssb-FDM multiplexers at the CTO and transmitted to the Los Angeles CTO over the RCA system as shown in Fig. 9. All transmission between the New York CTO and Los Angeles CTO, is by FDM-fm. At the Los Angeles CTO, the program audio is converted back to baseband, monitored, and routed to lines leased from the local telephone company for transmission to the Burbank studio. A similar service is provided from the west coast to the east coast.

In general, this satellite system provides a test tone-to-noise ratio of the order of 56 dB, harmonic distortion of less than 1%, and a virtually flat frequency response over the range 50 Hz to 15,000 Hz. In addition, stereo transmission may be easily implemented and it is anticipated that a stereo service will be requested in the near future.

The reception of a high quality audio signal is also feasible by using a small earth station. The range of performance

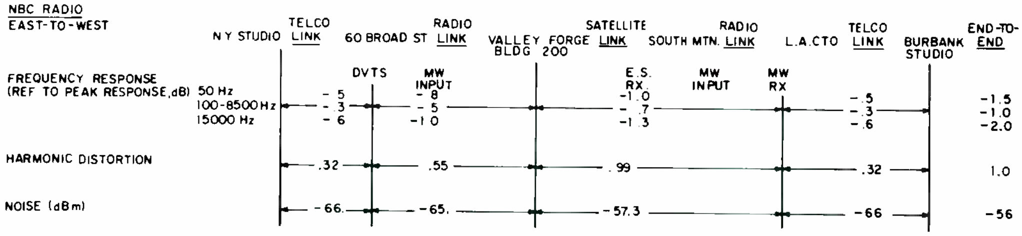


Fig. 9 — NBC radio distribution service. Performance objectives for 15 kHz radio.

objectives is to transmit one to six channels of stereo (up to twelve monaural) between one large station and many small earth stations.

The network is assumed to consist of a master control center that will feed recorded or live program materials of voice and music to a satellite earth station. The satellite earth station will relay this material via a domestic communication satellite to the various small earth station in the network. Further, some small earth stations will be capable of transmitting program material either to the master control center for later retransmission or directly to the entire network. The networks considered are expected to consist primarily of about 150 to 200 small earth stations located in the four most populous time zones of the United States.

A demonstration of high quality stereo music transmission was given by National Public Radio (NPR) at Washington, D.C., on March 27, 1975. The demonstration was a tremendous success. The quality of the satellite transmission was good enough to produce enthusiasm from the most skeptical of audiophiles. Brief technical details of this demonstration are as follows:

- *Antenna* — Prodelin 10 ft., receive gain 39.5 dB at 4 GHz.
- *Low-noise receiver* — AIL uncooled paramp, noise temperature 165 K, gain 42 dB.
- *Single channel per carrier* — California microwave system. Modified SCPC 64 terminals using 125 kHz nosie bandwidth, operating at a downlink carrier/noise of 14.43 dB. The estimated companded S/N at audio frequency was 51.5 dB with compander advantage of 8 dB.
- *Transmission* — Valley Forge 3-kW HPA with an output 47 dBW/carrier.

Motion picture distribution service

The concept of motion picture distribution by satellite facilities is essentially an extension of the closed circuit television principle to a complete program service for any of the 10,000 indoor theaters and 5,000 drive-ins in the United States. Our concept is to provide the theaters with the programs as the basic service. A feed to a catv system would be an additional outlet which could provide the picture directly to the homes of customers at a charge paid to the catv operator with appropriate compensation for the program. Film production companies could increase their revenues in this manner.

Numerous advantages, such as transmission of a program to any point served by an earth station regardless of distance, the satellite signal coverage over any number of earth stations without reduced quality, drastic reduction of the reproduction of the large number of film prints, nationwide distribution at the same time, etc. can be obtained by distribution of motion pictures by satellite.

The full-period service to the motion picture industry represents a new, unique potential of the system. It was estimated that about 193 theaters can associate with 18 theater circuits in New York City, the largest market, and twelve theaters in the 100th largest market. How many different major pictures would be shown at the same time is presently a matter for conjecture. For the purpose of estimating

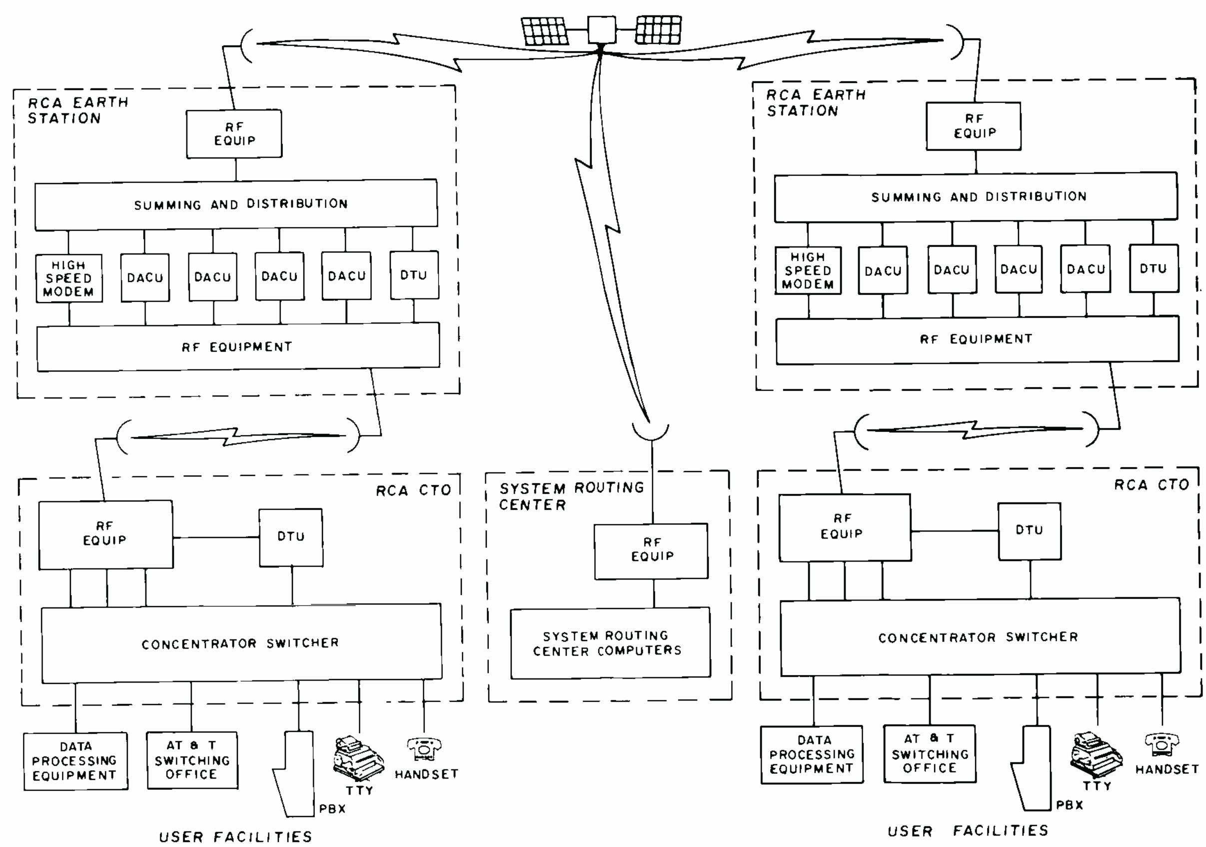


Fig. 10 — Functional elements of the private switched network service.

the capacity required in a single satellite for all services, the following numbers were selected as possible motion picture needs.

	No. of simultaneous channels
First 25 cities	4
Second 25 cities	3
Next 50 cities	2
Next 100 cities	1

These channels could care for all the theaters in a particular city or any part depending on the industry requirements. Certain theaters could become identified as satellite houses and would carry only programs provided in this manner. Others might join satellite-feed with regular projection facilities and others would stay with present projection methods. This service needs much more market development before an operational system is in service. Representatives of the motion picture industry have indicated only small interest at this time, while encouraging us to continue refinement of the system elements. The highest priority is in the area of cost reduction of the theater projection system.

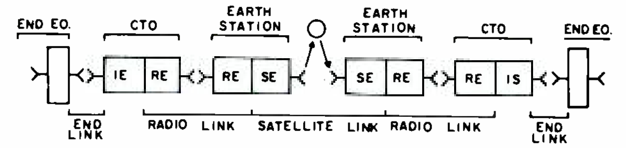
Private switched-network service

Private switched network service (PSNS) permits customers to signal over two or more separate private lines to form through-connections between a customer's locations. PSNS provides the interconnection through network switching and transmission facilities dedicated to that customer.

The major functional elements of the PSNS are the RCA primary earth station (PES) interconnected with an associated central terminal office (CTO) by microwave channels, the computer-based system routing center (SRC), the RCA communications satellites, and the supporting terrestrial line link. Fig. 10 shows the interrelationships of these major system components.

The private switched network service (PSNS) has many special features offering the following capabilities to private-line commercial and government customers.

- Demand assignment multiple access (DAMA) — provision of all satellite channels on an "as-required" basis.
- Network maintenance position - automatic monitoring of all hardware components from the central network maintenance position controlled by the SRC.
- Traffic service positions — provision of centralized operator assistance for all PSNS users.
- Special features — conferencing, call forwarding, station hunting, camp-on, executive override and others on a network-wide basis.
- Traffic reporting — recording of all call activities by the SRC that completely and accurately inform management on efficiency of PSNS.



PARAMETER	UNIT	TOL				SECTION PERFORMANCE ALLOCATION						OVER-ALL PERF.
NOISE CONTRIBUTION	pWpo	LESS THAN	79	794	25	631	562*	631	25	794	79	3620
AVERAGE TALKER (S/N) rms	dB		62	52	67	53	50*	53	67	52	62	44.7

* NOISE WHEN NO SIGNAL IS PRESENT

Fig. 11 — Transmission performance objectives for a private line voice channel (SCPC).

The service makes use of the general-purpose earth stations where possible. However large private users often have a sufficient density of traffic that a dedicated earth station is justifiable, located immediately adjacent to the customer plant or government agency installation.

A pilot system is under test using biphase delta modulation single-channel-per-carrier equipment at the earth stations and a system routing center which is leased from General Electric. The system is engineered to provide a range of grades of service which can be ordered by the customer and adjusted at will as his needs change. Currently service grades from $P(0.01)$ to $P(0.4)$ are being considered. P here is the probability of a call being blocked through the busy hour. Excellent transmission performance can be achieved with smaller earth stations since the microwave link and local loops at many locations will be eliminated. It may be seen that a reduction of about 2 dB in the earth station G/T is possible while still maintaining the end-to-end performance which is achieved on our private-line leased-channels circuits using the general-purpose earth stations. The transmission reference circuit and the performance objectives for a private-line voice channel (SCPC) are shown in Fig. 11.

Conclusion

The RCA domestic statellite system started service in December 1973, and has provided the opportunity for innovative new service offerings in addition to the traditional long-haul telecommunication services. Two communications satellites were launched and placed in geostationary orbits at 119°W and 135°W longitude. These new RCA advanced-technology, 24-transponder communications satellites in association with state-of-art terrestrial facilities make the services possible at a cost not previously realizable. With the special characteristics of the spacecraft, the system has the capability to provide near-optimum service throughout the United States.

As new satellite communications services become proven, the efficiency with which we use the existing facilities will continue to improve. The Satcom system provides the most flexible means of integrating new services of any of the domestic satellite systems and has the potential of virtually doubling the service per unit bandwidth compared to the present services.

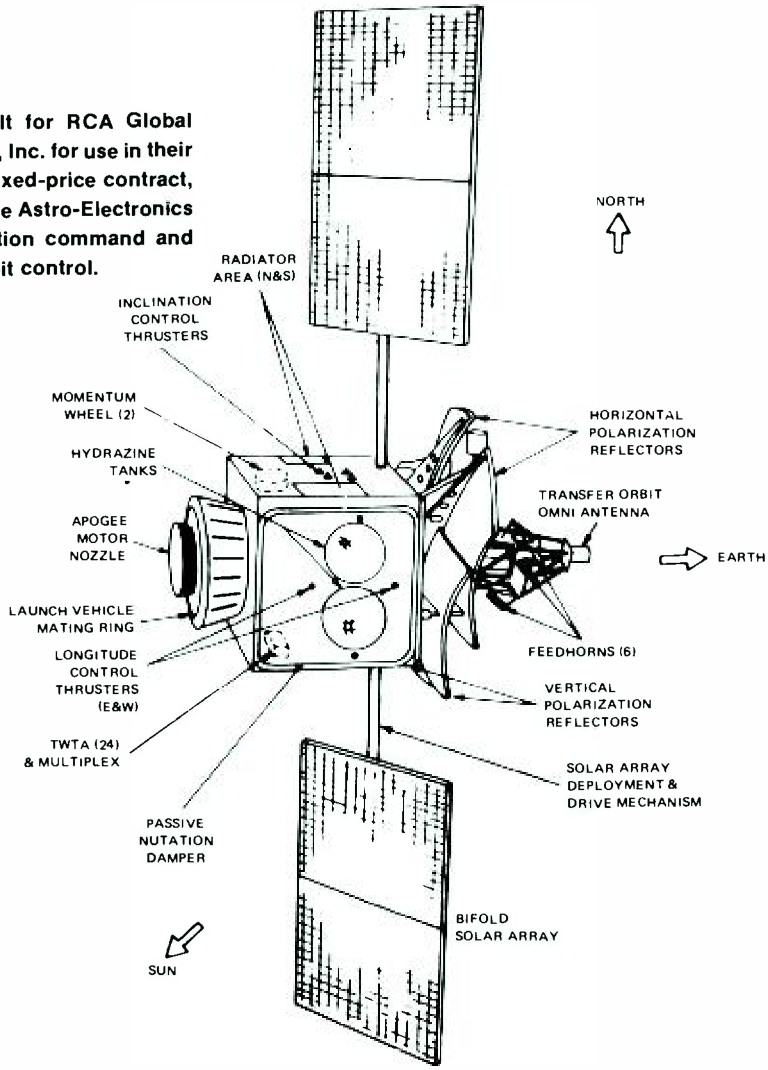
Acknowledgment

The author is indebted to the many RCA Global Communications, Inc., personnel who contributed to the data presented in this paper. Partricularly, I am indebted to Dr. Myung Ki Lee of the Transmission Engineering section who assembled much of the paper and made many useful suggestions on reorganization of the voluminous source data accumulated over the past five years.

RCA Satcom—maximum communication capacity per unit cost

Dr. J.E. Keigler

The RCA Satcom communications satellites were built for RCA Global Communications, Inc.* and RCA Alaska Communications, Inc. for use in their commercial system for U.S. domestic service. Under a fixed-price contract, with 24 months to delivery of the first flight spacecraft, the Astro-Electronics Division supplied the spacecraft hardware, ground station command and telemetry equipment, and software for launch and in-orbit control.



THE COMMUNICATIONS mission of RCA Satcom entails antenna beam coverage of all fifty states, with Hawaiian service provided by an offset spot from the primary beam for the contiguous 48 states and Alaska. To achieve minimum cost per channel in the competitive U.S. domestic market, Globcom and Alascom specified that their satellite should 1) incorporate 24 wide-band transponder channels in the commercial, 4/6 GHz band, 2) contain sufficient power and orbit control capacity to maintain all 24 channels operating continuously for a minimum of eight years, and 3) be compatible with the Delta 3914 launch vehicle, whose development they had funded jointly with the McDonnell-Douglas Astronautics Corporation at no cost to the U.S. government. This combination of requirements thus defined a communications satellite whose channel capacity is twice that of other current Delta class spacecraft but whose cost, including the launch vehicle, is significantly less than that of the corresponding 24-channel Atlas-Centaur class spacecraft designs. To meet these demands, weight-optimized designs were needed in four key subsystem areas: antennas, transponder multiplexers, power supply, and attitude control as well as in the structure itself. The resultant three-axis stabilized spacecraft design with sun-oriented solar panels provides maximum power and weight capability to the primary communications payload within the launch vehicle envelope.

Communications subsystem

Accomodation of 24 wideband channels within the 500-MHz allocation for commercial service (3.7 to 4.2 GHz space-to-earth and 5.925 to 6.425 GHz earth-to-space), previously occupied by only 12 such channels in existing domestic and international satellite systems, requires a spectrum reuse technique. RCA Satcom employs a cross-polarized antenna system to divide the 24 channels into two groups of 12 each on 40-MHz center-to-center spacing, with an interleaving offset of 20 MHz. Crossed linear polarization was selected to provide maximum isolation between the two sets of signals with minimum design complexity and feed component size. All channels have a fixed 2225-MHz displacement between the up- and down-link signals, as the transponder design is a single conversion, heterodyne amplifier without frequency inversion.

Each of the 24 channels can accommodate

- A standard color tv signal with audio subcarrier (fm-tv), or
- More than 900 frequency division multiplex one-way voice circuits on a single carrier (FDM-fm), or
- An appropriately reduced number of voice circuits on multiple carriers (FDM-fm-FDMA), or
- More than 500 single voice-circuit-per-carrier signals (fm-FDMA), or
- More than 60 Mb/s of digital data, or
- Time-division multiple access (TDMA).

All combinations of these types of traffic can, of course, be carried simultaneously by the 24-channel transponder. Realization of maximum channel capacity for

*Acting as trustee for RCA American Communications, Inc.

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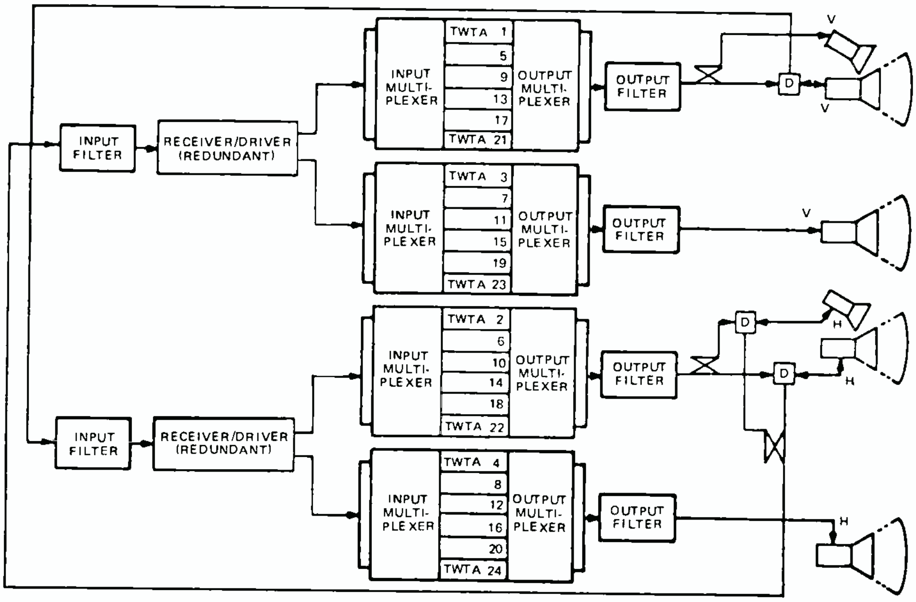


Fig. 1 — Transponder and antenna assembly block diagram.

Dr. John E. Keigler, Mgr., Communication Satellite Systems, Astro-Electronics Division, Hightstown, N.J., received the BE and MSEE from John Hopkins University in 1950 and 1951, respectively, and the PhD in Electrical Engineering from Stanford University in 1958. In 1958 Dr. Keigler joined AED as a Systems Engineer working on TIROS ground equipment and secure communications systems utilizing satellite relays. As Manager, Systems Engineering and Spacecraft Integration, he directed the engineering effort for system design and vehicle configuration of meteorological, navigation, communications, and military spacecraft. In addition, this group developed and successfully tested the Stabilite® three-axis attitude control system now being used on both polar orbiting and geosynchronous satellites. Most recently, he led the system design team whose work culminated in the present RCA Satcom program. He was a co-recipient of a 1976 David Sarnoff Achievement Award for this latter work. An associate fellow of AIAA, member of IEEE and Sigma Xi, he has published several papers on communications theory, spacecraft design, and attitude control, and has received several patents.

multiple access traffic depends somewhat on coordination of the type of traffic on adjacent co-polarized channels.

The entire transponder and antenna assembly (Fig. 1) was designed and fabricated by RCA Ltd. (Montreal). Functionally, the 24-channel transponder consists of two independent transponders of comparable characteristics to those of the 12-channel satellites now in domestic and international service. The receiver for each 12-channel set is fully redundant, allowing selection of either tunnel-diode amplifier front-end with its solid-state, transistor amplifier, TWT driver. Following each receiver, twelve input demultiplex filters divide the 500-MHz band into the twelve channels prior to high level amplification by the TWTA and subsequent recombination by the twelve output multiplex filters. As shown in Fig. 1, the input and output manifolds combine alternate channels at 80-MHz spacing to avoid the higher loss, complexity, and weight of a contiguous design of adjacent channels at 40-MHz spacing. A single, high-efficiency TWTA in each channel provides 5 W of saturated output. With no switching except for the receiver element selection and TWTA on/off, this transponder configuration of minimum complexity results not only in a low-weight design but also simplifies operational control and enhances in-orbit reliability.

The unique antenna design, selected to achieve the combined requirements of gain, coverage, polarization isolation, alignment stability, and light weight limitations, is shown on this issue's cover. Alignment stability dictated a design with no deployment of any feed or reflector members. Polarization isolation led to separate feed/reflector pairs for each polarization and for each of the two transponder output ports of each polarization. The reflector surfaces are grids of parallel wires embedded in a low-loss dielectric substrate, with the direction of the grid wires being parallel to the respective **E** vector of each antenna; thus the grids of two cross-polarized antennas are orthogonal. Gains and coverage requirements, within the volume constraints of the launch vehicle fairing, resulted in an overlapping configuration. Because the cross-gridded reflectors are virtually transparent to an orthogonally polarized wave, with the feed of each antenna displaced from the focus of the orthogonally polarized reflector, this overlapping of orthogonally polarized antennas provided polarization isolation greater than 33 dB over the full beam areas for all frequencies. All four feed/reflector pairs generate primary beams covering the 49 continental states; offset feeds in the two west antennas couple a portion of the respective signals in the direction of Hawaii. Utilization of a high-strength, lightweight dielectric for the reflectors, plus graphite-fibre epoxy composite (GFEC) for the feed tower, wave guides, and feed horns results in a total weight of only 50 pounds for the entire four-reflector, six-feed-horn antenna complex.

In addition to minimizing the weight of the transponder by using a solid-state driver stage instead of a conventional driver TWT, major weight reductions are achieved by fabricating the input and output multiplex microwave filters of GFEC. Invar has been used previously on other spacecraft because of its low coefficient of thermal expansion (and thus dimensional stability) as required for microwave cavities; but even with spark-eroded thin walls, Invar filters are relatively heavy. RCA has developed forming and plating processes for GFEC which achieve the necessary internal smoothness for low rf losses and insure adherence of the metal platings to the organic GFEC over the requisite temperature and pressure (i.e., vacuum) ranges. With conventional Chebyshev electrical designs of 8 poles for the input filters and 5 poles for the output filters, the net weight saving compared to corresponding Invar fabrication for 24 input and output filters using GFEC is approximately 35 pounds. One of the six

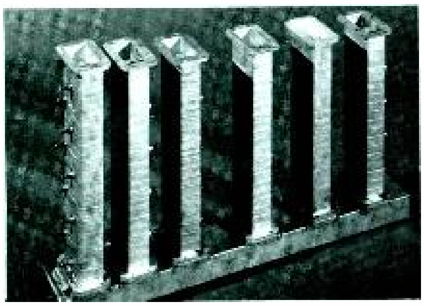
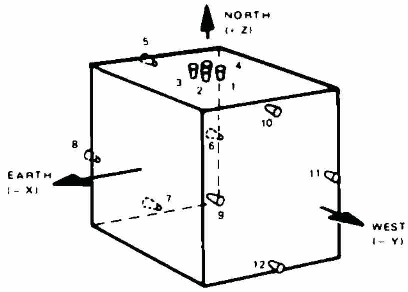


Fig. 2 — Output multiplexer.



SPACECRAFT MANEUVER	ROCKET ENGINE
APOGEE MOTOR SPIN-UP TRIM	7 & 10 (+) 5 & 12 (–)
APOGEE MOTOR RE-ORIENT	8 & 11 WITH 6 & 9
APOGEE MOTOR DESPIN	5 & 12
INCLINATION & N-S STATION-KEEPING	1, 2, 3 AND 4
EAST-WEST STATION-KEEPING	10 & 12 (EAST) OR 9 & 11 5 & 7 (WEST) OR 6 & 8
TORQUE ABOUT X AXIS (PANELS DEPLOYED)	5 AND/OR 12 (+) 7 AND/OR 10 (–)
TORQUE ABOUT Y AXIS (PANELS DEPLOYED)	1 & 4 (+) 2 & 3 (–)
TORQUE ABOUT Z AXIS	8 AND/OR 11 (+) 6 AND/OR 9 (–)

Fig. 4 — RCS thruster locations.

filter output multiplexers is shown in Fig. 2. Standard WR-229 waveguide sections comprise these output elements, while the input (low-power) elements are fabricated in a reduced-height waveguide for further weight optimization.

Power subsystem

Sun-oriented solar arrays and a direct array-to-load connection maximize the efficiency and reliability of the electrical power generation, storage, and regulation subsystem. With the main body always aligned with the local vertical and the orbit normal, a single-axis, clock-controlled shaft drive maintains orientation of the 75-square-foot array (6.97-square-meter) toward the sun. Adapted from the Direct Energy Transfer (DET) concept developed for NASA by RCA, the subsystem shown in Fig. 3 regulates voltage to the various loads by the shunt regulator during sunlight and directly by the battery during eclipse. Input converters in each subsystem translate the resultant 24.5- to 35.5-V range to their specific requirements at constant power and efficiency. Elimination of any central power system series regulator or battery-boost regulator decreases spacecraft weight and increases reliability.

Capacity of the solar array is sufficient to power all 24 transponder channels, in addition to supporting spacecraft equipments, after cell degradation from eight years of exposure to radiation. The 81 pounds of batteries can similarly support a full 24-channel total load throughout the longest eclipse (72 min.). Excess array capacity early in life is primarily constrained within the array itself by the unique partial shunt regulator which forces a mismatch between the two electrical segments of each string of solar cells; hence only a fraction of the excess power is dissipated within the internally mounted shunt transistors. Maximum battery performance, in terms of permissible depth of discharge, is obtained by the overall spacecraft thermal design that constrains battery temperatare between 0 and 10°C. Battery reconditioning prior to each eclipse season by deep discharge on a cell-by-cell basis and maintenance of a low trickle charge during the long dormant interval between eclipse seasons also contributes to battery optimization. Each of the three batteries is charged by its independent, internally redundant, regulator.

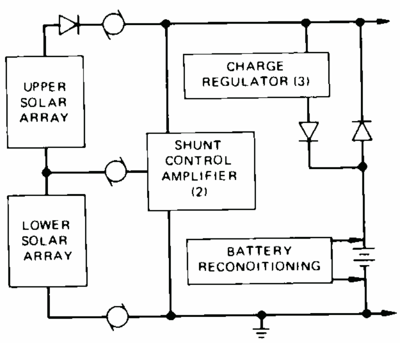


Fig. 3 — Power supply subsystem.

Attitude and orbit control subsystem

Precision pointing of the spacecraft and antennas is accomplished with the Stabilite® three-axis attitude control technique developed by RCA. A single, body-mounted momentum wheel provides full three-axis control by virtue of its gyroscopic stability and its servo-controlled exchange of angular momentum with the spacecraft mainbody. The inertial stability permits attitude determination with a single roll/pitch earth sensor without the complexity of a yaw sensor. Continuous control of the pitch axis alignment to the orbit normal (i.e., roll/yaw control) utilizes magnetic torquing with no expendables or moving parts. Magnetic torquing not only improves reliability and smoothness of control, compared to periodic thruster correction of pitch axis alignment, but it allows in-orbit compensation for residual solar torque by means of the adjustable bias coil that rotates with the solar array and so generates an opposing torque. Thruster back-up to the normal magnetic control is available on command for rare conditions of magnetic field disturbance by solar storms.

In addition to this primary control loop for long-term operation, a second fast-response loop is activated for the periodic, relatively short intervals of stationkeeping operations. These orbit corrections are required to maintain the satellite within assigned longitude and orbit inclination tolerances of ±0.1° to satisfy the many limited-motion earth stations of the RCA Satcom network.

The secondary control loop varies the duty cycle of the four north-pointing, inclination-control thrusters identified in Fig. 4. Since the force vectors of these thrusters are parallel to, but displaced from, the pitch axis (through the center-of-mass), pulsing the appropriate thruster(s) "off" produces a restoring roll or yaw torque simultaneously with the desired velocity change, thus minimizing the propellant required for orbit inclination control. For the duration of this maneuver, approximately one hour per month, the gyro furnishes a yaw reference to the control logic. With this short operating time, both per maneuver and cumulatively over the spacecraft life, neither the gryo drift nor reliability limit the system performance.

All components of the three-axis attitude control system are fully redundant and cross-connected for increased realibility. There is no single-point failure mechanism. Similarly, the 12 thrusters shown in Fig. 4 are cross-connected to the four propellant tanks with isolation valves such that failure of any thruster or either half of the system still permits velocity change forces and attitude control torques in each required direction. Within each of the four tanks containing more than 50 pounds of monopropellant hydrazine, passive surface-tension webs designed by AED insure liquid propellant expulsion of the integrally pressurized systems without the risk incurred by the use of bladders.

Structure

The physical relationships of the structural elements and subsystem components of the spacecraft are shown in Fig. 5. A central column and cruciform assembly carries the launch loads to the vehicle interface. The apogee motor is mounted within the column which extends up to, and provides a rigid base for, the earth-facing antenna panel. Except for the antennas and earth sensors on that panel, all of the equipment components are mounted on the two large panels which will face north and south in orbit. Segregation of all of the transponder and rf components onto the south panel and all of the spacecraft support components (attitude control, power, command and telemetry) on the north panel facilitates independent assembly and test of these two halves of the spacecraft system. Complete system electrical testing is conducted with this open configuration, and even after mechanical assembly, ample access is provided through the removable east-west shear panels.

The photographs of an assembled structure (Figs. 6 and 7) show the flat mounting surfaces of the large north-south faces which provide flexibility and ease of component mounting, while maximizing the areas for thermal radiation on these two faces of minimum solar thermal input. Actual weight of this flight structure is only 5.5% of the total transfer-orbit weight of the spacecraft and apogee motor. The internal construction of the structure is aluminum monocoque for the central cylindrical core and aluminum honeycomb for all of the flat panels. A tubular double A-frame truss supports the spherical propellant tanks.

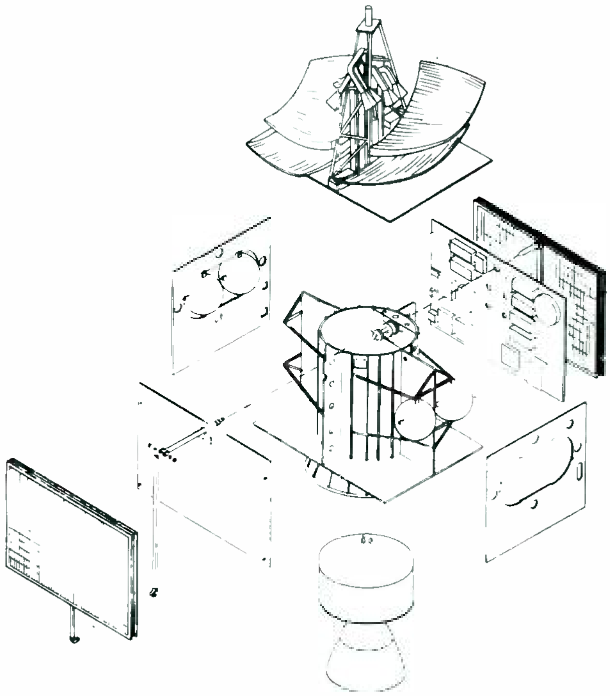


Fig. 5 — Exploded view of spacecraft.

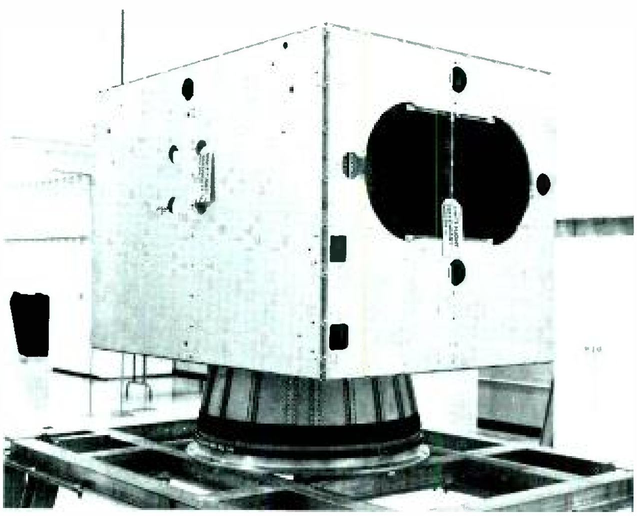


Fig. 6 — Assembled structure showing mounting surfaces.

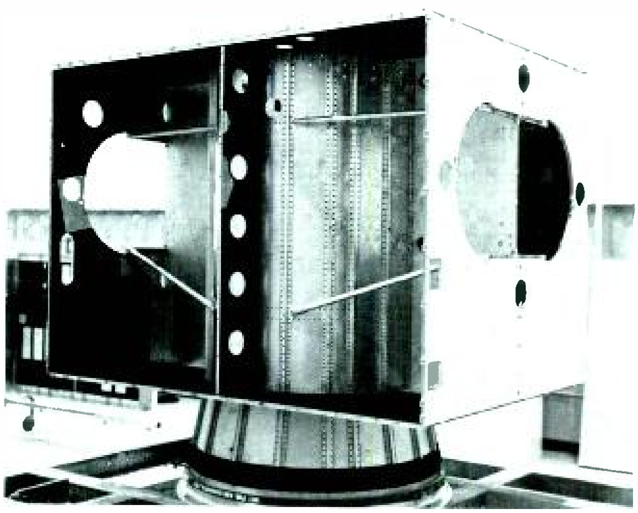


Fig. 7 — Assembled structure showing interior.

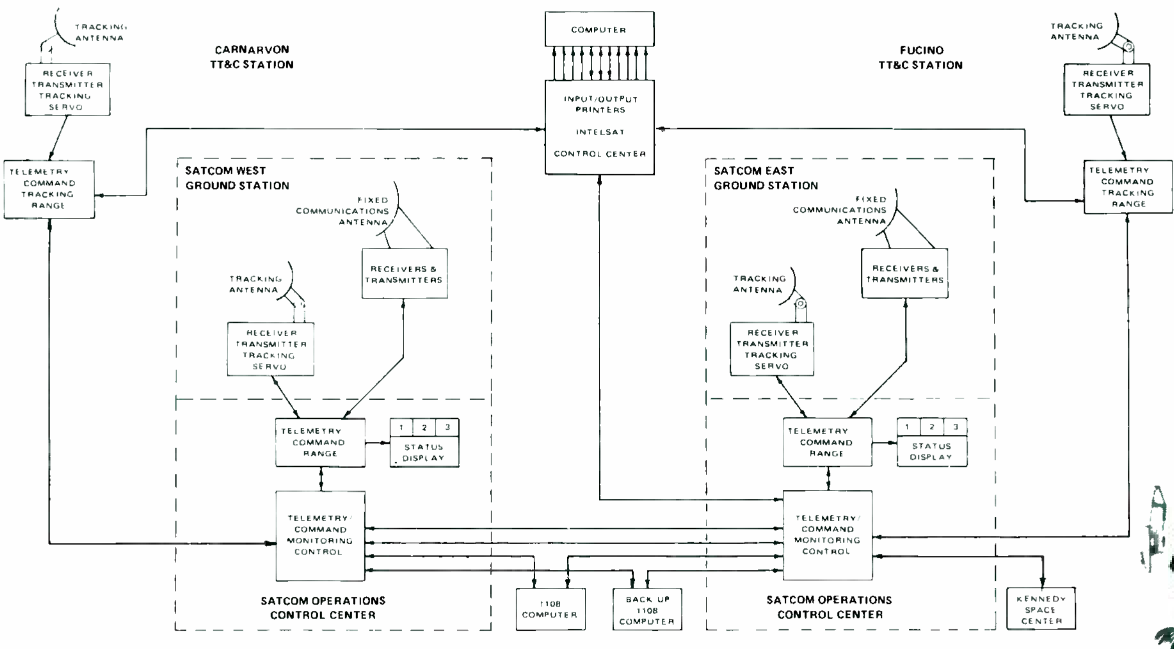


Fig. 8 — RCA Satcom mission operations complex.

Launch sequence

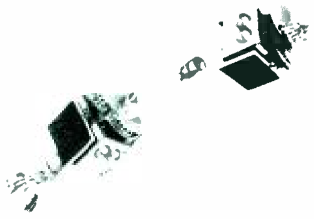
In its stowed configuration within the 8-ft diameter fairing atop the third stage of the Delta 3914, the spacecraft appears as shown in Fig. 8. Except for slightly different staging to the solid propellant strap-on motors, the launch sequence of the Delta 3914 (developed by joint funding of RCA and McDonald-Douglas) is the same as that of the standard Delta 2914. Its spin-stabilized third stage is fired at the first nodal crossing to inject the spacecraft into a 100 × 19,350 nmi transfer orbit. At separation of the spacecraft from the spent third stage, responsibility for, and control of, the spinning spacecraft shifts from NASA to RCA. AED developed the software, manned the stations, and directed the post-launch operations as part of the contract to RCA Globcom.

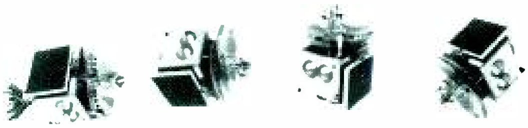
Using telemetered attitude and ranging data, the ground complex determines the orientation of the spin axis and generates commands as necessary to operate appropriate thrusters for reorientation of the spin axis. Either overseas station, together with either mainland TT&C station, is sufficient for control of the spacecraft in transfer orbit; together, the two TT&C stations can handle three spacecraft in synchronous orbit and one in transfer orbit. With the spacecraft spinning about its stable (i.e., maximum) inertia axis, and having a net power and thermal balance from the folded solar array, there is no haste to fire the apogee motor. The seventh apogee was selected as optimum for synchronous orbit injection nearest to the desired longitude zone of 119 to 129 W.

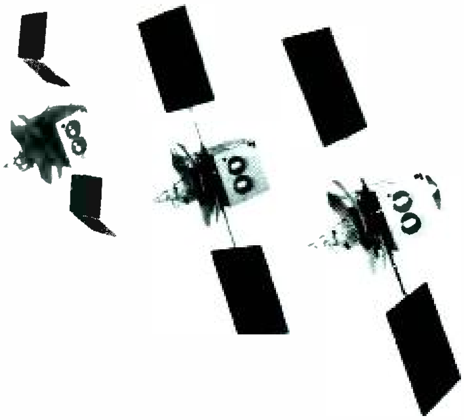
After apogee motor firing, the spacecraft remains spin-stable, and its spin rate is reduced by ground command from the 60 r/min acquired prior to the Delta third stage firing down to 5 r/min. Again using the body-mounted sun and earth sensors to measure attitude, the spin axis is reoriented from its apogee insertion attitude to be parallel to the Earth's axis and the orbit normal, while still in thermal and power equilibrium. Transition from simple spin stabilization to three-axis stabilization is then initiated by energizing the momentum wheel via ground command. With no requirement for inertial scanning maneuvers or further control, the momentum wheel axis converges to orbit normal from its initial transverse position according to the principles of dual-spin stability, and so the body axis rotates with respect to the spatially fixed angular momentum vector. Subsequently the solar arrays are released to their extended position and then three-axis stabilization is completed by closing the attitude control pitch loop.

Conclusion

The weight and power distribution shown in Table I was extracted from the actual values of the first flight spacecraft. Con-







trary to experience with many other spacecraft, RCA Satcom progressed through its development with a relatively small weight margin; the actual weight is within two pounds of that estimated in the proposal. For the two flight spacecraft, this margin was converted to additional propellant.

Beyond fulfilling the 4/6 GHz requirements of RCA Globcom and RCA Alascom: namely, the capacity of an Intelsat IVA on a Delta launch vehicle, RCA Satcom has emerged as a versatile spacecraft bus with maximum payload capability for other applications. Some of the various antennas that might be used are shown in Fig. 9. This capacity can be illustrated by subtracting all the fixed support subsystem weights (i.e., structure, attitude control, propulsion, thermal, command, telemetry, array drive, and power electronics) to obtain a mission weight which can be allocated to the communications antenna and transponder plus that portion of the array and battery necessary for operating the transponder. This capacity is plotted in Fig. 10, the dividion of mission weight being expressed in terms of payload power versus communication subsystem weight. As indicated, this relationship will depend on the quantity (i.e., years) of stationkeeping fuel and the percent of eclipse-to-daylight power. These curves clearly indicate the significant margin of RCA Satcom capacity over any spinning Delta class satellites, and, in fact, its competitiveness with spinning Atlas-Centaur class satellites.

Table I — Weight and power distribution.

Subsystem	*Weight (lb)*	*Avg. power (W)*
Structure	109.3	—
Power	181.1	19.3
Harness	26.4	—
Propulsion	41.2	—
AKM case	63.6	—
Thermal	17.5	25.0
Attitude control	55.5	15.3
Command, range, and telemetry	30.5	18.6
Transponders	176.1	434.6
Antennas	51.1	
Balance weights and misc.	20.2	—
Spacecraft margin	30.2	—
Maximum spacecraft dry weight	802.7	—
Reaction control	216.1	—
Apogee motor expendables	894.3	—
Adapter (including telemetry)	77.6	—
Lift-off weight	1990.7	

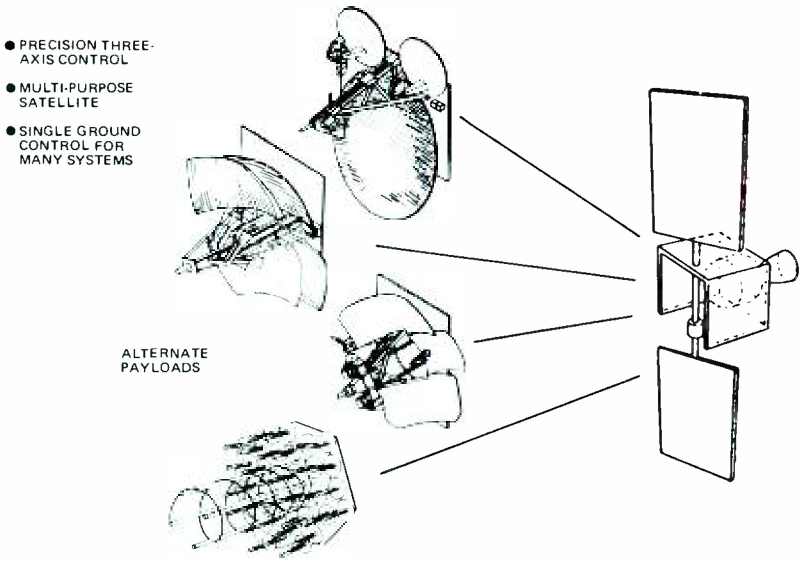


Fig. 9 — Modular bus applications.

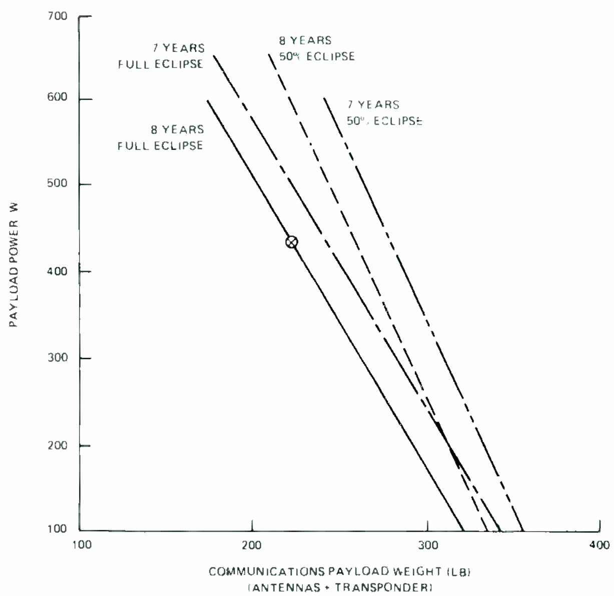
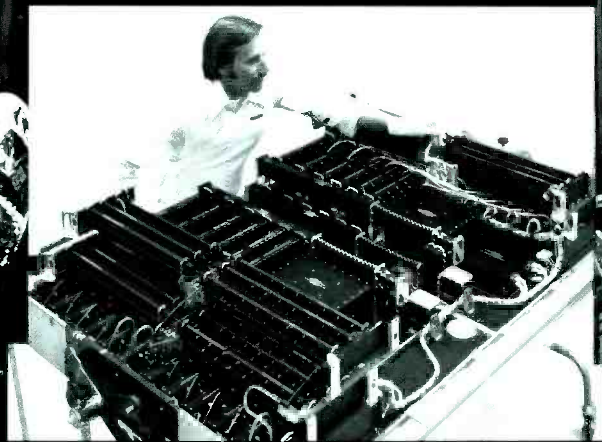


Fig. 10 — Spacecraft payload capacity.

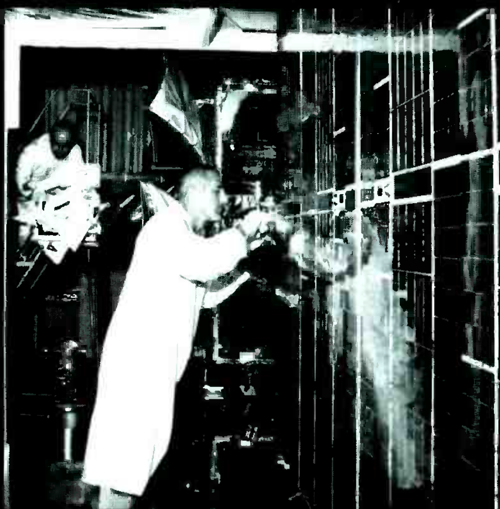
Satcom satellite milestones

Aerojet's technicians check out the apogee motor prior to its delivery to AED.

The South panel, containing the 24 transponders, was assembled and tested by RCA, Ltd. Here, AED technician Bob Parsons is shown preparing the transponder subsystem to mate with the spacecraft.

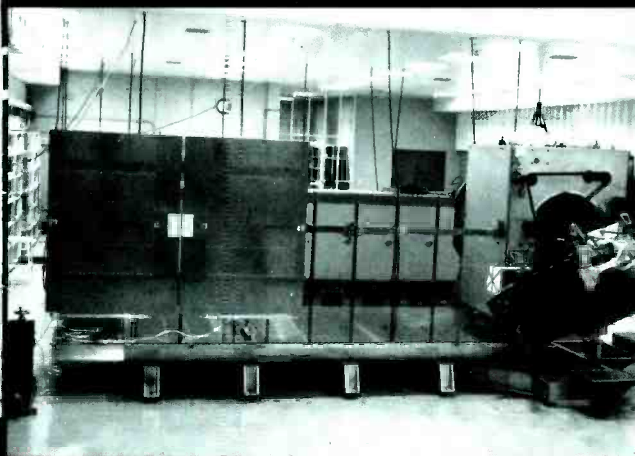


As components of the North panel ing subsystems) are installed at A

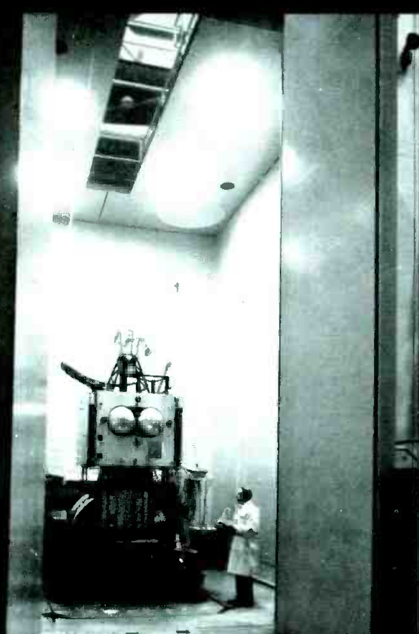


An AED technician, Al Theobald, adjusts the solar-panel deployment mechanism. (Note technician Jim McCollick working on the satellite main structure in the background.)

The solar array panels, which are designed for the zero-gravity environment of space, are tested for proper deployment. Here air bearings are used to support their mass in the Earth's gravitational field.

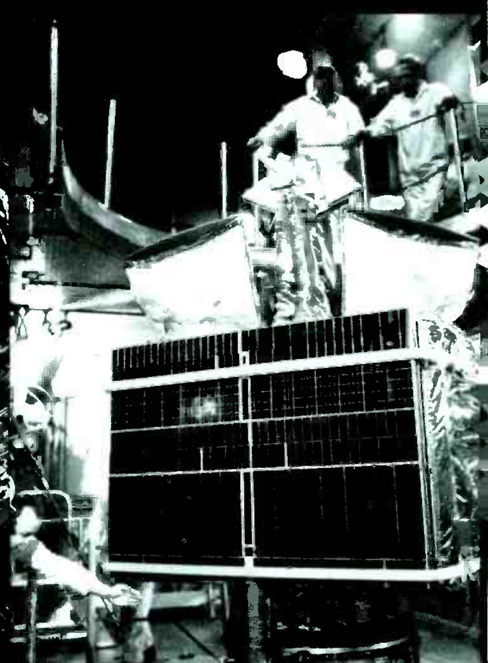


The completely assembled sate on the launch-vehicle adapter, is vibration environment simulat n



Dick Hartenbaum, AED engineer, is checking the preparation of the satellite for exposure to high-level acoustic energy (i.e. noise) simulating the launch environment.

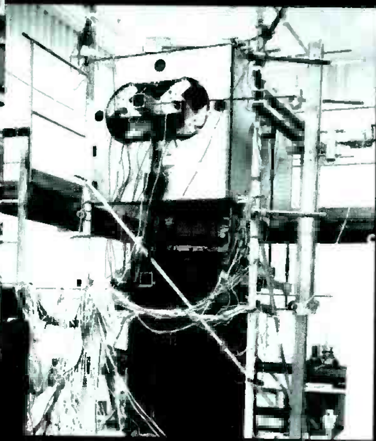
Viewed from the top of the 24-ft diameter thermal-vacuum chamber, the satellite shows through a network of metallized plastic baffles which "zone" the chamber to establish the thermal environment the spacecraft will encounter during its daily orbit and through the yearly seasonal changes.

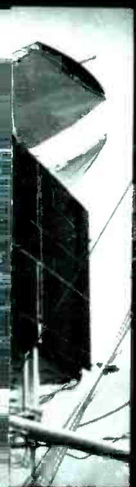


The satellite is mated to the Delta 3914 launch vehicle in the 9th level of the gantry (more than 100 feet above ground) at the Kennedy Space Center. Joel Bacher of AED and Joe Schwarze from Globcom can be seen at the lower left (l. to r.). Mc Donnell Douglas technicians are at the upper right. (NASA photo.)

containing housekeep-
D, they undergo tests.

The satellite's structural integrity is verified in this static load test performed at AED.





lite, mounted
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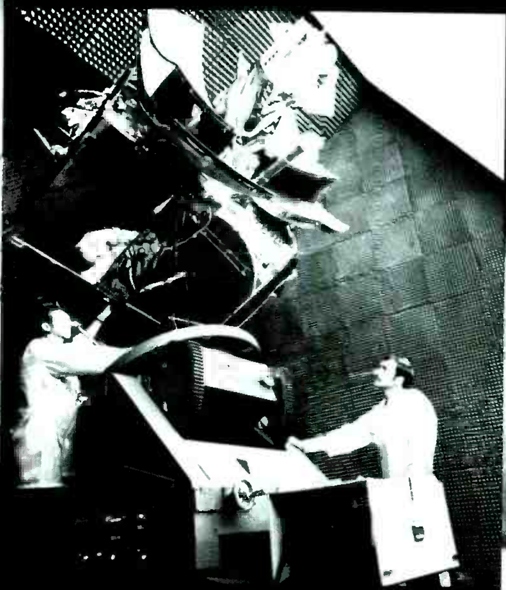
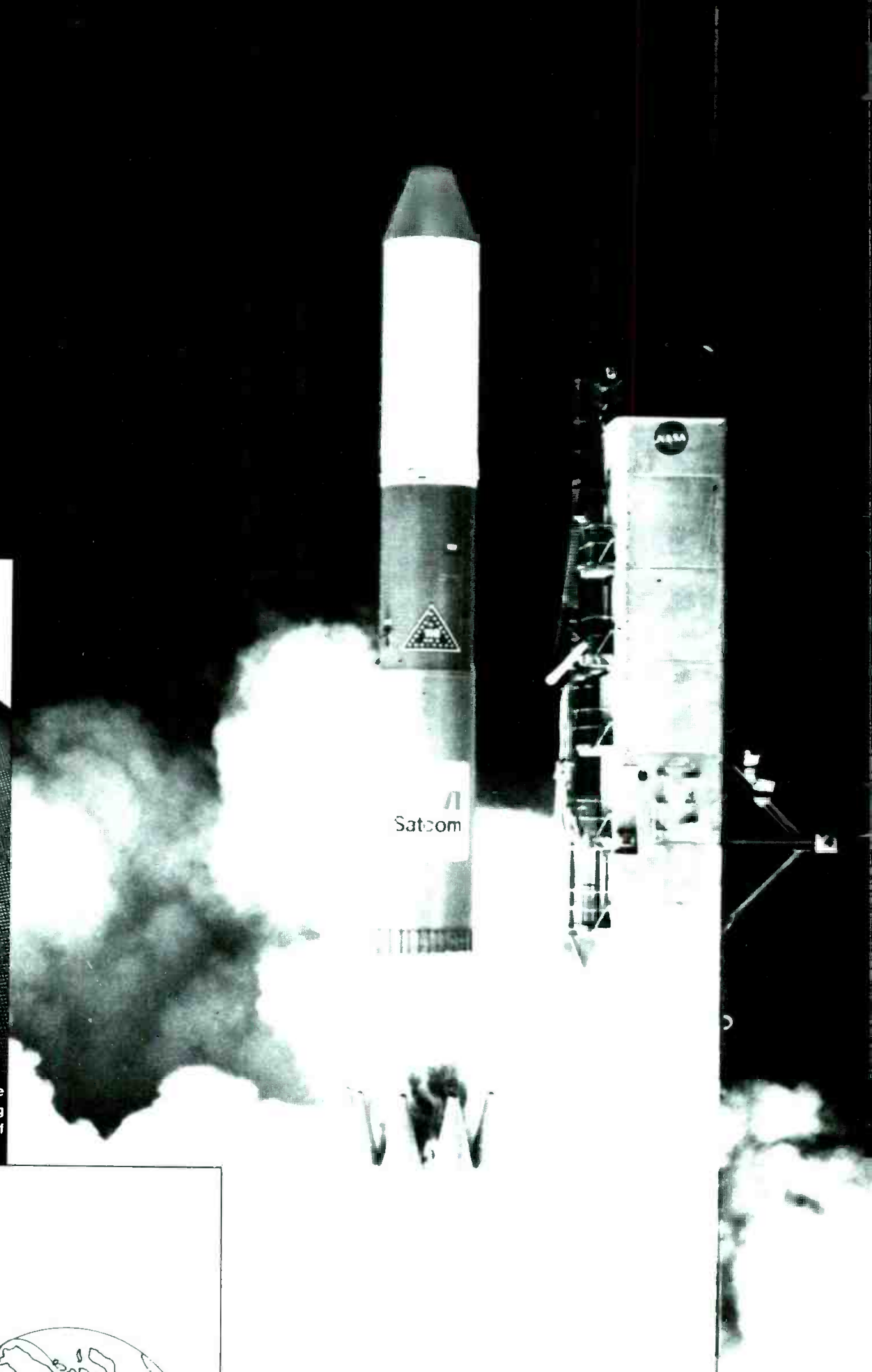
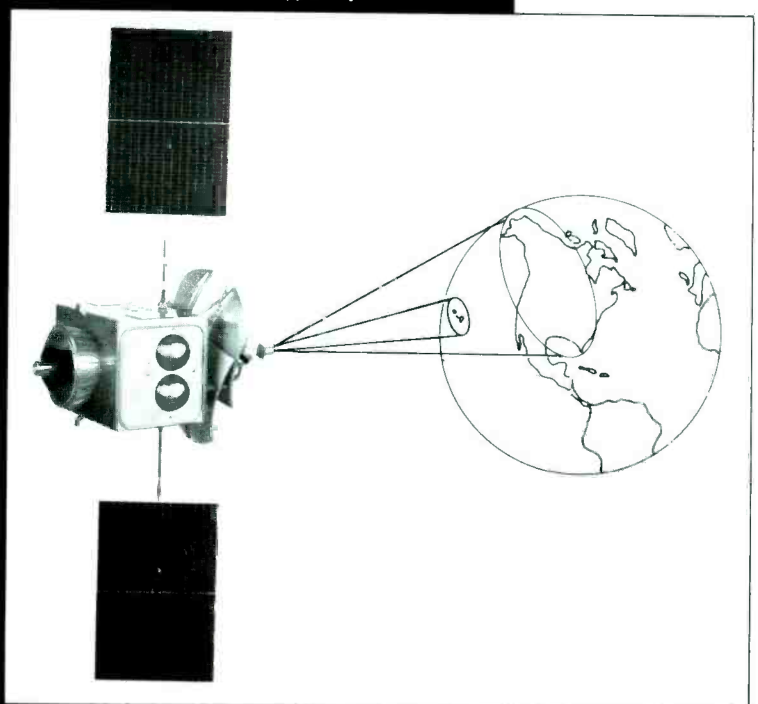
launch.



AED engineers Randy Bricker and Joe Arthurs examine the spacecraft after its being mounted on the three-axis positioning fixture in the anechoic chamber of the antenna range at AED for rf tests. The antenna assembly was supplied by RCA Limited.

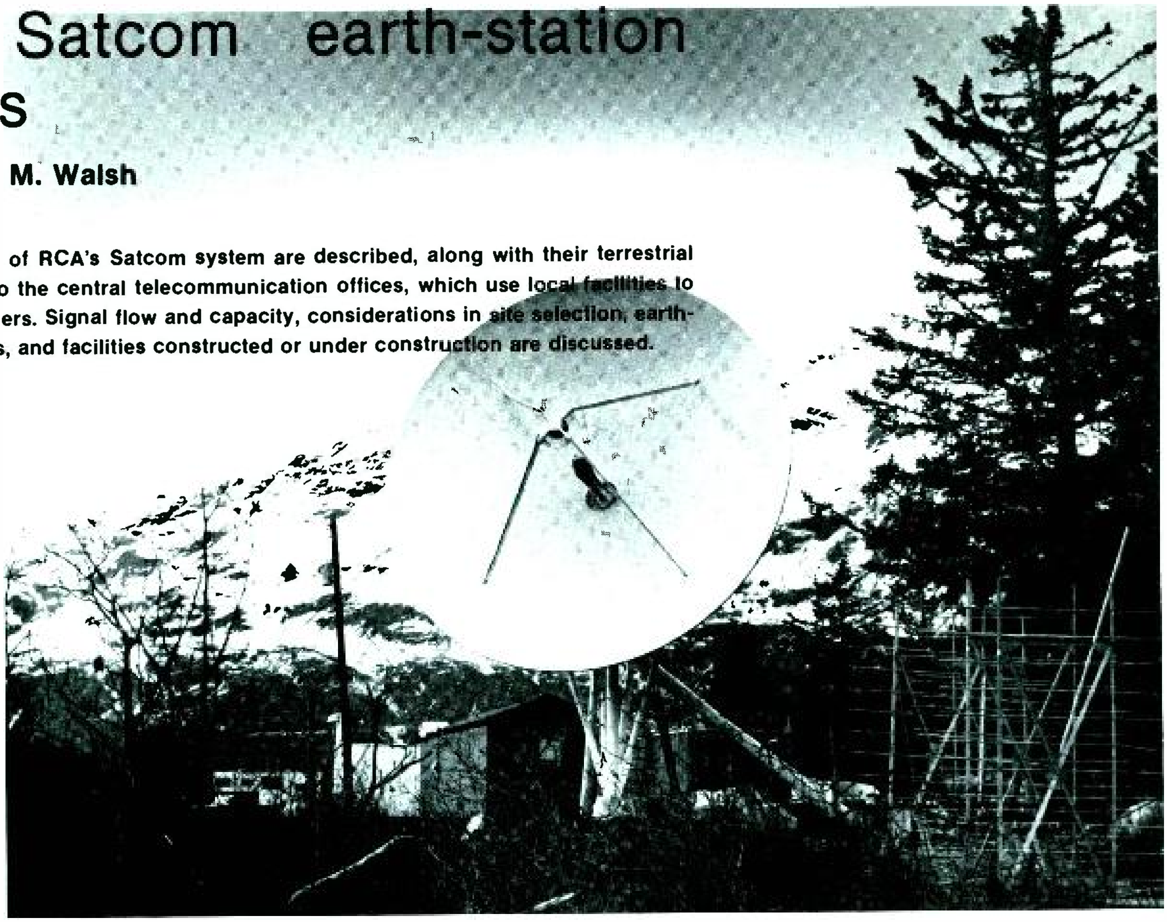




RCA Satcom earth-station facilities

J. Cuddihy | J. M. Walsh

The earth stations of RCA's Satcom system are described, along with their terrestrial interconnections to the central telecommunication offices, which use local facilities to connect to customers. Signal flow and capacity, considerations in site selection, earth-station subsystems, and facilities constructed or under construction are discussed.



PLANS to establish a domestic satellite communications system were first revealed by RCA Globcom and RCA Alascom in an application to the Federal Communications Commission (FCC) filed on March 11, 1971. That filing presented plans for the services that could be provided via the RCA system and also included specific applications for the associated satellites and earth stations. The entire program, as well as each satellite, carries the name RCA Satcom. RCA Satcom I was launched on December 12, 1975 and was placed in traffic operation on February 28, 1976, after successful completion of in-orbit tests. RCA Satcom II was launched on March 26, 1976 and, after being successfully tested, was placed in traffic operation on June 2, 1976.

The program envisioned a variety of telecommunication services to the contiguous 48 states, Alaska, Hawaii, and Puerto Rico. These services included private line voice service, message telephone service, narrow- and wide-band data services, and television and radio program transmission service. It was also encumbent upon RCA to increase the facilities for telephone services within Alaska and between Alaska and the contiguous states simultaneously to reduce the cost for telephone services at the earliest possible date.

Since the regulatory agencies were required to analyze a large number of proposals for domestic satellite systems on technical, financial, legal, and public interest grounds, the RCA application could not be processed and approved in the time required. RCA decided to request approval of an interim system to meet its traffic requirements utilizing the Canadian Telesat Corporation ANIK satellite. This interim system initially consisted of earth stations at Lena Point and Talkeetna, Alas., Valley Forge, Pa., and Point Reyes, Calif. serving, respectively, Juneau, Anchorage, New York City, and San Francisco. The RCA interim system began service as the first U.S. domestic satellite network on December 21, 1973.

The two Alaskan earth stations had originally operated in the Intelsat network and reoriented their antennas and feed systems toward Telesat to operate in the interim system. The earth station at Point Reyes was established at an existing RCA Globcom high-frequency radio station. At Valley Forge, a transportable earth station was installed.

Since the inception of the interim system, earth stations have been installed in Alaska at Put River (Prudhoe Bay), Valdez, Nome, and Bethel; and also for Los Angeles, Calif. and Thule, Greenland. In addition, the interim system has been used for a variety of tests and experimental programs.

These earth stations continued in operation via ANIK until transferred to the

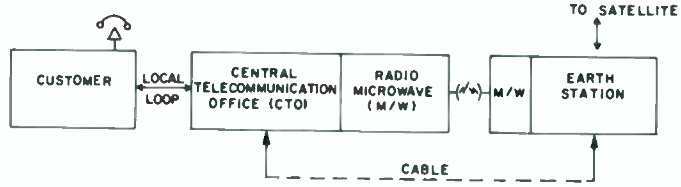


Fig. 1 — Signal flow from customer office to earth station.

Western Union WESTAR satellite on May 31, 1975 at the direction of the Federal Communications Commission. For reasons of satellite illumination and geographical location, the Thule earth station continues to operate via the ANIK satellite with an additional antenna erected at the Point Reyes earth station.

The system has undergone considerable change in regards to the spacecraft. Whereas the original application envisaged a spin-stabliized 12-transponder spacecraft, the RCA Satcom spacecraft have three-axis stabilization and contain 24 transponders utilizing cross-polarization techniques in order to use the same bandwidth twice. Furthermore a new generation of very efficient launch vehicles (Thor-Delta 3914) was developed to inject the satellite into proper transfer orbit.

The interim system traffic was transferred from WESTAR to the RCA Satcom I satellite in two stages on Febraury 28, 1976 and March 31, 1976. The permanent RCA Satcom system is now in operation.

Signal flow

To understand the complexity of the RCA Satcom network and the myriad of technical skills involved in its design, implementation, and operation, it is useful to examine the flow of the typical signal between the origination point (customer office) and the earth station. This signal path, which is applicable to voice, data, and television transmissions, is illustrated in Fig. 1.

The signal passes between the customer's office and the Central Telecommunication Office (CTO) via a local loop supplied by a local carrier. The CTO contains monitoring, signaling, control, alarm, and processing functions. The signal is then multiplexed and transmitted via a radio microwave (M/W) or cable system to the earth station. At the earth station, the signal is received, demultiplexed, and processed for transmission over the satellite link. Each segment of this path must be engineered to certain specific parameters so that overall circuit objectives are met. A signal from the satellite is handled in a complementary manner through each facility for bidirectional operation. The earth station transmits to the satellite in the (5925-6425)-MHz frequency band and receives from the satellite in the (3700-4200)-MHz frequency band. These frequency bands are shared between satellite and terrestrial services.

System capacity

The communications capacity of an earth-station network is defined largely by the sum of the saturated output of a satellite transponder equivalent isotropic radiated power (EIRP) and the figure of merit of the earth station G/T (the antenna gain divided by the receive-system noise temperature). The satellite EIRP is relatively fixed by the spacecraft antenna coverage pattern, power amplifiers, spacecraft weight and power allowances, launch vehicle, and flux density limitations at the earth's surface. The earth-station minimum antenna gain, and therefore the antenna diameter, is established by power amplifier output

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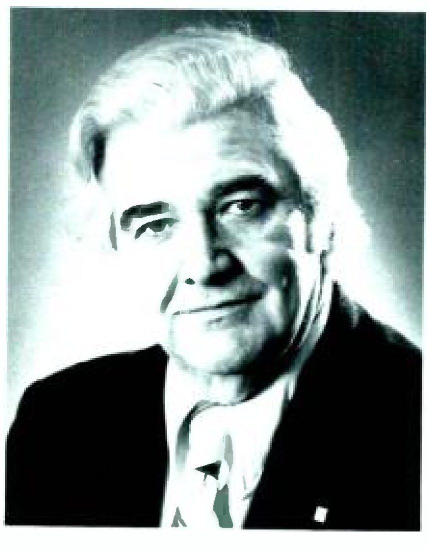

capacity and the requirement to provide a signal to drive the satellite transponder into saturation. Accordingly, technical and economic trade-offs were made between antenna sizes and low-noise-receiver operating temperatures with the objective of obtaining a G/T of 32.4 dB/K, while simultaneously allowing for future expansion in system capacity. This objective was achieved for the major earth stations by selecting antennas with diameters of 13 m and uncooled low-noise receivers with a maximum noise temperature of 55 K.

When dictated by traffic requirements, the uncooled receivers can be replaced with cryogenically cooled receivers with a noise temperature of 17 K. This would give a G/T of 34.0 dB/K.

While the interim RCA Satcom system was leasing capacity from other spacecraft operators, there was no need for RCA Globcom to have facilities to operate and maintain the spacecraft. With an RCA-owned spacecraft, it became necessary to construct facilities capable of tracking the spacecraft through transfer orbit, drift orbit, and on-station; receiving telemetry from the spacecraft; and transmitting commands to the spacecraft. These facilities are commonly referred to as a Telemetry, Tracking, and Command (TT&C) earth station. To assure that the spacecraft would always be under operational control, it was decided to construct two TT&C earth stations, one each located on the East and West Coasts, thereby minimizing the possibility of a natural disaster affecting satellite service.

Each TT&C earth station has one antenna capable of operating with a satellite during transfer orbit, performing on-orbit station-keeping functions, and carrying communications traffic. At each of these locations, a second antenna capable of performing on-orbit station-keeping functions and carrying communication traffic has been installed. The primary distinction between these antennas is that the TT&C antenna is capable of high angular velocity (3°/s) and range of azimuthal (±270°) and elevation (0°-90°) motion necessary to track the satellite at its maximum velocity during transfer orbit whereas the communication antenna is limited in range of azimuthal (±60°) and elevation (5° - 60°) motion with a tracking velocity of 0.1°/s, compatible with the velocity of a geostationary satellite. Both antennas at these locations are 13 m in diameter.

Site selection

The primary consideration in selecting an earth-station site is freedom from interference with terrestrial microwave systems. The earth station must not cause harmful interference to existing microwave receivers and it must not receive harmful interference from microwave transmitters. It is usually necessary to place earth stations in locations remote from the metropolitan areas to avoid frequency restrictions engendered by the density of common-carrier microwave systems. It then becomes necessary to establish one or more microwave links to interconnect the earth station with the metropolitan area being served.

In choosing an earth-station site, physical considerations affecting the viability of construction must also be evaluated. These considerations include site shielding, terrain, roads, commercial power, water, local ordinances, and climatic and seismatic conditions.

Once a candidate site has been selected, a thorough analysis of the interference environment must be conducted, for both the earth station and microwave links, in conjuction with other users of the frequency spectrum. The results of these surveys must be incorporated into the earth-station and microwave applications that are filed with the Federal Communications Commission.

Earth-station subsystems

The following is a general functional description of the major subsystems installed in the earth stations. The requirements were developed into detailed specifications and included in a consolidated request for proposals submitted to more than 70 equipment suppliers for competitive bids. Each bid was analyzed in detail prior to awarding contracts.

Antenna and feed

The most striking feature of any major earth station is its antenna. In the RCA Satcom system the major earth stations contain 13-m-diameter antennas. The other earth stations contain antennas in the 8- and 10-m categories, except for the Hawaii earth station with a 15.5-m antenna. The antenna simultaneously transmits to and receives from a particular satellite. In the transmit mode, the antenna concentrates polarized electromagnetic beams toward the satellite, thereby amplifying signals in the direction of the satellite. In the receive mode, the antenna collects energy emitted from the satellite and thereby provides amplification for the satellite signal. The major stations are equipped with cross-polarized feed so that signals of orthogonal polarization can be received and transmitted simultaneously. Other stations are equipped with feed systems that can only transmit and receive one polarization. All antennas are normally equipped with motors to point the antenna main beam in the direction of the satellite. The major earth-station antennas are further enchanced with the ability to step-track the satellite relative to azimuthal and elevation angular movements and to adjust the polarization angle of the feed to account for Faraday rotation that occurs as the signals pass through the atmosphere.

Low-noise receivers (LNR)

In order to provide the specific sensitivity for earth-station operations, a low-temperature receiver operating across the 500-MHz frequency band is utilized. The low-noise receivers are physically located close to the antenna feed to minimize the system noise-temperature contributions. Various receiver classifications may be used for different applications.

For the major earth stations, we have chosen, based upon performance, reliability, and economical consideration, a low-noise receiver with a noise temperature of 55 K, commonly called an uncooled receiver. The receivers are arranged in a redundant configuration for each polarization such that if an on-line receiver fails, the back-up unit automatically switches into active service replacing the failed unit. Cryogenically cooled receivers (17 K) are installed at some earth stations to achieve a greater sensitivity.

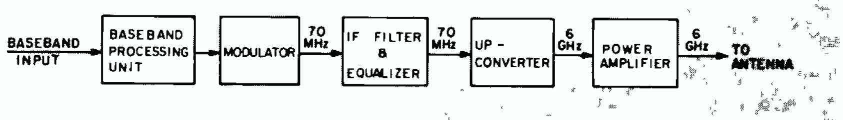

Fig. 2 — Transmit link.

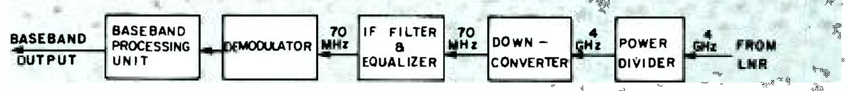

Fig. 3 — Receive link.

Transmit and receive links

The earth-station transmit and receive links consist of the equipment shown in Figs. 2 and 3, respectively.

- The baseband processing unit provides preemphasis, waveform spreading, and filtering in the transmit direction and provides de-emphasis and filtering in the receive direction.
- The modulator accepts the processed base-band signal, which then modulates a carrier frequency producing an intermediate-frequency (i.f.) signal centered about 70 MHz. Frequency modulation is used for analog signals such as multiplexed voice channels and television; phase modulation is employed when high-speed digital signals are transmitted.
- The demodulator accepts the received i.f. carrier and demodulates the signal producing a baseband signal. Both frequency and phase demodulators are used depending upon the specific signal. In some cases, threshold extension techniques are used to extend the operating range of the receiver to detect relatively weak signals.
- The i.f. filters and equalizers provide adjustments to the i.f. signal so that the modulator output is maintained within the proper bandwidth limitations in the transmit direction and so that the signal presented to the demodulator is as free from extraneous noise as possible, thereby improving the quality of the detected signal.
- The up-converter translates the i.f. signal from 70 MHz to the 6-GHz frequency range providing a low-level radio frequency (rf) output. The down-converter translates the 500-MHz spectrum in the 4-GHz frequency range to a 40-MHz signal centered at 70 MHz. A specific transmit/receive frequency is assigned to each carrier and the converters have a frequency source (usually a crystal) for the assigned frequency. The stability of the frequency source is determined by the particular traffic requirement through the converter.
- The output of the up-converter is amplified by a power amplifier, which together with the antenna gain provides sufficient signal to the satellite. In a major earth station, the parallel outputs of several power amplifiers are combined through a low-loss rf-combining network prior to connection to the antenna input. The earth stations employ two major classes of power amplifier tubes to obtain amplification. Klystron tubes are relatively narrow-band devices (40 MHz), which usually accept one rf input signal such as a television signal from transmission to one transponder, often saturating that transponder. Traveling-wave tubes are wide-band devices (500 MHz), which may accept several rf inputs for transmision to one or several transponders. In the RCA Satcom earth stations, klystrons are installed for applications where more than 500 W are required and traveling-wave tubes are used for lower power requirements.
- The power divider is connected to the low-noise receiver output and receives the full 500-MHz bandwidth. The amplitude of the received signal is divided through a passive network so that a maximum of 16 down-converters may be connected to each polarization.

Frequency-division multiplex (FDM)

Frequency-division multiplex equipment is installed at both the earth stations and at the CTO's. This equipment accepts voice-grade signals and translates these signals, via groups (12 channels) and supergroups (60 channels), into a composite baseband for transmission over the radio microwave (terrestrial link) or the satellite link. Conversely this equipment separates composite basebands into supergroups, groups, and channels for interconnection to the microwave terrestrial link and/or to the local loops to the customer. This equipment also contains frequency and level control functions to assure the quality of signal transmission. Each transmit carrier at the RCA Satcom earth stations can be equipped with 960 channels of frequency-division multiplex equipment. The associated microwave terrestrial link can handle up to 1800 channels of similar equipment.

Buildings, facilities, and construction

Early in 1974, the detailed operational requirements for a domestic satellite system to function as a long-lines carrier were sufficiently determined to start the long process of establishing the building, facilities, and construction specifications for each communications earth station and the two TT&C earth stations. This process included ascertaining the operational requirements for personnel and equipment, as well as the functional relation of the various activities to be carried out in the earth stations.

The building design philosophy was that each type of earth station was to be a standard design differing only to the extent necessary to adapt it to the local conditions of the individual sites. This philosophy has been followed, except possibly for the TT&C earth stations, which are almost mirror images of one another since one station is on the East Coast and the other on the West Coast.

Schematic representations of the physical plant and outline specifications were developed and requests for proposals were submitted to a selected list of engineers/architects. These responses were evaluated and an engineer/architect was selected for the detailed design process. After this selection, meetings were conducted with the consultant in which many concepts were examined until finally a basic design was acceptable to all groups involved. Detailed plans and specifications for each site were developed and submitted to local contractors for competitive bids.

Concurrently, the task of locating and securing suitable sites to meet the operational needs was going on. The parameters used for the selection of sites included radio-frequency compatibility, site shielding, accessibility, power supply, terrain, seismatic conditions, water, and, of course, availability. In addition, it was necessary to secure approval from the local zoning board, building department, the environmental protection agency, and a myriad of other permits. Prior to obtaining local approvals, many public meetings were required to advise and assure the community that these communication facilities would be aesthetically pleasing to the environment and that there would be no harmful radiation hazards from the earth station and microwave antennas.

TT&C earth stations

Construction of the TT&C earth stations was started in the early spring of 1975, and these were ready for the installation of telemetry, tracking, and command equipment and associated earth-station electronic transmit and receive equipment by mid-summer of the same year. Figs. 4 and 5 show the site and equipment layouts. These stations are located in South Mountain, Calif., and in Vernon Valley, N.J. Record-breaking rainfall in both cases caused delays in construction, which had to be made up by the use of overtime on the part of the general contractors.

The TT&C earth stations are each approximately 88 × 80 ft, for a total area of 7040 sq. ft. The building consists of a steel framework with exterior walls of prefabricated panels consisting of two aluminum sheets with 4 in. of isocyanurate insulation between them.

The roof has a steel deck with outer insulation and built-up roofing. The foundation is of poured concrete as are the floor slabs. The building is divided into specific areas, *viz.*, RF Equipment Room, Control Room, Mechanical Room, Offices, and Support Areas.

The RF Equipment and Control Rooms have a raised floor above the slab for underfloor wiring and piping, and for use as a plenum for air-conditioning the Control Room. The raised floor is designed for a live floor load of 300 lb/ft.^{2} In the RF Equipment Room, the space under the raised floor is used as a plenum for supplying outside air for cooling the high-power amplifiers. The hot air from the power amplifiers is discharged outside the building.

A reduction in capital and annual electric energy costs has been achieved by cooling the high-power amplifiers with outside air rather than via air-conditioning. The space in the RF Equipment Room proper, however, is air-conditioned for personnel comfort, as is the remainder of the building except for the Mechanical Room. The Mechanical Room is maintained, during mild weather, at outside air temperatures by thermostatically controlled ventilating fans. During cold weather, this room is warmed by the waste heat emanating from the rectifiers and inverters of the uninterruptible power supply.

The Mechanical Room houses such equipment as emergency diesel engine generators, main power switchboard, air-conditioning equipment, fire pump, and the uninterruptible power supply including storage batteries, rectifiers and inverters. For emergency power operation, each TT&C earth station has two 250-kW diesel engine generators and the other major earth stations each have one 250-kW unit.

Fire protection in these stations includes smoke detectors, a preaction water sprinkler system in the ceiling and below the raised floor and two 50,000-gal embankment fabric water tanks. Smoke venting fans and equipment shutdown facilities are also included.

Two Cassegrain antennas are installed at each TT&C site for communication and for control of the geostationary satellites. The main reflector of each antenna is 13 m in diameter. The dead weight of the TT&C antenna is approximately 30 tons. The center line of the TT&C antenna is elevated approximately 42 ft above ground elevation. The dead weight of the communication antenna is approximately 25 tons. The center line of the communication antenna is approximately 25 ft above ground elevation.

Each antenna structure is mounted on a main concrete foundation some 5 ft thick and with an area of approximately 400 ft^2. This foundation sets on a 5-ft-thick subbase of cementitious selected crushed stone. Stringent requirements for stability of the antennas necessitated such foundation design.

The earth-station building and the antenna foundations at Vernon Valley are considered "standard construction," but those at South Mountain were designed for seismic conditions. At South Mountain, grade beam construction for the building foundation was used as opposed to the more common spread footing design. The walls of the building incorporated cross bracing and roof deck plates were continuously welded to form an integral diaphragm to withstand the dynamic forces engendered by earthquake shocks.

The South Mountain TT&C earth-station site is approximately 43 acres and is located in a high valley in the mountains some 60 mi northwest of Los Angeles. The valley is used for walnut groves and for cattle grazing. It was necessary to construct approximately 2 mi of access road to the site. Water for fire protection, drinking, and sanitary usage is not available and must be brought in by truck.

The Vernon Valley site is approximately 13 acres and is located contiguous to a county road. Water is available from a well on the property. The station is tucked into a niche partially created by excavation of a hillside and overlooks another country road that is quite well traveled.

Communication earth stations

The Point Reyes earth station is being enhanced with the addition of a 13-m-diameter antenna, and the electronic equipment will be expanded and will continue to operate from the same areas as the interim station.

In late summer, 1975, specifications were drawn up and approval requests made for two major new communication earth stations having only communications facilities, located in Lake Geneva, Wisc., and Rayburn, Tex., and serving the Chicago, Ill. and Houston, Tex. areas, respectively. Construction at these two sites was started in January, 1976 and they are scheduled to be in operation this summer.

Both stations are being built in largely agricultural areas. These buildings are steel structures with ribbed metal inner and outer walls with fiberglass-type insulation. The buildings are approximately 62×60 ft in dimension for a total area of 3720 ft^2. The configuration and facilities are essentially the same as for the TT&C earth stations except that an uninterruptible power-supply system is not provided and a Halon system is used in place of preaction water sprinklers for fire protection. The Mechanical Room is heated when necessary by using it as a plenum for return air to the air-conditioning units.

Acknowledgment

The authors are grateful to the many members of the Earth Station Engineering, Implementation Engineering, and Construction Engineering groups for their contributions to this article and to the earth station program.

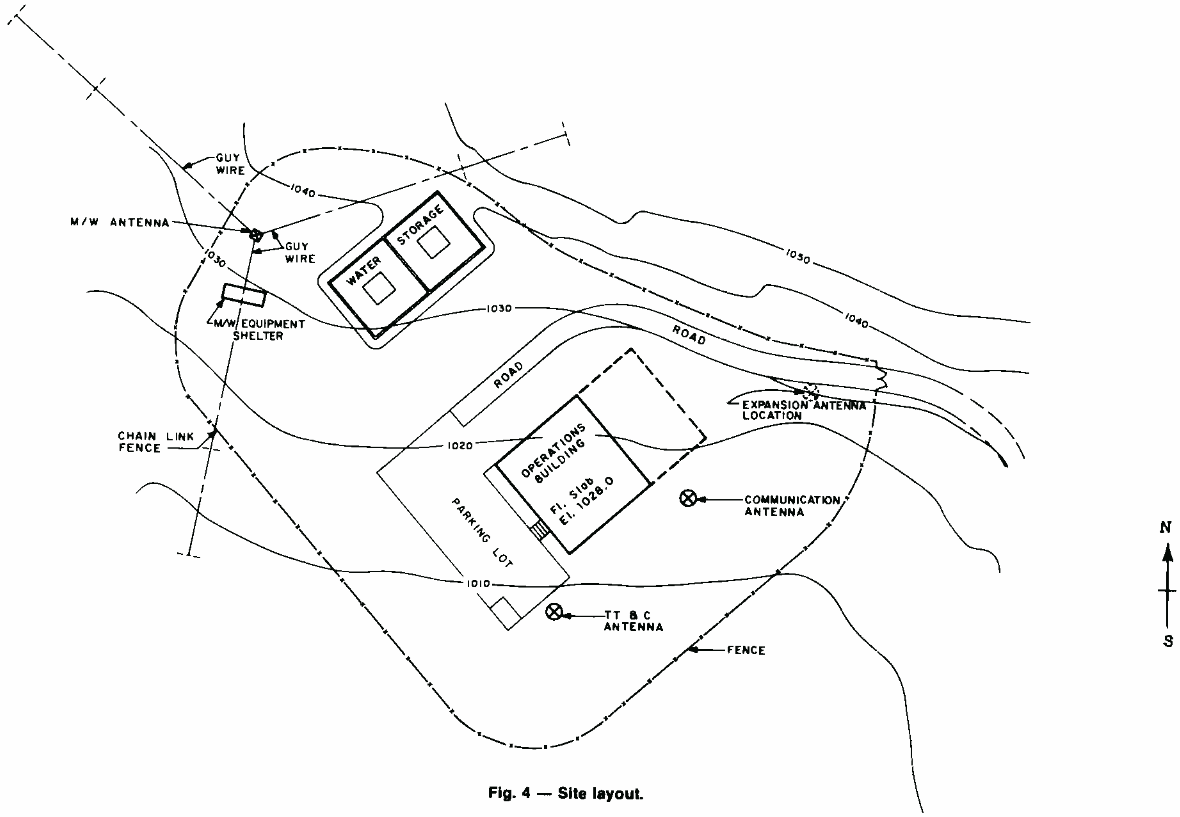

Fig. 4 — Site layout.

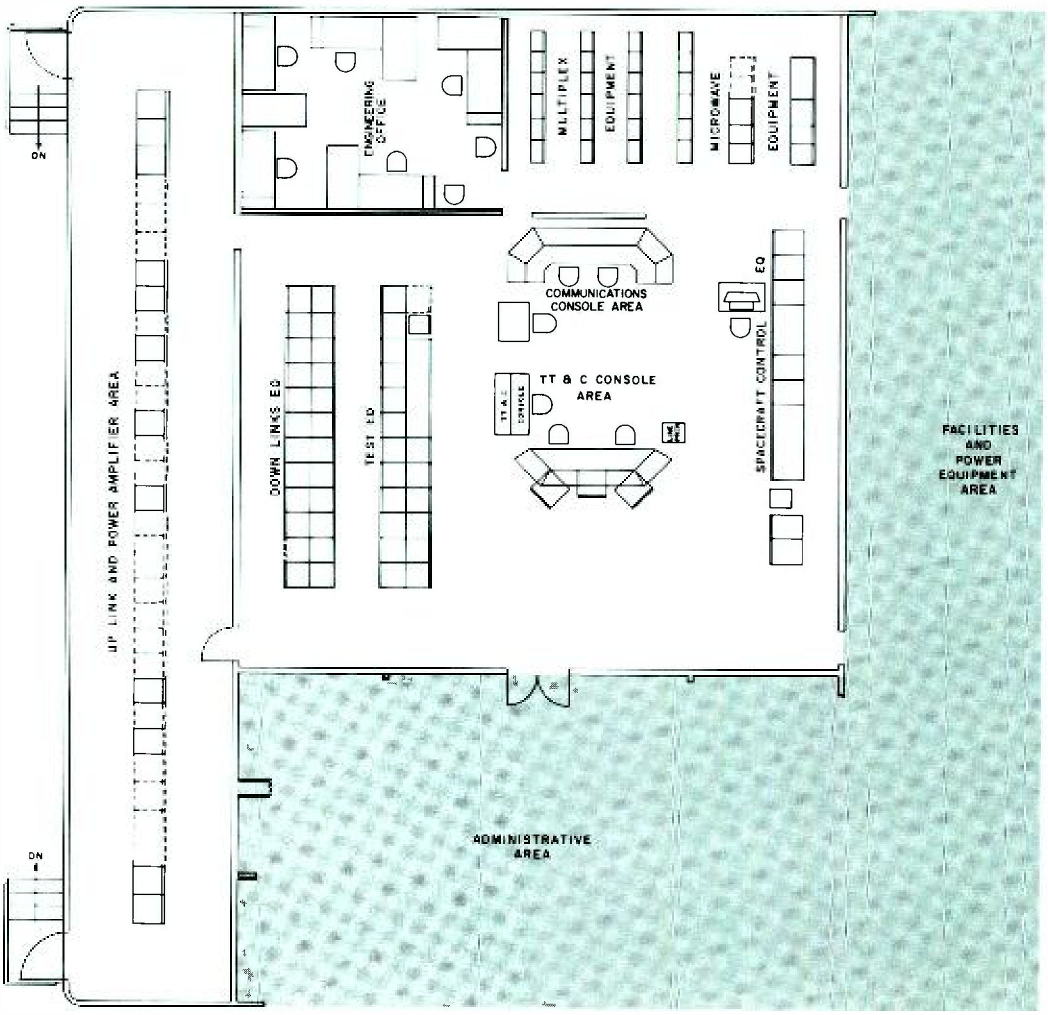

Fig. 5 — Equipment layout.

The launch and in-orbit test elements of the Satcom system

J. Christopher | D. Greenspan | P. Plush

Two aspects of RCA's successful Satcom program are described. The first segment discusses the launch vehicle development, which uprated the 2914 Delta from its previous transfer-orbit capability of 1550 lb to the new 3914 Delta with a 2000-lb useful load. The second segment gives results and a description of the in-orbit test of the spacecraft's communication subsystem.

ON DECEMBER 12, 1975, RCA Satcom I, the new-generation domestic communications satellite, was successfully launched from the Kennedy Space Center in Cape Canaveral, Fla. Several weeks later, after a complex series of maneuvers directed from the Vernon Valley, N.J., Tracking, Telemetry, and Control Station, the satellite was placed into a geostationary orbit 22,300 mi above the equator at 119° west longitude. This marked the beginning of RCA's multipurpose domestic satellite communication system, owned and operated by the recently formed RCA American Communications, Inc.

The RCA Satcom I, in operational service since February 28, 1976, is an advanced spacecraft providing 24 wideband transponder channels in the 4/6-GHz band, and containing sufficient power and propellent capacity to maintain all 24 channels operating continuously for over nine years. The three-axis-stabilized spacecraft with sun-oriented solar panels provides the maximum payload capability available within the newly uprated 3914 Delta launch vehicle envelope and offers the latest innovations in communications satellite technology. It's sister spacecraft, RCA Satcom II, was launched on March 26, 1976 and will be in service on June 2, 1976.

The implementation of the two in-orbit, one ground-stored spare satellite system, with parallel technical advancements in the launch-vehicle and ground-control stations, in an atmosphere of competitive bidding by qualified contractors, was a major undertaking by the RCA Global and RCA Alaska Communication Companies. To meet this challenge, a Satcom Project Management team was organized, relying heavily on experienced aerospace engineers from a variety of aerospace companies; and also the talents of selected RCA corporate engineering consultants, and the NASA-Goddard Space Flight Center design review team as required for evaluation of special problems and periodic design reviews of spacecraft and launch vehicle progress.

The space segment implementation activities, and the successful development by the Astro-Electronics Division and RCA, Ltd. of the spacecraft and portions of the ground segment have already been described. This article discusses two equally important facets of the overall system implementation—the launch vehicle development and in-orbit testing.

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Peter H. Plush, Mgr. Launch Vehicle Procurement and Integration, RCA Globcom, New York, N.Y., received the BSME and MSIM from the Polytechnic Institute of Brooklyn in 1962 and 1968. He has completed graduate work in control theory and advanced stress analysis. Mr. Plush has over 14 years experience in the design and management of aerospace electromechanical systems including microwave subsystems, optical subsystems, mechanical drives, and integration and optimization, of spacecraft/launch systems. In his present assignment he monitored the design and development of the Delta 3914 launch vehicle. In addition, his responsibilities included control and coordination of spacecraft/launch vehicle hardware, trajectory optimization activities, and launch services management. Prior to his assignment as Launch Vehicle Manager, Mr. Plush was the Principal Satcom Spacecraft Engineer for Mechanical Products.

A separate article, to be published in a future issue, will cover the design and control capabilities of the RCA Satcom Tracking, Telemetry, and Control stations constructed in Vernon Valley, N.J. and Moorpark, Calif. for this program, and manned by RCA Americom spacecraft controllers.

Acknowledgments

To all the team members from RCA Global Communications, Astro-Electronics Division, RCA Ltd., RCA Service Company, Telesat Canada, McDonnell Douglas Astronautics Company, Thiokel Corporation, NASA Headquarters, NASA Goddard Space Flight Center, and NASA Kennedy Space Flight Center—their dedicated contributions made the project a success.

J. Christopher

The Delta 3914

P. Plush

At a time when current technology of domestic communications via synchronous satellites employed 12-transponder, spin-stabilized spacecraft weighing approximately 1300 lb, the management of RCA Global Communications chose to surpass all existing competitive systems by advancing the state-of-the-art and implementing a domestic communications system based upon a 24-channel, three-axis-stabilized spacecraft in the 2000-lb weight class. The system would employ two satellites in orbit, one operational and one as a spare, and a third ground-stored spare spacecraft—all of the new high-capacity type.

Two primary RCA Satcom class candidate launch vehicles existed within the NASA stable of standard vehicles: the Atlas-Centaur vehicle, capable of placing 4200 lb of payload into synchronous transfer orbit at an estimated cost in 1972 of 17 million dollars per launch: and the Delta 2914 launch vehicle, capable of placing 1550 lb of payload into synchronous transfer orbit at an estimated cost of 9 million dollars. Clearly, the Centaur vehicle was too powerful and costly for the application. This could have been mitigated by a tandem launch of two spacecraft, which, would risk two spacecraft at a single launch. More importantly, the tandem concept did not allow a cost-effective and timely replenishment launch of the single spare spacecraft. The standard Delta vehicle, while substantially lower in cost than Centaur, was incapable of launching the new class of RCA Satcom spacecraft.

A proposed launch-vehicle configuration, the Delta 3914, in the conceptual stage at McDonnell Douglas Astronautic Corporation (MDAC) and supported by the Delta Program Office at Goddard Space Flight Center did appear capable of fulfilling the requirements of low launch cost, adequate payload capability, and cost-effective replenishment launches. The Delta 3914 was an evolutionary development of the standard Delta 2914 and was capable of lofting a 2000-lb payload to synchronous transfer orbit at an estimated cost of 11.5 million dollars per launch.

Technical and cost merits of the Delta 3914 were obvious for the RCA Satcom application; however, NASA management had in 1971 adopted a Standard Vehicle Policy, which stated that standard expendable launch vehicles in NASA's inventory could only be modified to enhance system reliability. The Standard Vehicle Policy permitted a particular mission to evolve its spacecraft design for a launch aboard Scout, Delta, Atlas-Centaur, or Titan launch vehicles with substantial flexibility in payload weight. However, the high-cost increments of the more powerful launch vehicles dictated the use of small commercial payloads.

The conflict between the NASA standard launch vehicle policy and the low-cost and high-performance objectives of the RCA Satcom system were resolved through joint RCA/MDAC/NASA/ management negotiations. RCA in particular and other commercial users in general were permitted to fund directly the development of new launch vehicles particularly suited to their requirements while also assuming any risks associated with that development. NASA retained the sole charter for launching nonmilitary payloads within the USA and therefore was still required to certify the new vehicle for flight. RCA Global Communications signed a standard NASA "reimbursable launch" contract for procurement of launch-vehicle hardware and launch services, and a unique "user's contract" with McDonnell Douglas, which paid a prorated portion of costs incurred by McDonnell Douglas in developing the Delta 3914. Thus, RCA Corporation became the first private company to fund a launch-vehicle development directly through the user's fee. In this particular case, it was to be the single largest increase in payload capacity (450 lb) experienced on the Delta program.

Description of the 3914

Through numerous changes, both major and minor, Delta vehicle performance had evolved over a 13-yr period from a 100-lb to a 1550-lb payload capacity. The Delta 2914 launch vehicle shown in Fig. 1 was a three-stage vehicle with stage performance as shown in Table I. Delta 3914 was created by substituting nine Castor IV thrust augmentation strap-on solid motors for the nine Castor II strap-on motors of the 2914 vehicle. The Castor IV motor provided 85,270 lb of thrust as compared to 52,150 lb for the Castor II motor and, by virtue of longer burn time, more than 2½ times the impulse.

Changes to the core vehicle were limited to those dictated by the change to Castor IV strap-on motors. The Delta 2914 and 3914 vehicle configurations remain quite similar (see Fig. 1).

Both the Delta 3914 and 2914 vehicles are 116 ft tall and 8 ft in diameter; the former has a gross weight at lift-off of 420,500 lb, the latter 295,000 lb. The first stages of both the Delta 3914 and 2914 launch vehicles consist of an extended long-tank Thor, 74 ft in length and 8 ft in diameter, equipped with a gimballed, liquid propellant RS27 main engine and two smaller Vernier control engines. During the booster phase of flight, the gimballed main engine corrects instantaneous yaw-and-pitch-attitude errors while the Vernier engines correct roll-attitude errors. The RS27 engine was derived directly from the H-1 engine of the Saturn launch vehicle. Thrust augmentation of the first stage is provided by the nine externally mounted solid propellant motors, which are jettisoned upon propellant depletion.

Deltas 3914 and 2914 employ identical

Fig. 1 — Delta 2914 and 3914 vehicle configurations.

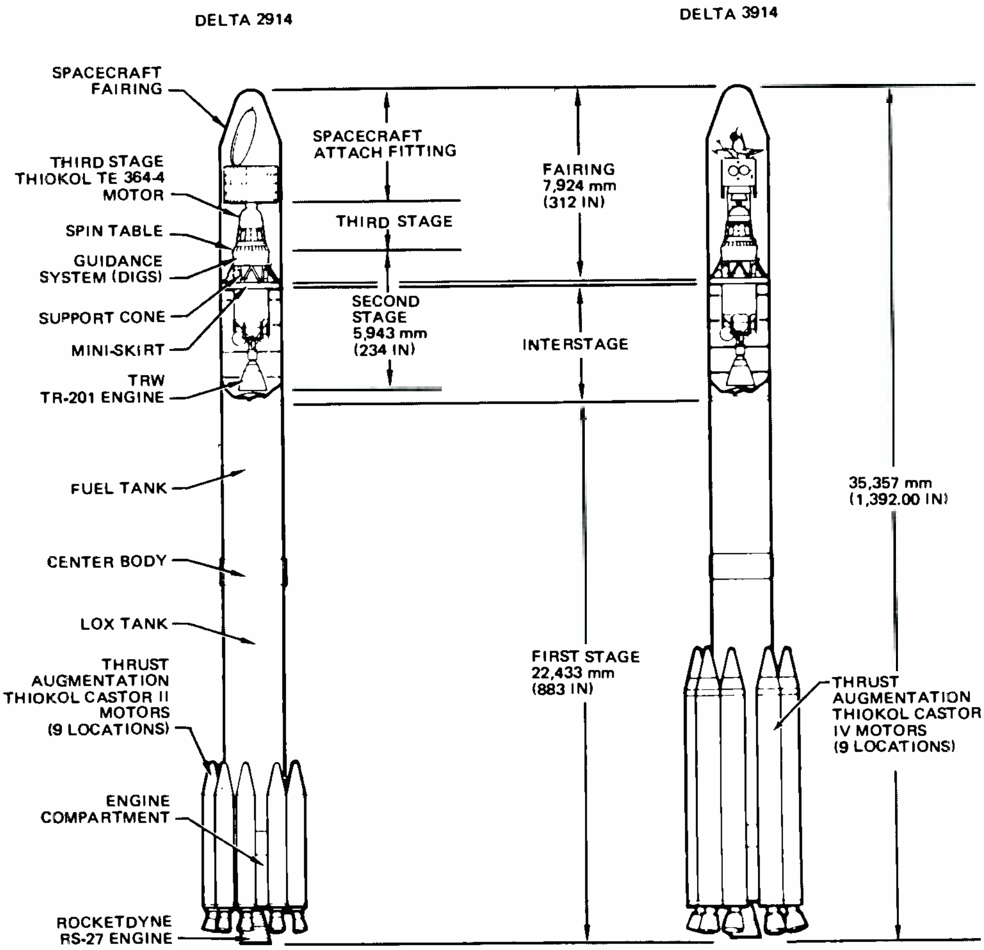

Table I — Launch vehicle characteristics of Delta 3914 and 2914.

	Delta 3914 *Strap-on*	*Delta* 2914 *Strap-on*	*Stage I*
Length	9.1 m (29.8 ft)	6.0 m (19.7 ft)	22.5 m (74.0 ft)
Diameter	101.6 cm (40 in.)	78.74 cm (31 in.)	243.8 cm (96 in.)
Engine type	solid	solid	liquid
Engine manufacturer	Thiokol	Thiokol	Rocketdyne
Designation	(Castor IV) TX-526	(Castor II) TX-354-5	RS-27
Number of engines	9	9	1 (+ 2 Vernier engines)
Specific impulse (avg)	229.9	237.6	262.4
Thrust per engine (avg)	379,299 N (85,700 lb)	231,974 N (52,150 lb)	911,840 N (205,000 lb)
Burn time	58.2 s	35.5 s	228 s
Propellant/fuel	TP-H-8038	TP-H-7036	RP-1
Oxidizer	—		LOX

second stages, which are 21 ft in length and 8 ft in diameter. The second stage engine, a pressure-fed liquid propellant unit, was derived from the Lunar Excursion Module Descent engine. The unit's restart capability is employed after a coast period during the launch to initiate transfer from circular parking orbit to elliptical transfer orbit. The second stage engine is gimballed and provides pitch- and yaw-attitude control during second stage powered flight. A second stage cold-gas thrust system provides roll control during second stage powered and coast flight.

A spin table atop the second stage engine spins: 1) the launch vehicle third stage: 2) the spacecraft attach fitting; and 3) the spacecraft to 60 r/min prior to separation of the third stage. Gyroscopic forces developed by imparting this spin rate to the spacecraft stabilize its attitude against external disturbances while in the synchronous transfer orbit. Deltas 3914 and 2914 use identical 37-in. diameter solid propellant third stage motors derived from the Surveyor Main Retro-Rocket design.

The Delta Inertial Guidance System (DIGS), consisting of an inertial sensor package and a digital guidance computer, controls the vehicle attitude and the sequence of operations from lift-off to beyond spacecraft separation.

Development program for RCA Satcom

In the course of developing the Delta 3914 concept, McDonnell Douglas performed many major subsystem studies and tests, and implemented numerous new and revised hardware designs (Table II). In addition, McDonnell Douglas contracted with NASA for program management services from the Delta Project Office, and for design review services from the Systems Reliability Directorate at Goddard Space Flight Center.

In consideration of RCA-Globcom's funding contribution to the development of the Delta 3914 vehicle, personnel dealing with program management, design engineering, and reliability and quality assurance from RCA Globcom's Space Systems Group participated in conceptual, preliminary design, design certification, preshipment, and flight readiness reviews of the new vehicle and in separate program progress reviews with MDAC.

Table II — Major hardware design changes and additions for the Delta 3914. (These changes have been analyzed and tested; data on this verification is available from the author.)

Item	Changes	Reason
Solid motor (Fig. 1)	Castor II to Castor IV	
Solid motor nozzle	Develop 11° canted nozzle. (Castor II used 7° canted nozzle.)	Castor IV, as used on Athena vehicle, had 'straight' nozzle. Cant is required to keep engine plume from impinging on Vernier engines and other boatail hardware.
Solid motor attach and separation system	Castor IV motor forward end is attached to core vehicle on LOX tank and at rear end on boatail. Belleville spring thruster uses stored strain energy to drive solid motor away from booster upon release. Swing arm at forward attach point accommodates expansion and contraction of LOX tank. A more extensive insulation system is used because of high temperatures.	Castor II motor attached only to boatail structure. Release is effected by firing explosive bolt at single thrust ball at lower end of motor. Motor then slides off ways of launch beam, driven by aerodynamic drag. Increased length of Castor IV motor dictates forward attach point on LOX tank. Wind tunnel tests provide basis for designing new separation system.
Vehicle altitude control	Resolver added to control system. Predictive filtering used in control system in conjunction with Wind Bias Trajectory.	Aerodynamic analysis indicated that larger projected area of Castor IV motors and assymetry of vehicle after staging five solid motors reduced probability of launch on a given day. Wind shears at altitude adversely affected vehicle angle of attack and roll attitude control, due to limit on control torque available from Vernier rocket motors and limitation on main motor gimbal excursion. Using *a priori* wind shear profiles with altitude, a predicted bias flight profile is flown to minimize angle of attack, and gimbal excursions. Addition of resolver to control system eliminates need to limit absolute roll angle of vehicle.
Booster structure	Add internal ring truss to LOX tank. Increase gauge of skins in LOX tank skirt. Increased boatail stringers size and gauge. Reconfigure LOX tank baffle configuration.	Distribute loads from solid motor forward-attach hardware into core vehicle without local overstressing. Sloshing modes change with revised natural frequencies of Castor IV vehicle.
Solid motor ignition and separation sequence	Castor II vehicle ignites six solids, which burn to propellant depletion, then three more. Nine spent motor casings stage together. Castor IV vehicle ignites five solids which burn to depletion. Three spent casings separate, followed one second later by two spent casings, followed by ignition, burn and separation of four remaining motors.	To keep acceleration of Castor IV vehicle within limits of Castor II vehicle. Monte Carlo analysis indicated possibility of casing hardware collision without one second separation lag.
Launch complex	Complex 17A refurbished and revised to accept Delta 3914.	Increased weight and larger dimensions of solid motors necessitated procurement of higher capacity motor hoists and redesign of platforms.
Launch safety	Safe and arm devices added to Castor IV motors. Drop zone for solid-motor casings revised.	Range safety chose to invoke a more stringent requirement for Castor IV solid motor arming, necessitating the addition of safe and arm devices permitting remote arming. Because of the longer burn time of the Castor IV motors the spent motor casings can impact over a larger area. A greater zone of ocean must be cleared prior to 3914 launch.

RCA Globcom's personnel via the "reimbursable customers contract" assumed overall mission and program management responsibility for the Satcom launch and technical responsibility for the program's peculiar interface tasks in addition to those unique tasks related to Delta 3914 development.

Launch integration addressed the following major tasks:

- Spacecraft/launch vehicle compatibility
- Launch/trajectory optimization
- Pre-launch services/KSC ETR facilities
- Mission planning requirements.

From the perspective of the total Delta launch system, the change from Castor II to Castor IV motors proved to be a direct and cost-effective concept for achieving the desired performance.

The broad role played by RCA Globcom Space Systems personnel in the launch-vehicle development program afforded an opportunity to participate in detail in the major effort of developing and using a new launch vehicle in the short period of two years and providing two picture-perfect launches on time.

Communication subsystem on-orbit test program

D. Greenspan

The more significant signal characteristics of the spacecraft communication subsystem (Table I) were first measured on the Astro-Electronics Division's test range to satisfy acceptance criteria and to establish baseline performance levels for the integrated spacecraft. After launch and arrival on station at 119° west

Table I — Measured communication subsystem characteristics.

Performance parameter	*On-orbit*	*Test range*	*Performance parameter*	*On-orbit*	*Test range*
EIRP	X	X	Amplitude linearity		
Sensitivity			In-channel	X	X
(saturating flux density)	X	X	Spacecraft receiver		X
Amplitude response	X	X	Intelligible cross-talk		
Group delay	X	X	In-channel		X
Cross-polarization			Spacecraft receiver		X
isolation	X	X	Oscillator stability	X	X
			Spurious outputs	X	X

longitude, each of these characteristics was re-measured and compared with baseline data. Except for a relatively few discrepancies, good correlation existed between the pre- and post-launch parametric performances.

Test objectives

The primary objective of the spacecraft communication subsystem performance tests was to verify range test results. However, check-out of some of the innovative communication satellite hardware, which could not be adquately characterized on the ground, was equally important. Precise pointing control of the high-gain communication beams by the Stabilite™ attitude-control system was verified by rf measurements taken at three points near the edges of the coverage zone. Also the cross-polarization isolation performance of the gridded-reflector spacecraft antenna subsystem was measured on an end-to-end space link between stations in New Jersey and California. Special measurement techniques were required to demonstrate the isolation between adjacent cross-polarized transponder channels, which share overlapping frequency bands.

Test facilities

On-orbit measurements were conducted at the RCA Americom earth stations located at Vernon Valley, N.J., and Moorpark, Calif., and at the RCA Alascom stations near Yakutat and Cordova, Alaska. The receiving equipment at each of the Americom stations featured a 43-ft parabolic antenna, redundant thermoelectrically cooled parametric amplifiers (60 K), and a Hewlett-Packard 8580B automatic spectrum analyzer.

Detailed calibration tests were run prior to and during the measurement program, in order to identify and separate the earth-station contributions from the indicated spacecraft responses. These calibrations included plotting the group delay and amplitude response curves for each of the 24 transponder frequency bands, with the earth-station transmitter and receiver connected in a looped-back configuration. Earth-station antenna gains were calibrated separately, both as

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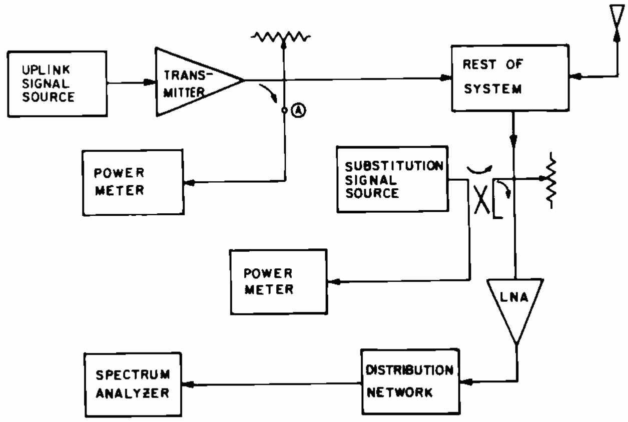

Fig. 1 — EIRP (effective isotropic radiated power) and flux density test setup.

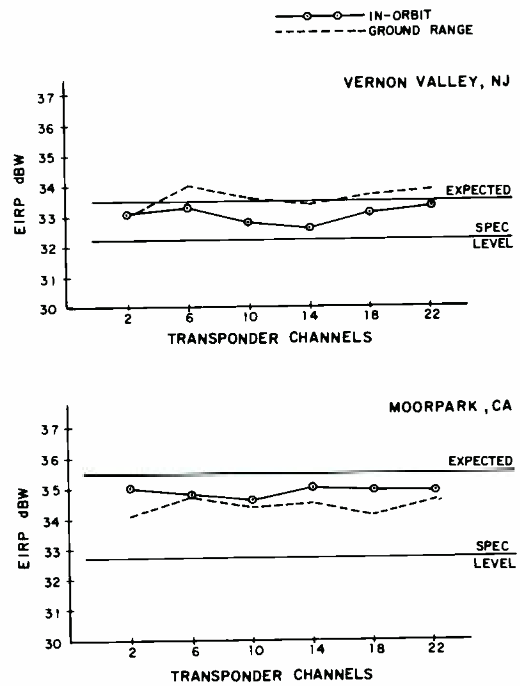

Fig. 2 — Typical EIRP performance (transponders 2, 6, 10, 14, 18, 22).

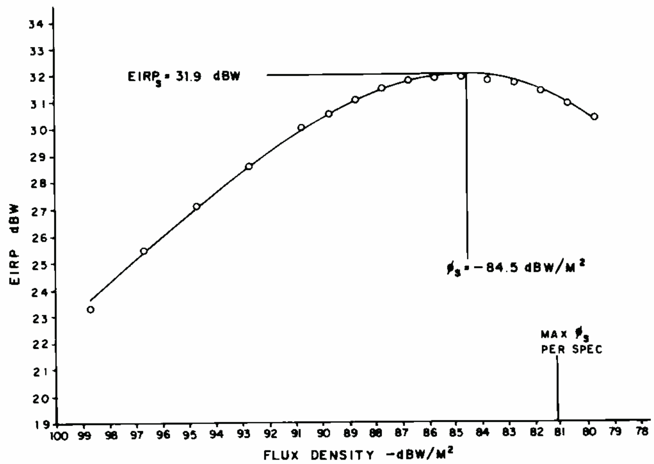

Fig. 3 — RF-power transfer curve (transponder 2 from Vernon Valley, N.J.)

part of station acceptance procedures and by project personnel employing a previously calibrated spacecraft in operation.

Measurements and results

Equivalent isotropic radiated power (EIRP) and sensitivity

Spacecraft EIRP was measured at the three test sites simultaneously, in order to verify correct spacecraft attitude and beam alignment. Signal substitution measurement techniques were employed, which consisted of injecting a continuous-wave signal at the LNA (low-noise amplifier) input of the receiving station and adjusting its level to produce the same indicated level as the spacecraft signal (Fig. 1). By measuring the power of the injected signal to determine down-link power delivered to the LNA, it was possible to reduce measurement error to the overall gain uncertainty of the earth-station-antenna and feed-line combination. A previously calibrated satellite, presently operating in the 4-GHz frequency band, was used as a check on the vendor-furnished antenna-gain figures employed in determining spacecraft EIRP.

Measurement results indicated that stringent spacecraft beam pointing objectives had been met and that spacecraft EIRP performance achieved nominal prediced levels (Fig. 2).

The test setup shown in Fig. 2 was also used to plot the individual transponder input/output transfer curves. The up-link power corresponding to the peak of each curve was mathematically converted to saturating flux denstiy at the spacecraft, taking into account the up-link path loss. A typical input/output response curve, noting the margin above specified minimum performance, is shown in Fig. 3. The average performance margin for all transponders was 2.4 dB.

Amplitude response and group delay

Standard swept-frequency measurement techniques were employed to plot the amplitude *vs.* frequency and group-delay responses of each transponder channel. The primary measurement instrument was the Hewlett-Packard microwave link

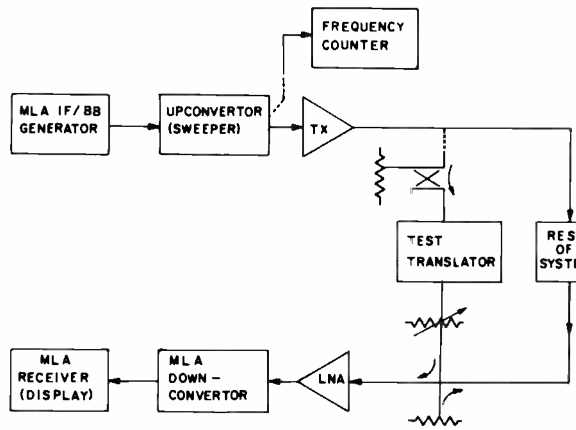

Fig. 4 — Amplitude response and group delay test setup.

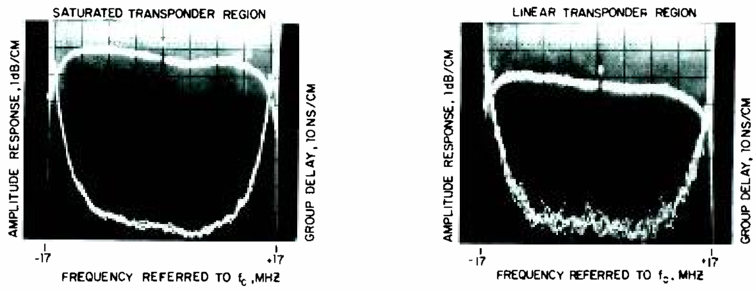

Fig. 5a — Transponder amplitude and group delay responses.

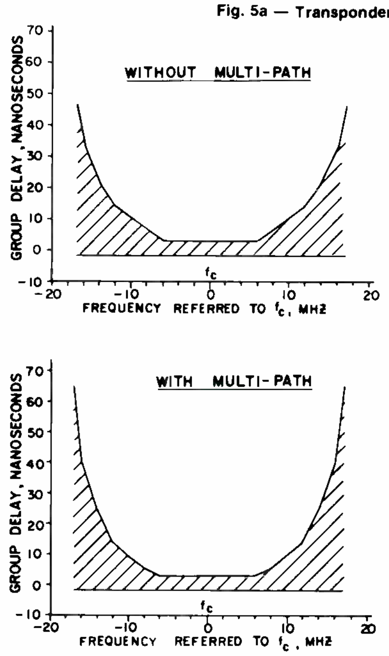

Fig. 5b — Transponder small-signal group delay response specifiction limits.

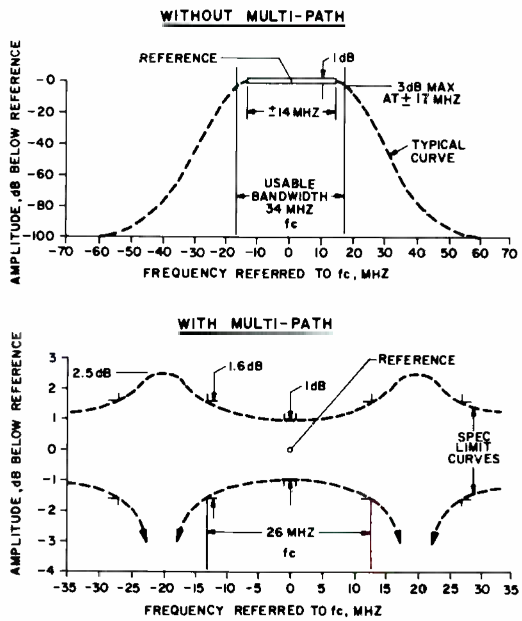

Fig. 5c — Transponder small-signal amplitude response specification limits.

analyzer (MLA), which was selected in order to achieve acceptable group-delay curves at low carrier-to-noise ratios and in the saturation region of the spacecraft transponders. The test setup is shown in Fig. 4.

Transponder measurements were performed under saturation and small-signal conditions, both with and without multipath interference through adjacent copolarized transponders. A typical set of measured responses is shown in Fig. 5a. All transponder responses were compared to the specification masks shown in Figs. 5b and c. With a few minor exceptions, all specifications were met.

Cross-polarization isolation

In-depth measurements of polarization isolation prior to launch had been confined primarily to antenna level tests at the vendor's range facility. The tests were designed to measure worst-case performance, applicable to the broad-band isolation between cross-polarized antenna *beams*. Tests in orbit, however, could not be performed in this manner and, in any event, would not necessarily be useful for communication-link engineering purposes. Therefore, the on-orbit cross-polarization tests were designed, instead, to measure the isolation between cross-polarized *channels*. The test setup is shown in Fig. 6.

Another test objective was to provide data representative of operational conditions. Thus interference from both channels immediately adjacent to the test channel was simulated. Since these adjacent channel are each transmitted via separate spacecraft reflectors, it was necessary to align the earth-station antennas at each end of the test link to an optimum "compromise" position that resulted in balanced interference levels.

Earth-station polarization isolation contributions to test results were judged to be minimal because of the superior isolation performance levels of the earth-station antennas, as compared to that of the spacecraft (as much as 10 dB at most frequencies). Tests were conducted on both eastbound and westbound links, and on transponders selected from each of the four spacecraft reflectors. Table II summarizes the cross-polarization isolation test results.

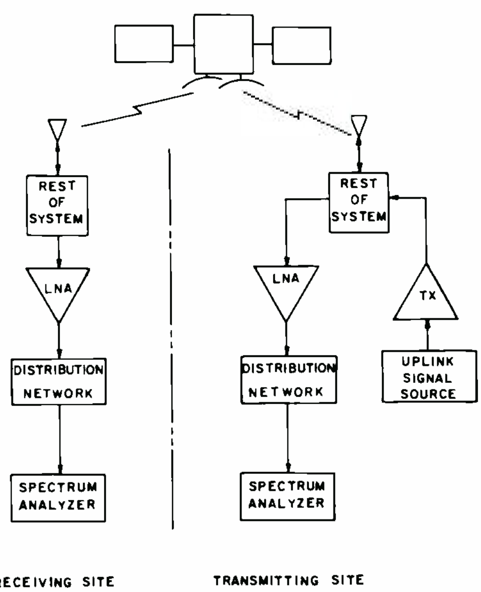

Fig. 6 — Cross polarization isolation test setup.

Other tests

Additional tests were also performed to measure amplitude linearity, translation frequency stability, and spurious output levels. Standard measurement procedures were employed and correlation with ground-test data was good. Test results are shown in Table III - V.

Table II — Measured link isolation

RCA Satcom transponder No.	*Measured two-way link isolation (±1 dB)*		*Specified one-way spacecraft beam isolation*	
	MP to VV (dB)	*VV to MP (dB)*	*Transmit (dB)*	*Receive (dB)*
2	37	36	33	33
11	34	42	33	33
12	34	37	33	33
21	36	35	33	33

Table III — Amplitude linearity within a transponder: 2-tone third-order carrier-to-IM ratios.

	Carriers backed off:					
	3 dB		*10 dB*		*17 dB*	
	On-orbit	*Ground*	*On-orbit*	*Ground*	*On-orbit*	*Ground*
Best transponder	13.0	11.2	19.0	18.9	29.0	28.3
Worst transponder	10.0	9.5	16.0	15.9	25.0	25.2
Avg. of all transponders	11.3	10.4	17.1	17.4	27.4	27.3

Table IV — Translation frequency stability.

Spacecraft receiver	*Designation*	*Peak-to-peak variation (kHz)*	*Period (hr) (approx.)*
1A	Odd channels (primary)	900	24
1B	Odd channels (back-up)	1300	24
2A	Even channels (primary)	Not tested.	
2B	Even channels (back-up)	1900	24

Table V — Spurious outputs.

	Ground measurement	*In-orbit measurement*
$2F_c - 4F_{lo}$ (receiver 1A, channel 1)	−49 dBc	−49 dBc
Command receiver L.O. leakage (receiver 2A, channel 24)	−52 dBc	−53 dBc

Solar energy: its status and prospects

Dr. D. Redfield

Desirable characteristics of future energy sources are that they be extensive, inexhaustible, widely available, and that they present the minimum hazards to health, the environment, and the "quality of life"—characteristics that only solar energy, among proposed alternative energy sources, possesses. The state of development of the different solar technologies varies widely from solar heating of buildings, which is ready for commercial development, to ocean thermal generation of electricity, which is in design stages. It is found that several solar technologies are well enough advanced to be "underused technologies" and their cost projections under conditions of industrial development are favorable. The time scale for significant contributions from solar energy is, by conservative estimates, 10 years.

AMONG the welter of cross currents that compose our growing energy problems, some facts are not in serious dispute. First, "···there is a real and increasing gap between the present energy production and essentially all projections of future energy requirements in the United States···."[1] More than 75% of present U.S. energy is supplied from conventional oil and natural gas, fuels that are being depleted significantly and cannot long continue to meet our needs (even reasonably reduced needs).[2] Furthermore, these hydrocarbon fuels have great value for other applications such as petrochemicals, fertilizers, etc. The use of all fossil fuels (including coal, which is much more abundant) also creates a number of hazards and environmental problems in fuel extraction, transportation, and combustion. It is therefore clear that major changes are required in our energy practices and a variety of alternative sources of energy are being examined as substitutes for the present ones. Also clear is the troublesome fact that the immense size of our energy industries will cause any change to be a slow one so none of these alternative sources can become important in the immediate future.

Nuclear-generated electricity is a newcomer and is supplying a growing fraction of our energy needs. But, apart from the controversies over the potential hazards of the plants and fuel, the plants now built or under construction will require through their lifetime a commitment of all the proven U.S. reserves of high-grade uranium ore;[3] thus there is a push for breeder reactors that can utilize nuclear fuels much more effectively.

The other alternative energy sources receiving serious attention are nuclear fusion, geothermal energy, shale oil, and solar energy. Desirable characteristics in any alternatives are that they 1) provide very large amounts of energy, 2) be inexhaustible, 3) be widely available, and 4) produce the minimum hazards to health and the environment. Solar energy (SE) appears particularly favorable with respect to such desired characteristics: it is obviously inexhaustible for human use; it supplies about 600 times as much energy to the U.S. (48 states) as our total energy consumption; and its use entails minimal (but nonzero) impact on health or the environment. The major uncertainties concern the time scale in which the potentialities of SE can be realized, the selection of the most promising of the SE technologies, and the eventual cost of SE systems.

As with all newly developing energy technologies, there is no large-scale solar industry whose products can be assessed in performance and cost for terrestrial needs. It is therefore necessary to examine the R&D programs to try to appraise the prospects of solar energy.

Categories of solar research and development

Nearly all of the Federal R&D programs are now managed by the new Energy Research and Development Administration (ERDA) although the National Science Foundation still supports small, longer range programs. ERDA's recently issued National Plan for Solar R&D[4] has the various technologies grouped into three major categories, each with its own subprograms. We will describe these briefly. In parentheses are shown the amounts (in millions of dollars) of FY 1976 expenditures.

Direct thermal applications (28.5 M)

There are two subprograms: 1) heating and cooling of buildings, including water heating; and 2) agricultural and process heat, including crop drying, greenhouses, and industrial process heat. Heating and

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cooling of buildings now consumes one-quarter of all U.S. energy and therefore represents an area of huge potential benefits. It is also the closest to commercial realization. The heating and cooling subprogram has the largest expenditure rate within the solar division.

Solar electric applications (43.6 M)

Wind Energy Conversion Systems WECS ($11 M) — This is an old technology that is being modernized to increase unit size and efficiency, and to reduce cost. Studies of wind patterns and direct mechanical drives are also included.

Solar Photovoltaic Conversion Systems, SPCS ($16 M) — This is another established electrical generation technology (in space vehicles) that is being adapted for terrestrial use. The primary requirement is the development of techniques capable of producing greatly increased quantities of arrays at a much reduced unit cost. Goals include both on-site (dispersed) generation and central station generation.

Solar Thermal Conversion ($10.6 M) — By concentrating sunlight, relatively high temperatures are produced in working fluids, which are then used to drive turbogenerators. Such thermodynamic cycles can be made quite efficient in electrical generation or can be used in "total energy" systems that supply useful heat as well as electricity.

Ocean Thermal Energy Conversion, OTEC ($6 M) — This scheme uses turbogenerators driven by a working fluid that is heated by the surface layers of tropical oceans (~ 25°C) and cooled by the deep layers beneath (~ 5°C). This is the only scheme that permits continuous operation without interruptions by sun or wind.

Fuels from biomass ($6 M)

Biological materials are converted into clean fuels (for purposes such as transportation) and petrochemical substitutes by a variety of methods including thermochemical, biological, and combustion processes. The starting materials are agricultural and forest wastes as well as crops of appropriate terrestrial and marine plants grown for this application. The important, closely related program of conversion of urban wastes is in the Conservation Program of ERDA.

In addition to these conversion technologies, R&D is being performed on associated components such as energy storage (thermal, electrical, and chemical) and compatibility devices known as "power conditioning" units. Studies are also being made on various sociotechnical programs, system integration requirements, and the solar data base.

Current status

The various subprograms are at quite different stages of technological development; some are sufficiently established that they represent "underused technologies."

The direct thermal application category is not only well advanced, but is in demonstration use in a number of ways. In fact, "...technologies for solar heating are close to the point of commercial application in the United States..." and "...no insoluble technical problem is now foreseen..." for combined heating and cooling.[5] Congress has already authorized $60 million for hundreds of demonstration buildings (residential and commercial) in all parts of the country to be equipped with solar heat by 1977 and with combined solar heating and cooling by 1979.[5] Present life-cycle costs for such heating units appear about equal to the cost of electric heat and about twice that of heaters fueled by oil or gas, but economics are rapidly changing to favor the solar heaters as mass production lowers their costs and fuel costs rise. Large companies are entering this field for the first time. Problems in this area seem to lie with the unfamiliarity of builders, architects, and consumers—a condition that will change with the growth of the industry. One unexpected stimulant is coming from three New England electric utilities, which are subsidizing the installation of solar water heaters in homes of some of their customers now using electric heating. In another application, one company produces a million tons of salt annually by solar sea-water evaporation.[6] An interesting recent example that uses solar energy for both building heat and sewage processing (Fig. 1) is a plant designed for a town in the mountains of western Maine. It has been estimated that by 1990 the overall savings by the direct thermal category could amount to 1.5% of the nation's total energy budget [Ref. 7, p. II-32].

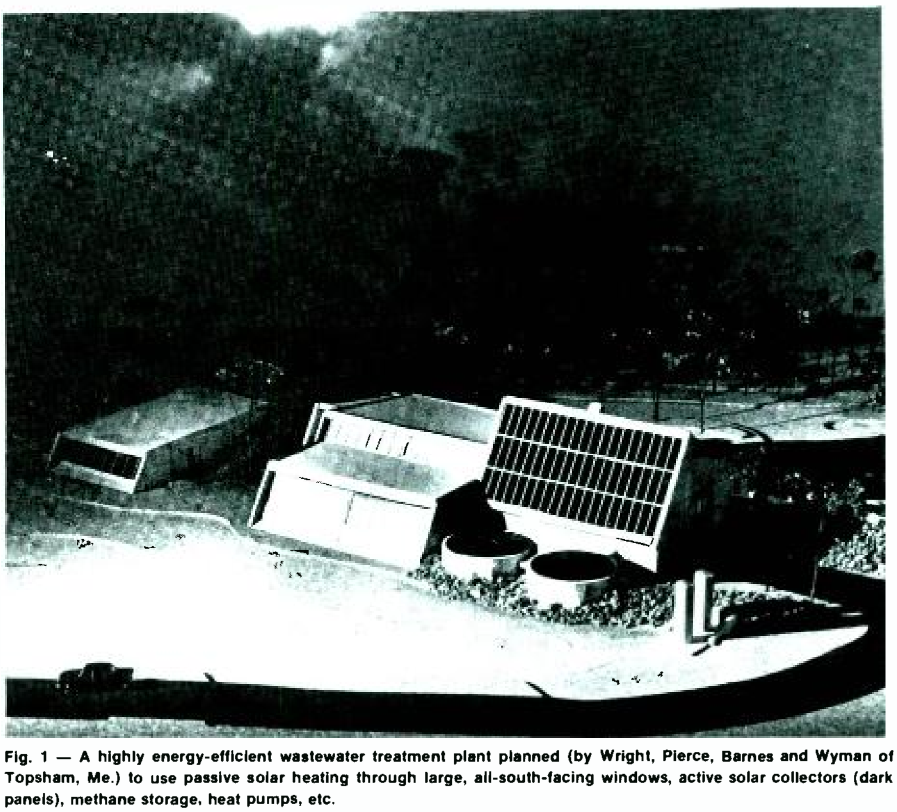

Fig. 1 — A highly energy-efficient wastewater treatment plant planned (by Wright, Pierce, Barnes and Wyman of Topsham, Me.) to use passive solar heating through large, all-south-facing windows, active solar collectors (dark panels), methane storage, heat pumps, etc.

In the category of direct electrical generation, solar photovoltaic conversion systems (SPCS) and wind energy conversion systems (WECS) are technologically the most advanced. At present, though, the manufacturing capacity of SPCS is insignificant on the scale of terrestrial needs. As a result, the current price of \$20/W (peak) for SPCS arrays is still far too high for widespread use. For future large-scale applications, one must look to projections of SPCS array prices; such a projection, together with the price history, is shown in Fig. 2 as an "experience curve." The sharp drop in 1974 was the first consequence of new interest in terrestrial systems stimulated by the oil price increases and embargo of 1973. The dashed projection follows the relevant 75% experience curve of the semiconductor device industry. It is noteworthy that the unit price is likely to reach ~ \$1/W around 1985 as a result of nothing more than the assumed growth in demand. In addition, ERDA has launched a large, single SPCS program[8] to provide by 1985 the capability of fabricating 500 MW (peak) of silicon solar arrays annually at a cost of \$0.50/W, a figure that is competitive for on-site applications (Ref. 7, p. VII-B-3).

On a nearer time scale, a variety of intermediate-size on-site SPCS's are planned at intermediate capital costs. There are, in addition, a number of other technically promising variations of SPCS that could reduce the cost more rapidly. For example, even the present high-cost cells might be used economically in very small devices with the sunlight focused onto them by inexpensive collecting lenses or mirrors. An illustration of one such system is shown in Fig. 3. Such concentrating schemes, however, must follow the sun and since they use only direct sunlight, they cannot benefit from the diffuse light present in the entire sky, particularly on hazy or cloudy days. They appear most favorable, therefore, for regions having generally clear weather.

Wind energy conversion in small units is also well advanced and a 1.25-MWe [MW(electrical)] system has been used in Vermont. A newly designed 100-kWe wind conversion facility has been built by NASA (as part of the ERDA effort) to serve as a prototype for future units; several more will be built this fiscal year, and construction of a 1-MWe system will also be started. Favorable areas with high-average wind speeds (power varies as the cube of the wind speed) have been identified and a variety of other technical, environmental, and social aspects of WECS are being analyzed. Costs for large-scale systems in mass production are not yet known although they are projected to be competitive [Ref. 7, P. IV-41]. Public acceptance of the large towers necessary may be a problem in developed areas but WECS's are compatible with agricultural and other land uses.

Solar thermal conversion is less well developed but in some forms it is conceptually simple. Construction of a test facility with 5-MWth [MW (thermal)] capacity is beginning this fiscal year and system analysis of a 10-MWe power plant is being initiated. These are based on a tower-mounted central receiver heated by a large array of heliostatically mounted mirrors as illustrated in Fig. 4. Dispersed collectors are also feasible in principle and are being explored. One feature of thermal conversion that is unique among the solar options — the generation of high temperature — will be exploited in a total energy system by use of the rejected heat of the generator for space (or process) heating. On the other hand, this is the one technique that requires cooling

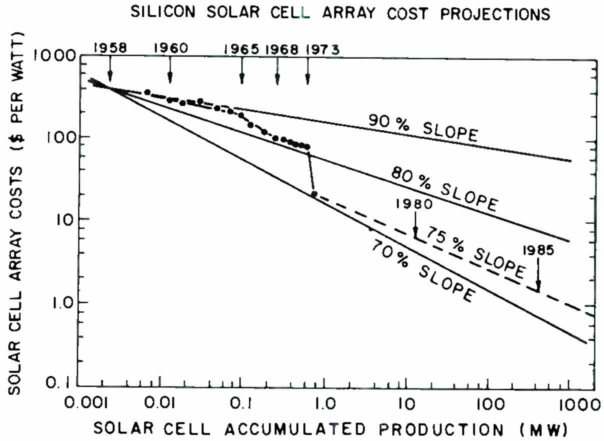

Fig. 2 — History (solid) and projection (dashed) of the cost of silicon solar-cell arrays. The association of fixed production levels with the years 1980 and 1985 are estimates that are dependent on the extent of the commitment made to this technology (adapted from Ref. 7, p. VII-C-64).

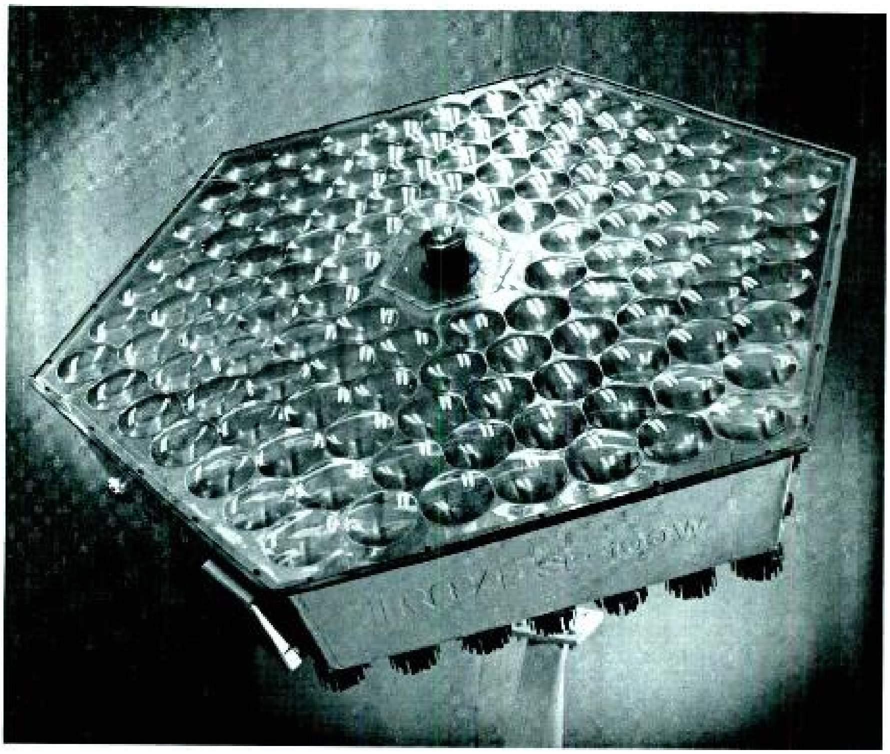

Fig. 3 — One version of a photovoltaic array using concentrated sunlight. The front cover is a molded plastic panel of lenses, each focusing its light onto a cell 1000 times smaller. The dark protrusions at the back are ordinary heat diffusers that limit cell heating to 20°C. At front center is a set of sun sensors that control the direction of the array (Courtesy L. Napoli, RCA Laboratories).

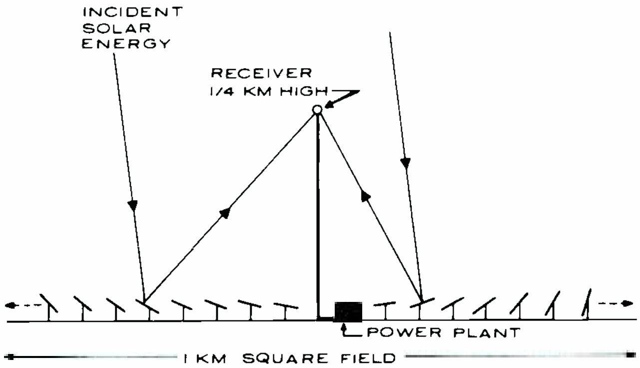

Fig. 4 — Schematic diagram of a central-receiver type of solar thermal electric converter. A field of sun-tracking mirrors approximately 1 km² is capable of generating nearly 100 MWe (electrical) during peak sunlight hours.

water. Costs are essentially unknown for commercial units but some estimates suggest that intermediate-load systems will be competitive with fossil fuel plants around 1990 [Ref. 9, p. 37].

Ocean thermal energy conversion (OTEC) is in perhaps the earliest stage of development with basic component and system designs still not resolved. The overall practical efficiency of these systems is estimated to be ~ 2% [Ref. 10, p. 70] so enormous quantities of water must be processed and heat transfer must be exceptionally good. Optimum plant size of 100 MWe is estimated[11] and the large floating stations needed would be built with shipyard facilities. Possible environmental effects of large numbers of OTEC plants are being examined.

Bioconversion to clean fuels is sufficiently developed that it "...is commercially feasible to a limited extent today, using urban, farm, and forest product wastes..." [Ref. 9, p. 2]. The use of forest residues as fuel is already saving large amounts of energy used by the forest industry; during World War II a significant portion of France's liquid fuel supply consisted of methanol made from wood (Ref. 4, p. III-29). Energy crops could cover very large land areas and thus compete with other agricultural requirements, but animal wastes and the residues of various existing field crops appear suitable for conversion to fuels with known methods. System studies are still in progress, with demonstration use of such processes a few years away.

Considerable work is being done on a variety of associated problems. The solar insolation (the rate at which solar energy is incident on a horizontal surface) data base is becoming well established [Refs. 9, p. 11; and 7, pp. A-I-3,4]. Land use studies show that the total present demand for electricity (~ 1/10 of the total energy) could be met (at 10% conversion efficiency) using an area about 1/10 of that now devoted to roads.[12] Further, there is no requirement for land to be used for fuel extraction or refining, or disposal of residues. In built-up areas, however, there are prospects for legal complications over "sun rights" somewhat comparable to water-rights questions in irrigated areas.

Energy storage will become an important requirement for all solar options and is receiving much attention. Thermal storage in water or rocks is quite effective for small systems; for larger ones a variety of more sophisticated options exist but need further development. Electrical storage requirements are nearly identical to the electrical utility load-leveling requirements that are also receiving considerable private effort.[13] For large systems, the options include advanced batteries, pumped storage (of gas or water), and hydrogen production. The requirements for power conditioning— the conversion from dc to ac and use of variable levels of generated power — present little technical difficulty but add another element to systems cost.

Perspective and conclusions

Any judgments of solar energy as a national resource must be made on the basis of its comparisons with the possible alternatives. In the past, oil and natural gas were such inexpensive alternatives that they came to dominate all others; resource depletion and environmental harm have only recently been widely recognized as serious problems. For the future, the major alternatives in the U.S. are coal (with potential liquid or gaseous fuels derived from it), shale oil, breeder reactors, nuclear fusion, and geothermal energy.

At present, geothermal sources are relatively low-cost sources of electricity and will probably be used more in spite of their generally polluting effluent. Their numbers are sufficiently limited, however, that they appear to offer only regional benefits (somewhat like hydroelectric sources). Nuclear fusion has great promise for virtually limitless amounts of energy but the scientific feasibility of power generation has not yet been demonstrated, serious engineering problems exist, and economic and environmental questions will be unanswerable for some time. The U.S. breeder reactor program has encountered steadily rising costs, difficult technological problems, and growing public opposition because of health and security concerns. The Clinch River Demonstration Plant operating date has been slipping regularly and it has been estimated that such plants will not be competitive in this century.[14]

Although there are very large quantities of shale oil in the U.S., its recovery is faced with such serious technical and environmental problems that its large-scale production is not in sight. Thus coal appears to be likely to be heavily used but it, too, has important disadvantages in extraction, transportation, and combustion. A problem receiving growing recognition is that the development of both of these fossil fuels "...imposes large demands for water at the source. Water problems are particularly acute for our most promising oil shale and coal deposits which are in the western areas of the lower 48 states..." [Ref. 15, p. 32]. In addition, *all* thermal electric systems consume large quantities of cooling water and, except for solar systems, add to the heat load in the biosphere.

We find that in none of solar energy's three major categories is there evidence of major scientific, engineering, or environmental obstacles to successful develoment, although not every sub-program will necessarily succeed. In fact, still other advantages appear. 1) When complete energy systems are compared, SE is significantly less capital intensive than is generally recognized because it requires no investment for fuel extraction, transportation, or refining. For example, the capitalized cost of nuclear fuel is estimated at $200/kW.[11] 2) For every joule of electrical energy provided this way, 3 J of primary fuel energy are saved. 3) SE is the most widespread energy resource and its technologies provide for energy systems of all scales; the modular nature of several of the converters offers a great versatility in system size (at about the same unit energy cost) which cannot be obtained from other energy sources.

The principal deterrents to the use of at least some SE technologies are the lack of the industrial base and the resulting high initial cost of the systems; this cost problem is increased by the need for supplemental energy of conventional types in most parts of the U.S. For these technologies, though, the projections are sufficiently promising that there is every reason to stimulate not only further development but also the necessary commercialization. As was recommended for new energy sources generally, governments should "...act as a catalyst and provide a climate for the private sector to achieve the required goals..." [Ref. 15, p. 2]. There are many precedents for such actions and a wide variety of steps are being considered by federal, state, and local governments to create this climate, e.g., tax incentives of several kinds, interest rate adjustments, zoning and planning actions, and the use of SE in public buildings. The major benefit that results just from the demand growth that can be stimulated by such steps is demonstrated in Fig. 2 for the case of SPCS.

The time scale in which SE can be expected to contribute appreciably to the nation's energy needs has been projected rather cautiously in the ERDA national solar energy plan[4] as shown in Table I. By 1985, with only a normal pace of development, replacement of ~ 10^{18} J/yr (10^{15} Btu/yr) of fuel use is expected, an amount of that would require about 40 full-sized (1000 MW) breeder reactors to match. By the year 2000 this grows to ~ 10^{19} J, which will be ~ 7% of all energy used; beyond that the replacement of other sources by SE continues further. The plan also asserts that an accelerated effort could provide "significantly higher levels" of replacement energy.

This prospect of substantial amounts of energy production in as short a time as 10 years is clearly a consequence of the fact that several of the solar technologies are available and nearly ready for widespread exploitation. Their successful application requires only a sufficient commitment to complete their development and reduce their costs. Nevertheless, the ERDA budget request for FY 1977 calls for funding increases for solar energy at a rate no larger than the average of all energy R&D programs, only one of several signs of a rather hesitant attitude to this field. There seems little doubt that American industries, universities, and laboratories could usefully apply a good deal more than the $116 million requested.

There is reason to expect solar R&D budgets to rise in the future. But the enormous promise that solar energy offers — to augment our energy supply, to reduce our dependence on imported fuel, to reinvigorate our economy, to rehabilitate our environment—calls for something qualitatively different. These factors add up to a unique capability of solar energy that warrants a national commitment, in both policy and funding, to make the utilization of solar energy our highest priority energy development goal.

Table I — Projected solar energy utilization based on normal development rates of the various technologies [Ref. 4, p. I-4]).

	Year 1985	2000	2020
Direct Thermal Applications			
Heating and cooling	0.15 Q*	2.0 Q	15 Q
Agricultural applications	0.03	0.6	3
Industrial applications (process heat)	0.02	0.4	2
Total	0.2 Q	3 Q	20 Q
Fuels From Biomass	0.5 Q	3 Q	10 Q
Solar Electrical Capacity			
Solar thermal	0.05 GWe	20 GWe	70 GWe
Photovoltaic	0.1	30	80
Wind	1.0	20	60
Ocean thermal	0.1	10	40
Total electric capability	1.3 GWe	80 GWe	250 GWe
Equivalent fuel energy	0.07 Q	5 Q	15 Q
Overall Energy Equivalent	~ 1 Q	~10 Q	~45 Q
Total Projected U.S. Energy Demand	100 Q	150 Q	180 Q

*Q = quads = 10^{15} Btu/yr.

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The XL-100 ColorTrak system

L.A. Cochran

This article describes some of the design philosophies which resulted in RCA's second generation XL-100 color television receiver—ColorTrak. Unique features, performance improvements, and kinescope developments are discussed and the new direct-address remote-control system is described.

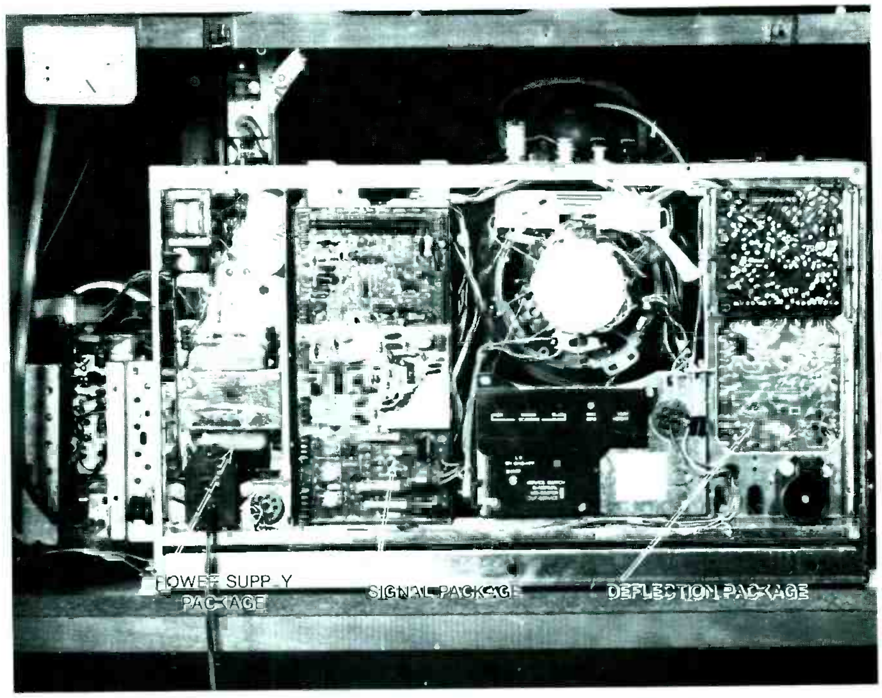

Fig. 1a — CTC-81 ColorTrak instrument with chassis in upright position.

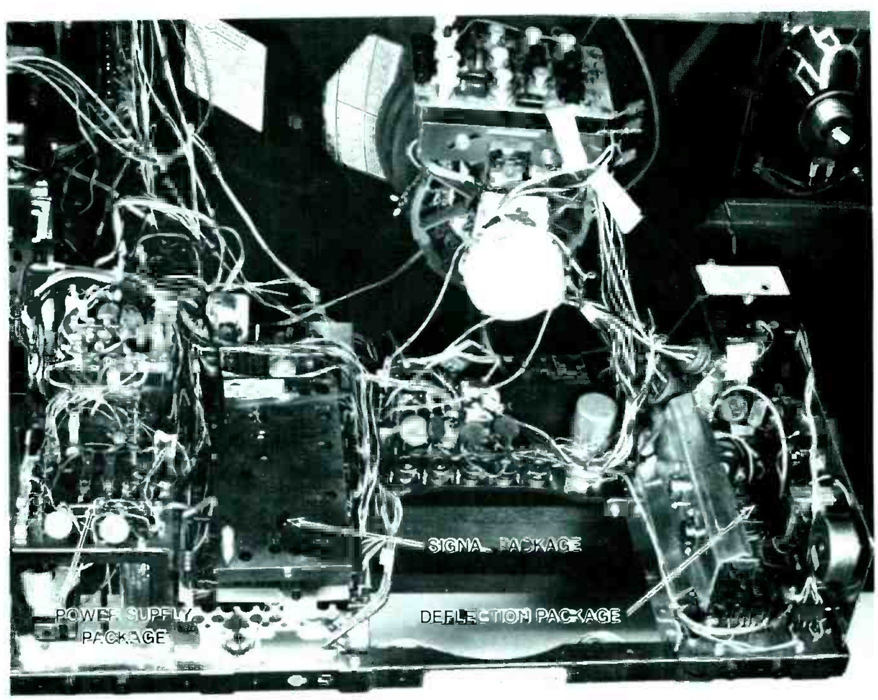

Fig. 1b — CTC—81 ColorTrak Instrument with chassis in service position.

Larry A. Cochran, Color TV Product Development, Consumer Electronics, Indianapolis, Ind., joined RCA as a summer employee in June 1962. He received the BSEE in January 1963 and the MSEE in June of 1968 from Purdue University. Since joining RCA, Mr. Cochran has worked in many areas of signal processing as a member of the color television product design group. He has been responsible for the design and development of new color synchronizing circuits, demodulation systems, and many other aspects of color signal processing. From 1968 to 1971, Mr. Cochran was associated with the utilization of silicon integrated circuit technology in the design of chroma processing circuitry. From 1971 to 1973, he was a leader in the advanced product development section of color television engineering. From 1973 to 1976, he was a senior member of the engineering staff, responsible for the design and coordination of new signal processing circuits. He is currently a project engineer responsible for new color tv product development. Mr. Cochran is a registered professional engineer, and a member of Eta Kappa Nu and Tau Beta Pi. He has five issued patents plus patents pending.

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In August of 1975, RCA introduced a new color television system called ColorTrak—the culmination of a concentrated design effort by several RCA divisions to produce a new-generation color television receiver that would be adopted as the performance standard of the industry. The XL-100 trademark was maintained since it had been instrumental in identifying RCA television receivers with solid-state reliability. The modular concept (which began with RCA's CTC-49 chassis, see *RCA Engineer*, Vol. 21, No. 1) was continued, but with a new generation of modules which reflected performance improvements in many areas. To facilitate manufacturing and testing, the receiver was subdivided into four functional groups: a power supply package, a deflection package, a signal package, and a tuning system (see Fig. 1).

Another design goal was to provide the consumer with a television receiver that would require a minimal amount of adjustment to maintain a high quality picture. The trademark ColorTrak was chosen since it seemed to best typify this design goal.

Kinescope developments

One of the integral parts of the ColorTrak system is the super accufilter picture tube which is an improved version of RCA's accucolor black-matrix picture tube. This new picture tube is characterized by the addition of a light-absorbing material to the tube's red and blue phosphors. Standard red and blue phosphors reflect a portion of the incident visible light of all wavelengths which causes the face of the picture tube to exhibit a grayish characteristic that limits the black-to-white contrast of the reproduced picture. This is due to the fact that the blacks can be no blacker than the unlit face of the tube. In the accufilter picture tube, the red and blue phosphors are selectively pigmented so that they absorb the incident light of most wavelenghts. This absorbing action results in approximately 25% less reflected light from the face of the picture tube, allowing black areas of the reproduced picture to remain blacker and colors to appear more saturated under high ambient-lighting conditions.

Color-contrast tracking

There are several new features in the ColorTrak system which are made possible due to a new RCA-developed low-level-luminance monolithic integrated circuit. These features are part of the automatic color-contrast tracking function of the ColorTrak system.

Blanking-level clamp

The TA6712 video processor integrated circuit contains circuitry that clamps to the blanking level of the transmitted television signal. Since the only blanking-level reference in the signal is the front and back porch of the horizontal retrace interval, some means had to be provided for recognizing this clamp level. This was achieved by recognizing that blanking level is the most negative part of the signal except for horizontal and vertical synchronizing pulses (see Fig. 2b). A sync-inhibit cirucit (Fig. 2a) was added to the clamp so that the synchronizing pulses would be ignored. The video signal is coupled to the base of Q2 via coupling capacitor C1. The most negative protion of the video signal would normally clamp to the base bias voltage of Q2; however, due to the saturation of Q1 during sync time, the clamp is inhibited. Since capacitor C1 cannot change its charge instantly, the clamp sees only the blanking level. Through the use of this circuit, the ColorTrak system is able to maintain 100% dc gain with no effects on the brightness of the picture due to variations in the transmitted sync height.

Contrast control

The contrast circuit consists of two voltage-controlled attenuators, a contrast buffer transistor, and a light-dependent resistor (Fig. 3). The two voltage-controlled attenuators control the luminance and chrominance gain of the receiver and have identical attenuation characteristics. As the voltage at the wiper of contrast control R1 is varied, the luminance and chrominance gain are varied simultaneously. Since the polarity of control voltage is such that increasing control voltage produces decreasing contrast, a light-dependent resistor can be implemented as shown in Fig. 3 to automatically increase the contrast and color of the picture as the ambient lighting increases. The color control R3 is used to match the chroma saturation to the luminance drive and is normally not used after the initial set-up. Since the brightness control has been set to produce the correct blacks in the picture, the only remaining adjustment which needs to be made is contrast. Once these three adjustments are made, the contrast of the picture is automatically maintained under a wide variety of ambient lighting conditions.

Auto-color (A/C)

Another important part of the ColorTrak

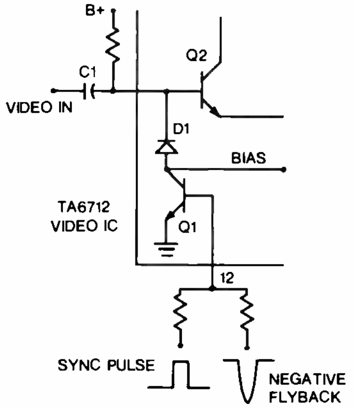

Fig. 2a.

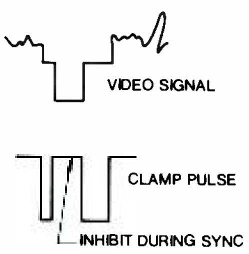

Fig. 2b.

Fig. 2 — Blanking-level clamp.

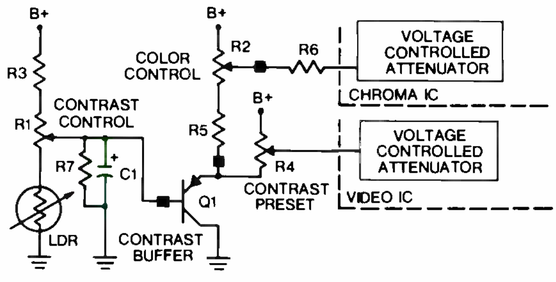

Fig. 3 — Contrast circuit and light-dependent-resistor.

system is the A/C (auto-color) function which consists of an overload detector and a dynamic fleshtone correction circuit. These circuits minimize changes in saturation and hue of the reproduced picture that are caused by varying broadcast conditions.

Overload detector

Most television receivers, including ColorTrak, use the amplitude of the color burst signal, which is transmitted on each horizontal line during the blanking interval, as a reference for maintaining correct color saturation. This is the conventional automatic color control (ACC) approach. This type of ACC system is predicated upon the fact that the amplitude of the transmitted burst signal always remains at a correct level relative to the chrominance information. This is not always the case since the burst information is frequently removed and later reinserted at an incorrect level prior to transmission. The ACC circuits in the receiver will then respond to this incorrect burst level and cause the saturation of the picture to be wrong. The ColorTrak system utilizes an overload detector for correction of gross oversaturations due to incorrect transmitted burst levels.

The overload-detector circuit (Fig. 4) operates as follows: The chroma signal is coupled from the emitter of Q5 to the base of the overload transistor Q6 whose base is biased to a predetermined point below conduction. When the chroma signal is added to the bias voltage, the peaks of the signal cause Q6 to conduct and remove charge on capacitor C2 that has resulted from B+ divider R8 and R9. The decreased voltage on C2 is translated via Q9 to the base of Q8 which is the current source for the second chroma amplifier. The gain of the second chroma amplifier is then reduced in proportion to the amount chroma peaks which extend above the threshold. If desired, the threshold bias of Q6 can be decreased externally by the A/C switch on the front of the receiver to override this function.

Dynamic fleshtone correction

Most color television receivers on the market today provide some type of fleshtone error correction. Fleshtone errors usually result from a static phase distortion of the color burst signal at some point in the transmission system. Since the hue (tint) of the reproduced picture is directly related to the phase of the color burst signal, these phase distortions cause fleshtones to have either a green or purple contamination. The effects on the receiver of these type transmission distortions can be minimized by choosing the decoding gains and angles of the receiver appropriately; however, the fidelity of the reproduced picture is compromised.

The ColorTrak system uses a unique RCA-developed integrated circuit which provides correction for fleshtone errors without greatly compromising the fidelity of the reproduced picture. Since this feature has been incorporated into the design of the new TA6606 demodulator integrated circuit, very little cost has been added to the receiver. A block diagram of the dynamic fleshtone correction circuit is shown in Fig. 5. The bold lines indicate normal decoding functions. The "two-phase modulated" chroma signal is fed in parallel to two balanced demodulators which are each referenced to a subcarrier signal that has been phase locked to the transmitted burst signal. The two subcarrier signals are in quadrature with each other so that one demodulator detects a maximum when the other demodulator has zero output. The detected *I* and *Q* signals are then passed through a linear matrix in order to produce three color-difference signals suitable for driving the kinescope driver circuits.

The correction portion of the circuit operates as follows: The chroma signal is passed through a limiter to remove amplitude modulation and is then coupled to a phase detector which is centered about the *I* (fleshtone) axis. A detected signal, which has a maximum when the chroma signal has a phase corresponding to fleshtones, is now coupled to an offset modulator (gate). A portion of the limited chroma signal, as determined by the signal from the phase detector, passes through this modulator. This selected portion of the limited chroma signal is then added to the subcarrier reference prior to demodulation of the chroma signal.

A plot of the corrected subcarrier as function of the phase of the chroma signal is shown in Fig. 6. When the phase of the incoming chroma signal is coincident with the *I* axis, the correction vector is exactly in phase with the uncorrected

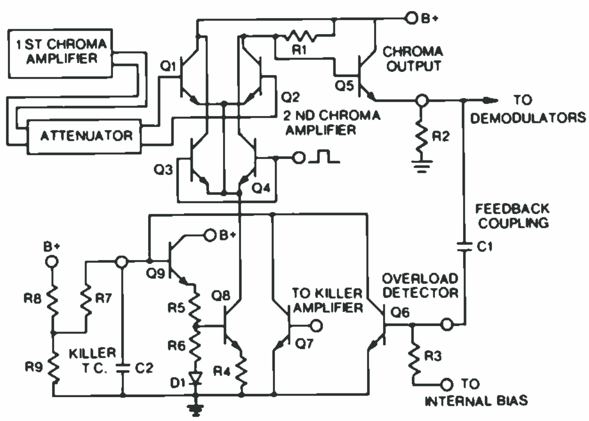

Fig. 4 — Chroma output stage.

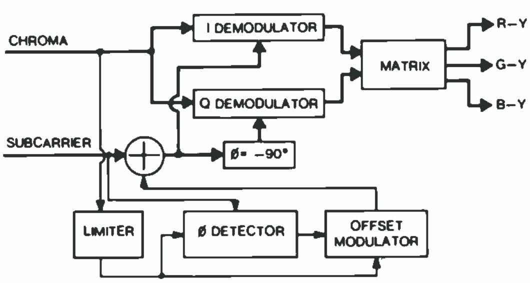

Fig. 5 — Dynamic fleshtone block diagram.

subcarrier. Since the two signals are added vectorially, no resultant change occurs in the demodulated chroma signal. As the phase of the incoming chroma signal varies from the *I* axis, a correction vector which tracks the chroma signal is produced and added to the uncorrected subcarrier. The effect of this correction is to desensitize the receiver to variations in subcarrier phase which occur about the positive *I* (fleshtone) axis without causing colorimetric distortions to colors about the negative *I* axis.

Circuit performance improvements

Several other areas of circuit performance have been improved in the ColorTrak system. None of these items can be focused upon individually as a major contributor to system improvement; however, when taken as a group they add significantly to the overall performance of ColorTrak receivers.

Transversal filter peaking

To enhance picture sharpness, it is desirable to design television receivers with some amount of preshoot and overshoot in the luminance channel. It is also desirable to have this preshoot and overshoot externally controllable to provide the best reproduced picture under a variety of signal conditions. Most receivers achieve this flexibility with video processing circuitry that has a fixed amount of preshoot and a controllable amount of overshoot. The ColorTrak system uses a unique tapped-delay-line transversal filter circuit for enhancing picture sharpness (see Fig. 7). A standard luminance delay line with a linear phase characteristic is tapped at three points such that signals *A*, *B*, and *C* are produced with the time relationships shown in Figs. 7a, 7b, and 7c. With the appropriate additions and subtractions, a peaking component shown in Fig. 7d can be produced and a controllable amount of this peaking component can then be added to the low-frequency component *B* to produce enhanced picture sharpness. The additions and subtractions necessary for achieving the transversal filter peaking are performed in a luminance integrated circuit. A block diagram of the circuit and resulting frequency responses in shown in Fig. 8. By using diodes D1

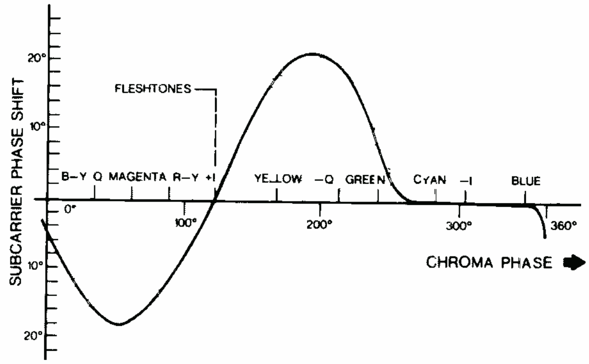

Fig. 6 — Subcarrier phase shift.

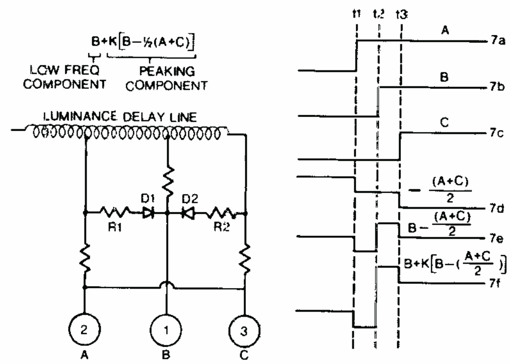

Fig. 7 — Luminance delay line.

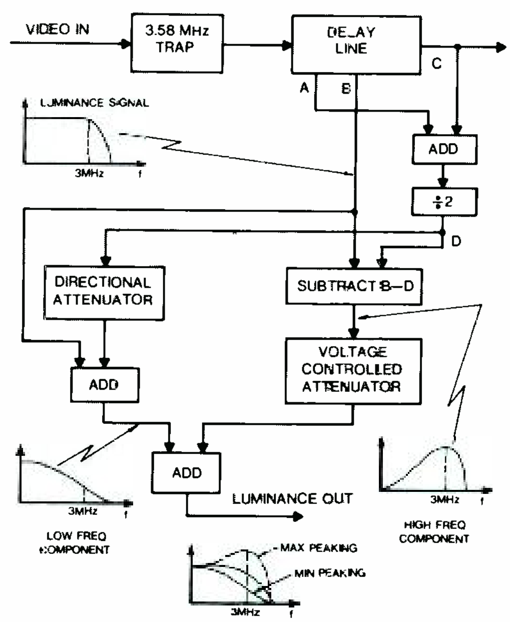

Fig. 8 — Transversal filter peaking.

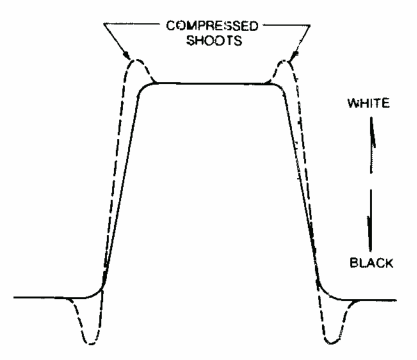

Fig. 9 — Transversal filter peaking.

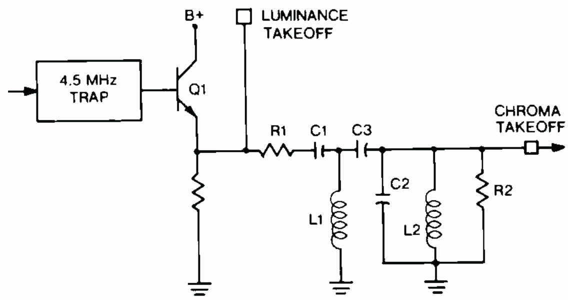

Fig. 10 — CTC74/81 chroma-peaker circuit.

and D2 shown in Fig. 7, the peaking can be compressed in the white direction to prevent spot blooming of the kinescope while still maintaining an enhanced risetime of transitions. Fig. 9 shows the idealized effects of the peaking on a video transition.

Resolution improvements

Both the luminance and chrominance resolution have been improved in the ColorTrak system. The increase in luminance resolution has resulted partially from improvements in the low-level processing circuitry and, to an even greater extent, from improvements in the kinescope-driver circuitry. Series-shunt peaking has been utilized in each of the three driver stages to help compensate for frequency response roll-off due to kinescope capacitance. In addition, the design of a new kinescope socket has allowed resistance in series with the kinescope cathodes, normally needed for protection against kinescope arcs, to be lowered and thus achieve further improvements in resolution.

Chrominance resolution has been improved through the use of a new double-tuned chroma peaker circuit shown in Fig. 10. This circuit, which is needed for compensating the frquency response roll-off of the i.f. in the chroma passband, provides a symmetrical frequency response about the color subcarrier with a 3-dB bandwidth of 500 kHz.

Signal-to-noise improvements

All XL-100 and XL-100 ColorTrak models now utilize new tuners which have MOSFET rf amplifiers and mixers. This complete MOSFET front end allows AGC voltage to the rf stage to be delayed longer for an improved signal-to-noise ratio (S/N) without causing mixer overload that would normally result in cross modulation. Current ColorTrak models also utilize a newly developed MOSFET i.f., system which gives further improvements in system S/N.

Optimized colorimetry

All XL-100 and XL-100 ColorTrak receivers are set up to produce a white of D 6500 (color temperature of 6550 K + 7MPCD) which matches NTSC standards. [The color temperature of a light source refers to the temperature, in degrees Kelvin, at which a black body would have to be heated to match most nearly the color of the light source; an MPCD is a unit representing mean-perceptible color difference. See Ref. 4 for further information on television colorimetry.]

The ColorTrak system also utilizes new color decoding gains and angles that have been chosen to compliment the white reference of D 6500. In addition to providing more nearly correct reproduced colors, these new decoding angles result in a subjective improvement in S/N due to improved constant luminance performance.

Tuning systems and displays

Every ColorTrak chassis contains the features and performance improvements discussed above—the only exceptions being the type of display and tuning system used. The top-of-the-line ColorTrak receivers use a unique remote-control system that features on-screen display of the selected channel number and the time of day. In addition, the customer selects channels by addressing the system with the channel number desired, thereby eliminating the necessity of the customer having to sequence through a series of undesired channels. This system is referred to as the direct-address system. The customer addresses the system via an ultrasonic transmitter called the "XL-100 Control Center." The Control Center is the only means of

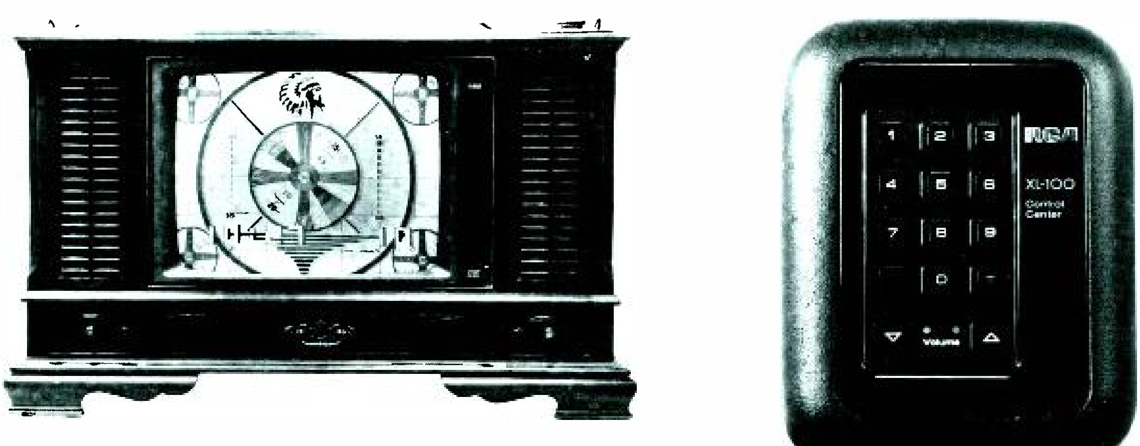

Fig. 11 — ColorTrak direct-address package: Remote instrument (right) and control center (above).

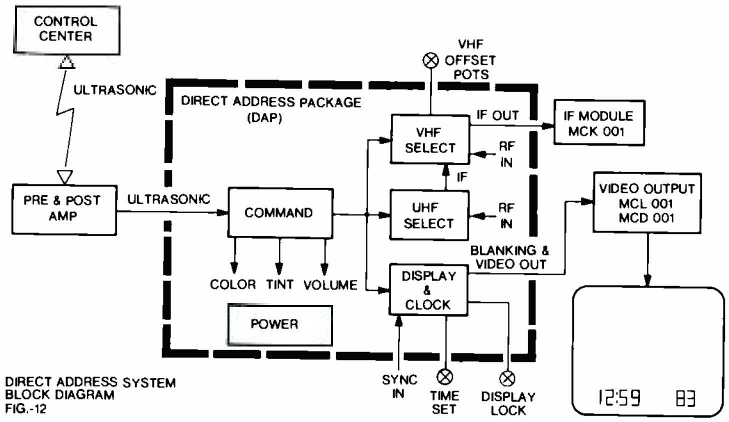

Fig. 12 — Direct address system block diagram.

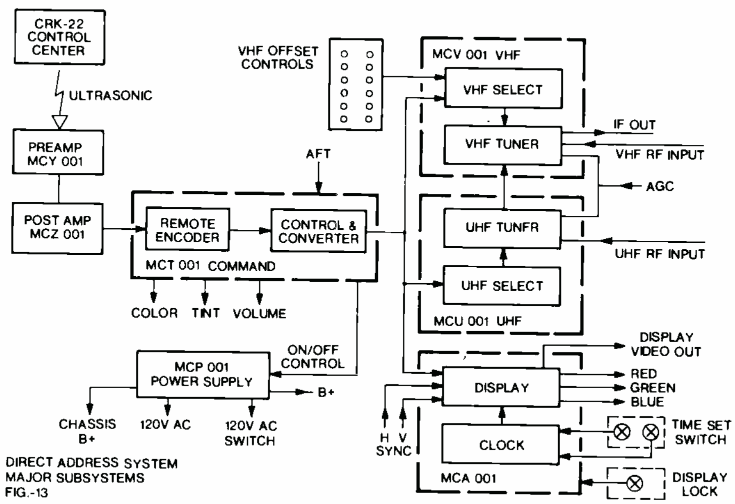

Fig. 13 — Direct address system major subsystems.

instrument control available to the customer (see Fig. 11).

An in-depth description of the direct-address system is beyond the scope of this article; however, a brief discussion is warranted for the sake of completeness. The system has seven RCA custom-designed large-scale-integrated circuits. Block diagrams of the system are shown in Figs. 12 and 13. The ultrasonic signal, after passing through a preamp and postamp, is applied to a command module which converts the fourteen possible ultrasonic frequencies into digital codes which control the functions desired: on/off, channel select, volume, color, and tint. The same digital codes are applied to the display module which converts the channel-number codes into video information to be displayed on the kinescope. The display module also contains an electronic clock which supplies time-of-day information for display on the kinescope. The channel-select digital codes from the command module are applied to the vhf and uhf tuning modules for selecting the appropriate analog voltage for varactor-tuner operation.

Safety and reliability

The areas of safety and reliability in television receiver design are assuming a role of ever-increasing importance due to warranty programs, government regulations, and foreign competition. The consumer electronics safety and reliability center, dedicated in 1973, has helped RCA meet these new challenges. Current ColorTrak television receiver are more reliable than their predecessors at comparable times on their reliability learning curves. This has been achieved 1) by eliminating components that have exhibited lower reliability, 2) by earlier reliability testing in the product development cycle, 3) by improved failure analysis and reliability predictions, and 4) by instituting more rigid testing and evaluation of components construction. RCA has always been committed to the safety of its consumer products. Periodic reviews to prevent potential fire, shock, and X-ray hazards are a normal part of every new product development schedule. Safety-critical components are reviewed on a regular basis in order to check compliance with design specifications.

Combined effort

The XL-100 ColorTrak system has resulted from an interdivisional design effort within RCA. Significant contributions to the system have been made by not only the Consumer Electronics Division, but also the Solid State Division, the Picture Tube Division, and the RCA Laboratories. Through a joint effort of CE and SSD, the custom-designed large-scale-integrated circuits for the direct-address system were designed and manufactured in an unparalled period of time. The Picture Tube Division contributed the new high-contrast "filtered phosphor" kinescope in both the standard 25-inch delta-gun construction and in a new 19-inch precision-in-line (PIL) construction. Efforts from the RCA Laboratories have resulted in video processing improvements (transversal filter) and higher fidelity color reproduction.

Conclusion

Throughout this article the word *system* has predominated. ColorTrak is a system. No one item can be pinpointed as identifying ColorTrak. It is the combination of a variety of features and performance improvements which have resulted in a color television receiver that exhibits exceptional performance with minimum customer adjustments.

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An overview of the small shf satellite ground terminal development program

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The Small SHF Satellite Ground Terminal Development Program* was contracted to RCA in December, 1972 by the U.S. Army Satellite Communications Agency (USASATCOMA)—an agency under the Army Materiel Command. The program was for development of a new family of tactical and strategic satellite communications systems. To date, the development program has been completed and the basic terminals are currently undergoing service test evaluation. After evaluation is completed, terminals will be procured to fulfill the requirements of ground mobile forces and strategic users.

THE SMALL SHF Satellite Ground Communications Terminal Development Program consists of a new family of TACSATCOM terminals for tactical and strategic satellite communication systems. These quick-reaction terminals provide nodal and non-nodal full-duplex multichannel voice communication links and consist of three tactical terminals—AN/MSC-59, AN/TSC-85 V1, AN/TSC-85 V2— and one strategic terminal—the AN/TSC-86. These highly mobile terminals provide a high degree of communication availability at high performance.

All terminals meet the full spectrum of military environmental specifications when deployed in an operational environment. The tactical terminals are configured from common unitized designs which may be regrouped to form communication terminals other than those currently planned. The strategic terminal is somewhat more sophisticated than the tactical terminal in terms of frequency selection, satellite signal tracking, and output power.

DSCS system concept

The small shf satellite ground terminal family of equipments will be used over the next five- to ten-year period, fulfilling both strategic and tactical requirements. These terminals will be utilizing the DSCS II and future satellite transponders for terminal-to-terminal communication links. Initially, multiple-access techniques such as frequency-division multiple access (FDMA) or spread-spectrum multiple access (SSMA) will be used. Time-division multiple access (TDMA) may be employed at a future time.

FDMA is currently the most actively employed accessing technique in which the satellite rf channel bandwidth is divided into a number of non-overlapping frequency slots (contiguous channels) which determine the number of satellite accesses.

These channels are then used to pass any

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type of angle modulation such as fm, pm, frequency-shift keying (fsk) and phase-shift keying (psk).

In spread-spectrum multiple access (SSMA), each of the accessing signals are spread over a wide portion of the transponder bandwidth either through direct modulation, referred to as pseudo noise, or through frequency-shift keying, referred to as frequency hopping. The particular pattern of the band spreading is determined by the code generator of the transmitted signal and may be demodulated by a synchronized code generator in the receiving station (this technique is also called code-division multiple access). Time-division multiple access (TDMA) is a high performance accessing technique where only one carrier is present in the transponder at any one time and utilizes the full bandwidth capacity of the satellite. Multiple access is accomplished in a time-gating manner where each access transmits at a specified time slot non-overlapping with other transmissions. Thus, a common frequency may be used for all accessing links.

To accommodate various defense communication modes, satellite communications will use a mixture of these access techniques in the near future.

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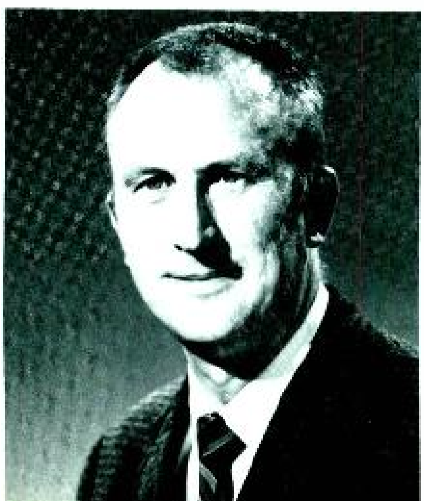


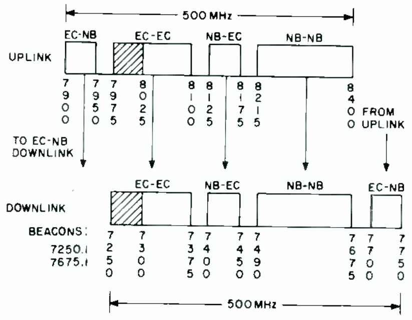


Fig. 1 — DSCS phase II satellite frequency translation plan.

Communication evolution of defense satellite communications system

Currently the Defense Satellite Communications Systems (DSCS) are evolving through several stages or periods of communication capabilities.[1] This evolution will see the transition from: 1) all-analog equipment to, 2) a combination analog/digital (hybrid) approach, and 3) all-digital equipment. The transition to all-digital equipment should take place approximately in the 1980 time frame when introduction of TDMA equipment initiates stage II of the DSCS II program.

Near-term spacecraft system —DSCS II satellite

The satellite transponder assigned for near-term use during phase II of DSCS will be multichannel DSCS II satellite which provides four basic modes of operation:

Earth coverage to earth coverage (EC-EC)
Earth coverage to narrow beam (EC-NB),
Narrow beam to earth coverage (NB-EC),
Narrow beam to narrow beam (NB-NB).

The repeater is basically a single conversion device which may be operated in linear, quasi-linear, or hard-limiting modes and will be positioned in equatorial geostationary synchronous orbit.

The transponder operates in the 7900 to 8400-MHz uplink band and translates the uplink signals to the down-link frequency band of 7250 to 7750 MHz.

Fig. 1 shows the frequency plan of the repeater channels which have 1-dB bandwidths of 125 MHz for EC-EC, 185 MHz for NB-NB, and 50 MHz each for the EC-NB and NB-EC channels. Exclusive bands (50 MHz) are contained in the uplink and downlink frequency bands. These exclusive bands are used only for satellite communications between fixed earth stations as defined by the International Telecommunications Union (ITU). Mobile/transportable users are assigned channel allocations in the remaining portions of the frequency bands depending upon their geographical location with respect to the satellite coverage.

Tactical system concept

Satellite communications for ground mobile forces in the near future will employ the narrow-beam repeater of the DSCS II satellite transponder and, in general, will be configured in networks extending from Army Headquarters down through Corps and Division, to Brigade level.

This multichannel earth terminal network represents the major user of the satellite transponder along with some independent pairs of terminals which will provide special service. In addition, some percentage of the repeater capacity will be filled by other users.

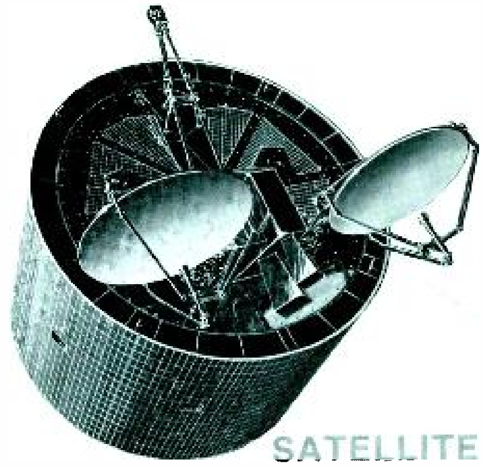
The communications network consists of both nodal (multipoint) and non-nodal (point-to-point) satellite communications links. The multiple satellite links are separated via frequency division multiple access (FDMA) in the transponder.

Each tactical earth terminal employs phase-shift keying (PSK) as its modulation method sending multichannel PCM data using currently standard PCM equipment. In general, most other users will be passing digital data employing PSK modulation; however, fm may be employed where FDMA is the accessing method.

With multiple earth terminals accessing the satellite repeater, certain disciplines must be maintained so that each user has satisfactory communications. To assure that the various users are remaining in their set disciplines, a Network Control Terminal (NCT) is employed to monitor the repeater output frequencies and power levels (down-link) for each signal

Transmits 1
Receives 2, 3, 4

NODAL or MULTIPOINT TERMINAL



SATELLITE REPEATER

access. With this data, in conjunction with individual earth terminal status and link performance from the user network, the network control terminal maintains the system power balance and repeater operating point through communications to each network terminal. Inherent in this control is 1) the frequency plan for accessing the satellite, 2) control of the total system uplink power, and 3) balance of signal powers among the various network terminals in the system.

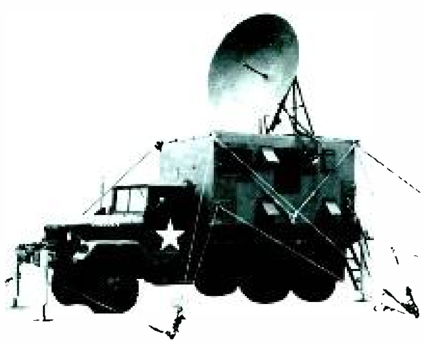
As part of the current development program, RCA has designed a Control Terminal, the AN/TSQ-118, which monitors and controls the communications through the satellite. This terminal will accompany the tactical terminals during the service test phase.

In general, it will be desirable to operate the satellite repeater below saturation to avoid intermodulation products which degrade the various link performances depending upon the frequency spacing (frequency plan) of the accesses.[2] Satisfactory link performance for the tactical earth terminals is determined by the bit-error rate (BER) of each of the links since digital data is being transmitted. PCM modes of communications require minimum link BER figures of 1×10^{-5} while secure voice modes require 1×10^{-3} BER.

As indicated, the tactical network represents a combination of nodal and non-nodal network terminal groups. A specific example (Fig. 2) is sufficient to detail the basic operations in a multipoint link arrangement.

Considering the case where a nodal (multipoint) terminal is linked from one to four non-nodal network terminals, the nodal terminal is co-located with, or remotely located from, a multiplexer/-demultiplexer van where standard inventory PCM equipment is utilized to provide four PCM data stream groups to the nodal terminal for transmission via satellite links to the distant non-nodal terminals. The nodal net terminal contains a tactical satellite signal processor which combines the one to four group data streams from the mux van into a single super-group data stream which is then modulated on a *single carrier frequency* via PSK modulation.

Each of the four data streams represents a data group for each of the distant non-nodal terminals. Each non-nodal terminal demodulates the entire super-group data stream, (which consists of the one to four data groups) and, via a demultiplexer, selects the proper group intended for that non-nodal terminal. Each of the non-nodal terminals transmits its respective group data on independent carrier frequencies which are received by the nodal terminal. The nodal terminal demodulates each of the four group data streams separately and, via appropriate signal conditioning sends each of the data groups to the mux-/demux van completing the communications links.



Transmits and receives strategic communications

Tactical terminal modulation technique and performance

Each of the three tactical net terminal types contains common binary PSK modems for transmitting and receiving high-speed PCM data using standard-inventory PCM equipment and newly-developed tactical satellite signal processing equipment. The modulation/coding technique chosen for the system consists of differential-encoded phase-shift keying (DEPSK) in conjunction with convolutional coding and Viterbi decoding.

The coding consists of a rate ½, constraint length $K = 7$, convolutional code used with maximum likelihood Viterbi decoding which provides a coding gain of approximately 5 dB at BER of 10^{-5} and 3.9 dB at BER of 10^{-3}.

This approach provides a terminal which yields a high communication performance in terms of link BER.

The common binary PSK modems also permit uncoded operation where system performance is within 1.5 dB of theoretical performance or for BER of 10^{-5} at $E_b/N_o = 11.4$ dB. Fig. 3 shows system BER performance for both coded and uncoded modes of operation.

Transmits 2
Receives 1

Transmits 3
Receives 1

Transmits 4
Receives 1

NON-NODAL TERMINALS

The tactical terminals also permit ultimate inclusion of other types of PSK modulation, such as QPSK or offset-keyed QPSK modems which will eventually be employed in satellite communications.

Light transportable terminal (AN/TSC-86) concept

The light transportable terminal—the 2½ ton AN/TSC-86—fulfills the contingency and quick-restoral requirements needed by the strategic users in the Defense Communications Systems.

The AN/TSC-86 terminal provides the strategic users with the following prime missions:

- Quick reaction contingency,
- DCS extension and restoral,
- Scientific mission support, and
- Disaster relief effort support.

In these missions, a short deployment of the AN/TSC-86 is made in an area where communications are not readily available. Communications by the terminal is made to the larger terminals in the DCS operating in the satellite EC-EC channel. Communications are effected via teletype and digitized voice. In cases where extended communications are needed, additional capacity is achieved through deployment of additional equipments accessing the narrow beam of the transponder and by utilization of larger ground-mounted antennas.

The AN/TSC-86 will also be used in other applications such as: diplomatic support, survivable network, special users, and intra-area trunking.

AN/TSC-86 terminal modulation technique

As currently developed, the AN/TSC-86 terminal does not contain modulation and demodulation equipment; however, the interfaces permit standard modems to be readily incorporated with available rack space. The current interfaces exist at 70 MHz on the transmit and receive sides of the terminal. The terminal is capable of multi-carrier operation on both the transmit and receive side with up to four independent carrier signals.

Various modulation/demodulation equipments will be employed or developed for the AN/TSC-86 to meet the particular needs of the DSC and other users as the evolution of Phase II proceeds into the 1980 time frame.

Small terminal family

The small shf satellite ground terminal family of equipments consists of four radio terminals—AN/MSC-59, AN/TSC-85 V1, AN/TSC-85 V2, and AN/TSC-86. All terminals transmit in the 7.9- to 8.4-GHz band and receive in the 7.25- to 7.75-GHz band, each including automatic tracking 8-foot diameter antennas mounted as an integral part of the equipment enclosure.

AN/MSC-59

The AN/MSC-59 is the smallest and lightest terminal of the small shf satellite terminal family and is intended for non-nodal or point-to-point operation in tactical trunking systems. The complete terminal is mounted across the rear portion of a modified M-569 trailer (palletized transit frame) with the overall trailer frame structure used as support for an "on-mounted" antenna when the terminal is deployed in the operating mode.

The terminal is normally towed by a modified jeep (M-151) containing a palletized redundant 3-kW engine/generator configuration which may be removed from the jeep after the operational site is reached. A ground connection system consisting of tie-downs, anchors and jacks is used to maintain antenna pointing on the satellite during various wind-loading conditions. Deployment of the terminal normally requires 20 minutes.

This low power terminal includes a 100-W TWT power amplifier, a low noise parametric amplifier providing a maximum system noise temperature of 300° K, and up/down converters tunable in 1-MHz increments across the band.

AN/TSC-85 V1

The AN/TSC-85 V1 is a redundant (except antenna and tactical satellite signal processor) point-to-point (non-nodal) terminal capable of transmission and reception of high capacity multiplexed voice and data. The electronic equipment is housed within a S-250 shelter for transport and operation and is normally mounted in a 1¼ ton truck. The shelter proper is utilized as a mounting and stablizing platform for the antenna when the terminal is deployed. A ground connection system of tie-downs, anchors and jacks is deployed to maintain antenna pointing on the satellite during various wind-loading conditions (as in the AN/MSC-59). The antenna system is identical to the AN/MSC-59 except for the method of mounting which allows orienting the antenna independently of the vehicle. A companion M-101 trailer is used as an integral part of the terminal and serves as a mobile platform for stowage, transport, and operation of power-generator equipment. Deployment time for this terminal is also 20 minutes as for the AN/SC-59 terminal.

ment. Deployment time for this terminal is also 20 minutes as for the AN/MSC-59 terminal.

The AN/TSC-85 V1 terminal provides 500 W transmitter power using a klystron tube, employs low noise parametric amplifiers, and is completely redundant with exception of the antenna system. All modules and assemblies of this terminal are directly interchangeable with those used in the AN/MSC-59 with the exception of the power amplifier.

AN/TSC-85 V2

The AN/TSC-85 V2 is a multipoint (nodal) terminal capable of transmission of a single multiplexed high-data-rate carrier and reception of up to four low-data-rate carriers. Physically, the terminal appears identical to the V1 configuration in exterior appearance and the companion M-101 trailer is essentially identical to that of the V1 terminal.

The AN/TSC-85 V2 terminal is a multipoint version of the AN/TSC-85 V1 and includes three additional down converters and modems, and uses a full 500-MHz bandwidth preselector. This allows simultaneous communications with up to four other terminals.

AN/TSC-86 strategic terminal

The AN/TSC-86, similar to the AN/TSC-85 V1 and V2 terminals, is a fully redundant (except antenna) terminal intended for use in trunking systems. This terminal fulfills the so-called light transportable, or contingency, terminal requirement for strategic users in the DCS. The terminal is contained in a standard S-280 shelter and transported on a 2½ ton truck. Associated power generating equipment (redundant 30-kW diesel-engine generators) is transported on the M-353 trailer. As in the ANTSC-85 terminals, the common antenna is mounted directly on the S-280 shelter in the deployed state. A ground connection system of tie-downs, anchors, and jacks is employed to maintain antenna pointing on the satellite during various wind conditions. The basic units of the AN/TSC-86 are not common to its counterpart tactical terminals, being somewhat more complex and sophisticated.

Table I — Various data rates consisting of standard tactical pcm 48-kb/s channels (designated PCM) and processed rates (designated TSSP). Performance requirements are presented in terms of *C/KT* providing traffic links at 10^{-5} BER using coded operation. Uncoded operation requires a 5.0-dB increase in *C/KT* to achieve 10^{-5} BER performance. During traffic operation, the on-line orderwire may be employed with little degradation to the traffic channels.

Channels/ carrier	*Signal description*	*Data rate (kb/s)*	*Coded C/KT biphase @ BER = 10^{-5}*
6	PCM	288.0	61.0
12	PCM	576.0	64.0
24	PCM	1152.0	67.0
18	TSSP	921.6	66.1
24	TSSP	1228.8	67.3
36	TSSP	1843.2	69.1
48	TSSP	2457.6	70.3
72	TSSP	3686.4	72.1
96	TSSP	4915.2	73.3

The AN/TSC-86 contained in an S-280 shelter is the largest and most sophisticated of the terminals. It includes a 1000-W klystron power amplifier, is fully redundant with exception of the antenna system, and can be tuned to transmit or receive across the respective bands in 1-kHz increments. Further, a beacon receiver is included for antenna tracking signals, whereas the small terminals derive their tracking signals from the communications channel itself.

Transmission modes — tactical terminals

Three basic transmission modes are provided in the tactical terminal group: 1) orderwire (off-line and on-line), 2) secure voice, and 3) traffic.

The off-line orderwire mode is used initially to acquire the satellite and communicate with a distant net terminal in setting up a traffic link. In this mode, analog fm is impressed on the transmit modem carrier (70 MHz) and detected via the carrier extraction circuitry in the receive modem. In conjunction with orderwire circuitry containing appropriate signal processing, a test-tone-to-noise ratio of 14 dB is obtained with a *C/KT* of 47.5 dB.

In the secure-voice mode, all other modes are inhibited permitting transmission and reception of single channel 16.0 kb/s digitized voice. A common binary PSK modem is used which provides digital data demodulation with a system bit error rate (BER) of 10^{-3} at a *C/KT* of 47.5 dB with coded operation.

In the traffic mode of operation, a variety of data rates (Table I) are provided by the common binary PSK modem and tactical satellite signal processor equipment accommodating non-nodal (point-to-point) and nodal (multipoint) operation.

Transmission modes —AN/TSC-86 terminal

The current terminals contain no modulation/demodulation equipment; consequently transmission modes other than multicarrier operation are not provided. However, expected communication modes of the terminal cover a wide range of applications such as: TTY, digitized voice (50 kb/s), Vocoded voice, 12/24 (64 kb/s/channel) voice channels, high data rate operation, and FDMA multiple access 12-, 24-, 48-, or 96-voice channels.

Terminal performance characteristics

The major performance characteristics of the terminals are summarized and compared in Table II. Tactical terminal system performance is based upon coded and uncoded operation in terms of BER and E_b/N_o (or equivalent C/KT). The performance of the strategic terminals is not specified as a system parameter since modem equipment is not contained in the present configuration.

Summary and conclusion

Through RCA development and the conduct of service testing of the small shf

Table II — Composite terminal performance characteristics.

Parameter	*AN/MSC*-59	*AN/TSC*-85 V1	*AN/TSC*-85 V2	*AN/TSC*-86
Frequency				
— Receive	7.250 to 7.750 GHz in 1-MHz steps	7.250 to 7.750 GHz in 1-MHz steps	7.250 to 7.750 GHz in 1-MHz steps	7.250 to 7.750 GHz in 1-kHz steps
— Transmit	7.900 to 8.400 GHz in 1-MHz steps	7.900 to 8.400 GHz in 1-MHz steps	7.900 to 8.400 GHz in 1-MHz steps	7.900 to 8.400 GHz in 1-kHz steps
Antenna				
— Reflector	8 ft.	8 ft.	8 ft.	8 ft.
— Polarization				
Receive	LHC	LHC	LHC	LHC
Transmit	RHC	RHC	RHC	RHC
— Tracking	automatic	automatic	automatic	automatic
Transmit power	100 W	500 W	500 W	1000 W
System noise temperature	300° K	300° K	300° K	300° K
Amplitude response				
—Transmit	±1.0 dB, any 10-MHz bandwidth	±1.0 dB; any 10-MHz bandwidth	±1.0 dB, any 10-MHz bandwidth	±0.5 dB, any 10-MHz bandwidth over 40 MHz
—Receive	±1.0 dB, any 10-MHz bandwidth	±1.0 dB, any 10-MHz bandwidth	±1.5 dB, any 40-MHz bandwidth	±0.5 dB, any 10-MHz bandwidth over 40 MHz
Phase linearity				
— Transmit	±15°, any 10-MHz bandwidth	±15°, any 10-MHz bandwidth	±15°, any 10-MHz bandwidth ±20°, any 40 MHz	±0.1 radian over 30 MHz ±0.25 radian over 40 MHz
— Receive	±15°, any 10-MHz bandwidth	±15°, any 10-MHz bandwidth	±15°, any 10-MHz bandwidth ±20°, any 40 MHz	±0.1 radian over 30 MHz ±0.25 radian 40 MHz
Transmission modes				
—Transmit				
PCM—48 kb/chan.	6 or 12 channel	6,12, or 24 channel	6,12,24,48 or 96 channels	70-MHz interface
Single chan. dig. in.	16 kb	16 kb	16 kb	
Orderwire	fm analog	fm analog	fm analog	
— Receive				
PCM—48 kb/chan.	6 or 12 channel digitally decombined	6,12 or 24 channel digitally decombined	6,12 or 24 chan. digitally combined decombined	70-MHz interface
Single chan. digital out.	16 kb	16 kb	16 kb	
Orderwire	fm analog	fm analog	fm analog	
Modem capability	6,12,18,24,36,48 72,96 16 kb/s dig. chan.	6,12,18,24,36,48, 72,96 16 kb/s dig. chan.	6,12,18,24,36,48, 72,96 16 kb/s dig. chan.	N/A
—Digital bit-error performance				
Coded	10^{-5} @ $E_b/N_o = 6.4$	10^{-5} @ $E_b/N_o = 6.4$	10^{-5} @ $E_b/N_o = 6.4$	N/A
Uncoded	10^{-5} @ $E_b/N_o = 11.4$	10^{-5} @ $E_b/N_o = 11.4$	10^{-5} @ $E_b/N_o = 11.4$	N/A

family of satellite terminals, military users (tactical and strategic) will be provided with ground terminals that achieve high performance satellite communication links in the immediate future. The currently developed group of ten terminals has completed the service test phase of the program.

The results of these service tests provide the military with the basis for procuring limited production equipments of various configurations. It is expected that, in the very near future, production contracts will be awarded for manufacturing the first group of operational terminals for use by the ground mobile forces.

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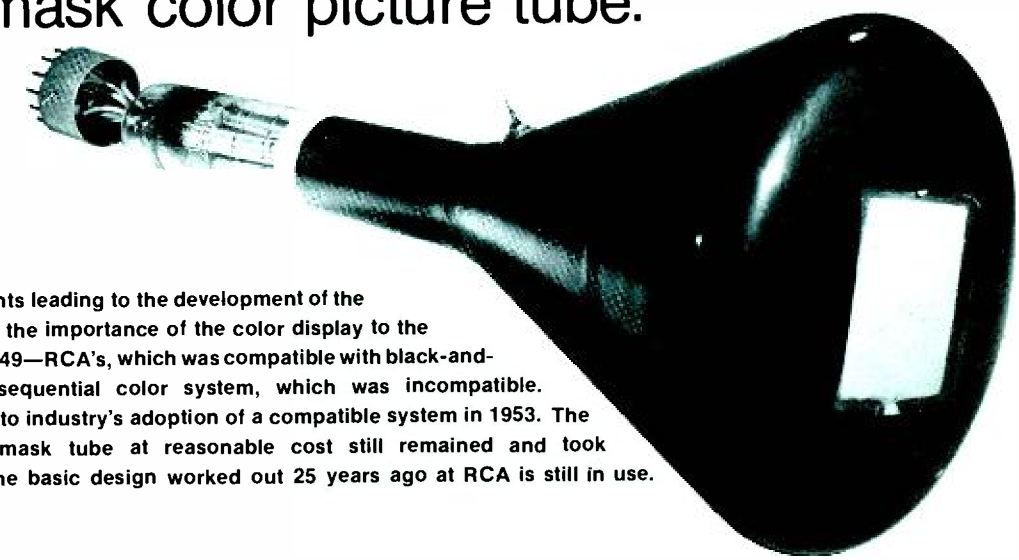
An eyewitness account of its early history

The shadow-mask color picture tube: how it began



Dr. A.B. Law

The author describes early experiments leading to the development of the shadow-mask color picture tube and the importance of the color display to the two systems under development in 1949—RCA's, which was compatible with black-and-white receivers; and CBS's field sequential color system, which was incompatible. An all-out crash program at RCA led to industry's adoption of a compatible system in 1953. The problem of producing a shadow-mask tube at reasonable cost still remained and took many years to resolve. However, the basic design worked out 25 years ago at RCA is still in use.

TOWARD the end of September, 1949, at RCA Laboratories, Princeton, N. J., selected members of the Technical Staff were asked to attend a special meeting. No reason for the meeting was given. However, one of the main topics of interest at the Laboratories was RCA's ongoing objective to devise a system for broadcasting television pictures in color without obsoleting the million or more black-and-white receivers then in use. I suspected the meeting might be concerned with this subject. My suspicion was well founded.

Black-and-white television, by 1949, was well advanced and receiver sales in the United States were expanding rapidly. In various research laboratories, notably CBS and RCA, work on color television was active. However, the circuit engineers were handicapped because there was no counterpart of the black-and-white cathode-ray tube for displaying pictures in color.

At CBS a field-sequential color system had been developed in which a mechanically rotating color disc was placed in front of a black-and-white picture tube to display pictures in color. The pictures were excellent, but the system was incompatible with the black-and-white system, and the picture size was very limited.

At RCA a simultaneous system had been developed which used three side-by-side broadcast channels, one of which was compatible with black-and-white. However, the increased number of channels could be made available only at a frequency region just beginning to be explored for broadcast purposes. The greatest disadvantage for the RCA group, however, was the lack of a satisfactory display for color comparable in size and performance to the picture tube used for black-and-white.

At the September, 1949 meeting, we were told that color television was at a critical stage. The Federal Communication Commission had called a series of hearings earlier in 1949 to discover whether or not it was possible to standardize on a color system within the 6-MHz channel then in use for black-and-white. The CBS group advocated a field-sequential system, which they demonstrated by using a rotating filter-disc display. Because this system was not compatible with the black-and-white system, the transmitted pictures could not be received on the large number of receivers already in use, and being sold by RCA and others at a great rate.

RCA had devised a subcarrier color system which was compatible; that is, it produced good black-and-white pictures on existing receivers, and color pictures on experimental color receivers designed to demodulate the subcarrier. Unfortunately, existing projection-tube displays, and a very complex direct-view display containing three orthogonal picture tubes whose pictures were combined by mirrors, lacked convincing evidence of practicality. It appeared that, unless a direct-view color picture tube was developed, the CBS color system would have to be used, and it would compete with black-and-white, rather than complement it.

It became clear at the September meeting that those invited were about to be challenged to show feasibility of a direct-view color tube and to produce results in double-quick time. We were told that RCA had decided to embark on an all-out, no-holds-barred effort to develop a color-picture tube. Feasibility was to be shown in three months. There was to be no limit to expense, and any manpower that could contribute, anywhere in the company, would be made available. The task of coordinating and organizing the activity was assigned to Dr. Edward W. Herold.

When the meeting ended, the enormous importance to RCA and to the television industry of successfully meeting this challenge was quite clear, but how it could be done was equally unclear. My close associate, Al Rose, prepared an internal report outlining all the previously suggested ways to make a color-picture tube. The report was not very encouraging—there just did not seem to be a really workable idea.

Before describing what happened next, it will be helpful to provide some background to put in perspective the events that were to follow.

I had joined RCA in 1941 at Camden, N.J., where I worked under the television pioneer, Dr. V. K. Zworykin, on more sensitive camera tubes. In 1942 we were moved to the new RCA Laboratories facility at Princeton. There, Dr. Paul Weimer and I joined Dr. Albert Rose, who had been at RCA, Harrison, N.J. The three of us began work under Dr. Zworykin to develop the image-orthicon camera tube, an idea originally advanced by Dr. Rose. Our work during the World War II years was directed to military applications, and we were quite successful in our efforts to increase camera-tube sensitivity by means of this new device. One of my own tasks for the image-orthicon was to devise a technology that would make feasible the fabrication of high-transmission, very fine metal screens. In this I was successful, and I also became involved in other sophisticated construction aspects of the tube.

At the war's end, although I continued on camera-tube work, I became interested in the color television work of some of my colleagues at RCA, particularly the need for a cathode-ray display that could be used for color. I watched with interest as Dr. Frederick Nicoll tried to make a color screen by settling color phosphors through a wire grill onto a flat glass plate. By settling phosphor three times with different color phosphors and shifting the grill, a screen was produced with the phosphor stripes nested together. Neither Ted Nicoll nor I knew how to use the screen in a practical way to display color pictures, but it seemed like a step forward to be able to make the phosphor-line structure.

Another inventive colleague, A . C. Schroeder, was devising possible color-tube structures, although he was primarily a circuit engineer. Al actually built a projection tube with three electron guns in three necks where the necks blended into one neck, which made possible a single-deflection yoke. The beams produced three small adjacent black-and-white pictures on the tube face. Red, green, and blue filters, mirrors, and a lens were used to project and superimpose the pictures on a screen, but the resulting color picture was extremely dim.

Staff members in research had great freedom to work on their own ideas, and we found it very stimulating to talk to others about their ideas and problems. Because of my interest in color display work, I undertook a few experiments of my own, dating from 1946. In mid-1946 I learned of a Schroeder idea, which prompted me to record the following in my notebook:

> It seems on thinking the matter over that Schroeder's idea for a three-color kinescope deserves a try. The idea referred to is one in which three guns scan a grill that serves to mask lines of different color phosphors from certain of the beams.*

I then made several attempts to construct a screen. The first attempt produced a fine particle cloud over a pinhole in a chamber that was continuously evacuated. I had hoped that particles would be accelerated through the pinhole and fly in straight lines to a grill and that those going between the wires would form lines of particles. However, the lines produced were not nearly sharp enough to be useful.

Next I tried evaporating boron oxide through a grill to the glass and then dusting phosphor over the glass surface, hoping that when heated the phosphor would adhere to the boron oxide made tacky by the heat. Other materials were also tried but sufficient adherence could not be obtained. Settling the phosphor first and then evaporating the binder through the grill also was tried but did not show promise.

After several months, I returned to the problem but this time applied a layer of Hanovia rose-red luster stain on the glass and then a layer of cold top engraver's enamel, a shellac-type photosensitive resist sometimes used when making half-tone printing plates. An exposure with uv light was made through a wire grill. Upon develpoment with alcohol, the alcohol undercut the resist lines and lifted the entire pattern. An attempt was made to mix the cold top enamel and stain so that the combination could be coated and exposed. The two materials were incompatible and formed a useless mess.

A year or so later I returned to boron oxide and found that a much thicker layer, when made tacky by heat would retain phosphor, but definition tended to be lost by spreading of the boron oxide with heating when satisfactory adherence was achieved.

Another year elapsed before I tried again, this time by settling a screen through a grill, somewhat as I had seen Nicoll try. A sharp line pattern was obtained but with

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*Neither Schroeder nor I knew in 1946, or even long afterwards, of a related earlier invention by a German scientist, Werner Flechsig, which issued as a French patent in 1941. Since the Flechsig patent appears to be the origin of several basic ideas, it is discussed in the Appendix.

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Harold B. Law, Staff Adviser, Materials Reserach Laboratory, RCA Laboratories, Princeton, N.J received the BS in liberal arts and the BS in education in 1934 from Kent State University. He received the MS and PhD in physics from Ohio State in 1936 and 1941. Dr Law joined RCA, Camden, in 1941 and in 1942 transferred to RCA Laboratories He became a Fellow of the Technical Staff in 1960 and from 1962 to 1975 was Director of the Materials and Display Device Laboratory, a laboratory affiliated with the Electronic Components and Devices Division Upon joining RCA, Dr Law first worked on television camera tubes and then on color television display tubes. He is a Fellow of the Institute of Electrical and Electronic Engineers, a Fellow of the Society for Information Display, and a member of the American Physical Society and Sigma Xi. For their development of the image-orthicon television camera tube, Dr. Law and two of his colleagues received an award from the Television Broadcasters Association in 1946. In 1955 he received the IEEE Zworykin Television Prize, in 1966 the Consumer Electronics Outstanding Contribution Award of the National Electronics Conference, and in 1975 the Frances Rice Darne Memorial Award from the Society for Information Display and the IEEE Lamme Medal. He is co-author of the book *Color Television Picture Tubes*, published by Academic Press, has been issued 40 U.S. patents, and has published 11 technical papers.

defects. It was then (1948) that I made the following entry in my notebook:

> It would be highly advantageous if the phosphor strips could be applied by a photographic process since it would be easy to get a good mask by ruling and etching glass and filling the grooves with opaque material. Such a process would accommodate itself to a curved faceplate.
>
> It may be possible to do the job by settling the phosphor in a photosensitive solution of gelatin, potassium dichromate, and silicate binder. When the solution is poured off it would be light-sensitive. Exposure would harden the gelatin and trap the phosphor while the unexposed portion would rinse away. The silicate binder might have to be omitted.
>
> Subsequent firing in the air would remove the gelatin and leave the phosphor. The second set of strips could then be applied.

I was not to become aware of the importance of this entry until some years later when it became the basis of phosphor deposition now used in all color-picture tubes.

It was early 1949 before I again returned to color-tube experiments. Working with a demountable vacuum system, I turned to a different structure consisting of thin metal vanes mounted perpendicular to the faceplate with phosphor on the sides of the vanes and on the faceplate between the vanes. With alternate vanes electrically tied together, the electron beam could be made to strike the sides of one set of vanes or the other set, or go through to the glass for the third color, depending on the voltage applied. The voltage required between the sets of vanes to obtain a single color was excessive, so I started to design a three-gun system that avoided high-voltage switching to change color. Slot apertures between the vanes permitted each beam to see only one color in an application of the shadowing principle.

In a separate experiment related to this vane-structure idea, I built three guns in a delta formation and put them into a 12-in. tube with a 2-in. neck and a white screen so that I could examine the problem of keeping the spots together during deflection. The angle between the guns and the tube axis was about 2°, and each gun was independently mounted on a rod in a small glass tube so the spots could initially be brought into coincidence at the center of the screen by carefully warming up the glass to repoint the gun before removing the tube from the pump.

This experimental tube was not quite complete when the opportunity came to go all out on the "crash program" to build a color tube. After the meeting, my mind again went back to the shadow-mask idea, but this time to a different form of the Schroeder design in which the mask contained a hexagonal array of holes instead of a wire grill. The problem was to locate precisely the positions, beyond the apertures, where the electrons were going to strike, and to then place phosphor dots at exactly these locations in a practical and straightforward manner.

All at once the thought occurred to me that, after deflection, the electrons travel in field-free space so their paths are straight and can be simulated by light. Therefore, a light-sensitive material, such as a photographic plate, temporarily positioned in the same location as the faceplate, could record the phosphor-dot positions for a given color if a point light source were placed at the deflection center of the beam for that color. If a photographic plate were used, one could then print a photoresist pattern on thin metal foil such that the black spots or phosphor-dot locations would not be exposed and would develop out free of resist. Holes could then be etched through the foil where the phosphor dots should be, so the foil could be used as a settling mask. All that would be required in addition was to provide some way to locate the settling mask in the proper position on the faceplate. For this purpose, alignment holes in the mask frame could be used to record alignment marks on the photographic plate at the time of exposure.

All of the above procedures seemed to be relatively easy to carry out with a high probability of success. However, there was one experiment I decided to do before getting too excited. I prevailed on Paul Weimer to let me use his demountable vacuum system to scan an electron beam over a wire mesh placed about ½ in. in front of an aluminized phosphor screen. With a microscope I observed that the shadows cast by the mesh were very sharp and clean, so the beam could certainly be shielded from striking phosphors of a different emission color lying extremely close by. It was then that I felt confident that I would be able to build and demonstrate the basic Schroeder-tube design.

The mask-screen structure was repeated for a sealed-off version and after a couple of tries a tube was produced in which red, green, and blue color fields could be produced and the grids could be modulated with video. At this point, about six weeks after the September meeting, the tube was turned over to L.E. Flory and his associates, who had been assigned the circuit program for operating the tube. They used small permanent magnets to achieve coincidence of the undeflected spots in the center of the screen and were able to show three-color pictures for the first time on a Schroeder-type tube. I recall Les Flory being so pleased with the result that he declared "we would be making color pictures the same way five years from now." It sounded like a rash statement then, but actually after more than 25 years the shadow-mask tube is still the only one in use. Moreover, light exposure in a piece of equipment called a lighthouse is still used today in practicing the same basic procedure for locating the phosphor-dot positions. A photograph of this first tube is shown in Fig. 2.

I immediately began to design the tube geometry and to think about construction details. Since I had no thin metal with a hexagonal array of apertures for a

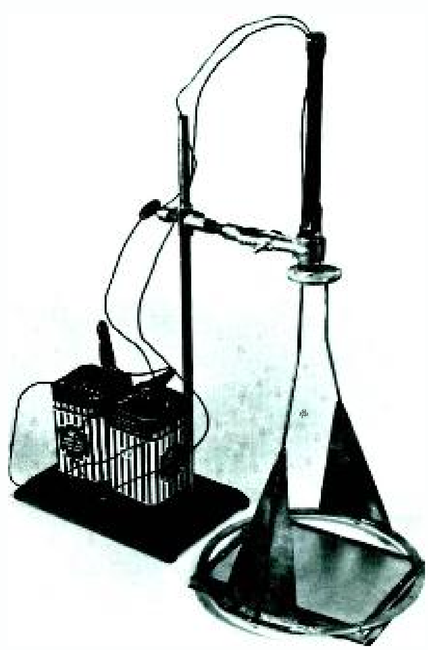

Fig. 1 — Lighthouse used in printing the first experimental shadow-mask color tube. A photosensitive film is located in the phosphor-screen plane. It is exposed from a point source in the lighthouse and through the shadow mask to locate the desired phosphor dot positions.

Fig. 2 — Experimental shadow-mask tube used to display color pictures on this type of color tube for the first time.

mask, I decided to make the mask by etching. First, though, I needed the proper photographic pattern of dots, so I wound a wire grill on a frame of threaded rods and with the help of Tom Cook, our laboratory photographer, made a double-contact print, the second exposure after rotating the grill 60°. A hexagonal array of diamond-shaped elements was produced, but Tom was able, by printing with an overexposure, to round off the sharp corners to produce a usable pattern. With this pattern I made the first thin metal masks.

In preparation for making the phosphor screen, the next step was to make exposures through the mask from three points located according to design with respect to the mask assembly. It was desirable, also, to somehow keep track of the physical location of these exposure points, or color centers, so the mask-screen assembly could be mounted in the proper position in the tube; that is, mounted in such a position that the color centers would coincide with the center of deflection of the yoke when the yoke was placed in its normal position on the tube neck. In addition, it was necessary to have a means to determine the correct orientation of the three-gun cluster at the time it was being sealed in the tube neck. For this experiment the problem was solved by building a superstructure or "lighthouse," which was attached to the mask-frame assembly and carried a small metal plate with three exposure apertures as shown in Fig. 1. After three exposures were made on three pieces of photographic film, the remaining steps were carried out according to plan. Finally the lighthouse was removed after the mask-screen structure had been put in place in the tube. Three individual electron guns were sealed into the tube neck on tungsten rods, as described in the earlier experiment, and the tube was placed on a vacuum system to pump. Two guns gave enough emission to test but the third was inoperable. Nevertheless, it was a thrill to see the screen change from one color to another by simple adjustment of the grid biases. The experiment was considered a big success and resulted in a number of people at the Laboratories dropping in for a demonstration.

Of course, the inauguration of the RCA crash program led to many other projects within the company. One team, headed by a colleague, Dr. Russell Law, devised a one-gun version of the shadow-mask tube using masks and screens that I supplied for the first tubes. A full description of accomplishments of these and other projects at RCA plants in Lancaster, Pa. and Harrison, N.J. will be found in a series of 11 papers published in the special Color Television Issue of the *Proceedings of the IRE*,[1], but the status of the projects at RCA Laboratories as of two months after the September meeting are contained in notes made by Ed Herold at the time. He wrote, in part, as follows:

> A group from Harrison, another group from Lancaster, and a somewhat larger group from RCA Laboratories at Princeton, was shown a number of color reproducer projects at Princeton···.
>
> One of the demonstrations showed a color picture on a single tube reproducer using 150 sets of three-color phosphor lines and a single electron gun···. A 150-line, non-interlaced, scanning raster was used, accurately aligned with the ruled phosphor line sets. The picture was approximately 4½" by 6"···and was quite excellent and showed about 300 lines horizontal resolution and good color fidelity···.
>
> A second demonstration showed···a single-gun tube using the shadow-mask direction screen (see below). This tube was demonstrated with a television black-and-white broadcast picture, which could be shown in any one of three colors by rotating a yoke around the neck of the tube.
>
> A three-gun tube was demonstrated that employed a shadow-mask screen aligned with tri-color phosphor dots. This tube produced a color picture approximately 4" by 5" with good rendition of colors, and adequate brightness. The color picture appeared to be well registered and converged at the center of the picture, and fair registry was obtained out to the edges. Either simultaneous or dot-multiplexed signals could be employed. Because of the small number of dots employed, resolution was not high but the future possibilities of this method seemed clearly demonstrated.
>
> Still another demonstration showed a demountable form of reflected-beam tube in which the colors were switched by manual adjustment of the voltage on the transparent conducting coating. A monoscope test pattern was employed and could be shown in any one of the three colors.
>
> A two-color reproduction of a three-color signal was shown on another tube that used grid control between two closely-spaced phosphor-bearing electrodes. This demonstration made use of the standard RCA multiplex signal and the switching was done at 3.6-Mc rate. The picture was small (approximately 3" by 4"), showed some evidence of parallax, and was low in brightness. Because of the simplicity of the circuits and tube, however, the system appeared to be potentially useful for a low-cost color system.

The results described, after only two months of intensive work, were so encouraging that doubts and gloomy forecasts were forgotten.

I decided to make the shadow-mask tube with a larger screen size and found that the mask had to be stretched tightly over a frame to obtain geometric stability. The settling masks were more difficult to make and use, and the assembly techniques were very crude for the accuracy needed. However, Ed Herold and many others were convinced of the promise of the shadow-mask tube and the lighthouse technology for making it. My own efforts were soon swamped by an avalanche of others helping in many ways to make a tube with a 12-in. diagonal picture size.

Dr. Jan Rajchman took the lead in enlisting the Buckbee Mears Co. to furnish masks to our specifications with very gratifying results. Norm Freedman and Ken McLaughlin were soon supplying phosphor screens for tubes made by silk-screening instead of settling; they used the lighthouse exposure of a Kodalith glass plate to obtain the pattern for their silk screen.

Nan Moody and Dave Van Ormer at Lancaster went to work on the gun cluster and came through with assemblies that worked very well. The three guns gave beams that emerged parallel into an electrostatic converging lens. Al Friend found ways to visualize the problems of keeping the three beams together at the screen during deflection, and was able to make modifications in the magnetic yoke windings to help keep the beams together as well as control especially troublesome areas by the insertion of magnetic tabs. B.E. Barnes and Dick Faulkner were faced with the task of making a bulb that could be opened near the faceplate and provide assembly tolerances for the mask-screen and triad of guns that was far beyond anything that had been attempted in such a large structure. In fact, the most frightening aspect of the whole tube was soon appreciated as being the extremely tight tolerances that needed to be held in essentially all phases of manufacturing the tube, including particularly the mask-screen assembly where some errors could not be compensated for by means external to the tube. Details of work in all the areas mentioned are recounted in Ref. [1].

At the FCC the showdown was still ahead over which color system would be approved by virtue of the type of standards to be adopted, so that efforts were redoubled to produce the best tubes possible for the upcoming demonstration. At Harrison, box after box of Kodalith plates were used in fabricating mask-screen "Telechrome" units that were sent to Lancaster for tube finishing. The finished tubes were transported to Princeton for appraisal and feedback.

Early in February, 1950, another internal company demonstration was held, which was described in Ed Herold's notes as follows:

> A large group of visitors from Lancaster, and from Harrison, were shown a series of demonstrations on Saturday, February 11, 1950 at RCA Laboratories, Princeton···. By the time of this demonstration, 16" metal envelopes had been employed for some of the types and a silk-screening technique had been worked out for making line-screen tubes and shadow-mask dot-screen tubes···. Substantial progress had also been made on the reflected-beam type of tube, which was made in a sealed-off version···.
>
> A 9" by 12" picture using the shadow-mask direction screen and a single electron gun operated from a standard RCA dot multiplex signal and was demonstrated and shown to have good color fidelity with fair picture brightness. A three-gun form of shadow-mask tube was also demonstrated and showed a picture that was also considered to be generally excellent at the time. The reflected beam tube was operated, using a 7 ½" diameter screen with a picture having approximately 150 to 200 lines resolution, with good fidelity and complete freedom from the registration or convergence problem···. A two-color tube using grid control was demonstrated, but was somewhat low in brightness. Black-and-white pictures as well as color reproductions were shown on all these types of tube.
>
> The line-screen tube was shown in operation with an automatically registered scanning raster but no picture was shown.
>
> Among the important items on which progress was demonstrated at this time was the use of a single color filter between the color tubes and the observer for improving the color fidelity. Some small pieces of didymium glass were available and showed the combined effect of reduction of ambient illumination analogous to the gray glass commonly used with black-and-white tubes, and a marked improvement in the color of the red phosphor, which was shifted toward the red quite markedly. The blue and green colors were substantially unaffected by this filter. The scanning yokes which were used in the demonstration of the 16" envelope tubes were all specially designed, in the case of the line-screen tube to give a perfectly rectangular pattern, and in the case of the shadow-mask tubes to give very low astigmatism.

Continuing, we learn of further developments:

> Work was started on a receiver for the three-gun type of shadow-mask tube and a second receiver for the one-gun type. In each case, a standard 16" black-and-white receiver was used and the additional tubes and circuits added for the color kinescope so as to convert the receivers. In the case of the three-gun type, it was decided to use a cathode-sampling circuit and every effort was made to use a sufficient number of tubes and components to permit a high-quality picture reproduction. Separate high-voltage supplies were used, capable of delivering about 13 kV for the early test. The finished receiver used 19 additional tubes over those originally in the black-and-white receiver. The receiver for the single-gun shadow-mask color tube, on the other hand, was designed so as to introduce the fewest number of tubes and the simplest of components. It was found possible to make this receiver with only 10 additional tubes over the black-and-white chassis···
>
> Some preliminary tests were made on these receivers at the Silver Springs Laboratory in Washington early in March, 1950. As a result of these tests, it was decided to increase the high voltage so as to obtain improved light output···. A highlight brightness of about 4 foot lamberts was achieved on the single-gun kinescope receiver, and about 7 foot lamberts on the three-gun receiver, with both receivers using a didymium glass filter to improve red response. This filter absorbed approximately 50% of the kinescope light output···.
>
> On March 23, 1950, an informal demonstration was given to the Federal Communications Commission···. On March 29, a public demonstration was made, which received major attention in the press···.

One succinct trade-press comment comes from the Television Digest after the March 29 demonstration:

> Tri-color tube has what it takes: RCA shot the works with its tri-color tube demonstrations this week, got full reaction it was looking for—not only from more FCC members and several score newsmen, but from 50 patent licensees who came to see for themselves.
>
> So impressed was just about everybody by remarkable performance, that it looks now as if RCA deliberately restrained its pre-demonstration enthusiasm to gain full impact. "Now we're getting somewhere," was essence of comment, especially among manufacturers. Previously, solidly sold on compatibility and fairly well sold on RCA's system, many seemed ready to go all the way with RCA now that they've seen normal-looking, compact receivers (no "grand pianos") giving decent pictures.
>
> Adoption of either CBS or CTI, by themselves, can not be ruled out unequivocally. Their only chances, particularly those of CBS, lie in multiple standards permitting virtually any 6-Mc system···.

Multiple standards it was, for on September 1, 1950 the FCC issued its first report on the hearings, stating that the CBS system was the only one ready for standards. It proposed that the industry adopt "bracket" standards to permit either CBS or standard transmissions for all receivers made in the future. RCA held that bracket standards were impractical and petitioned the FCC to withhold a decision until June 30, 1951 pending further comparative tests. The FCC denied the petition and issued orders setting the standards for the CBS system, with commercial operation to begin November 20. RCA filed suit in the U.S. District Court to set aside the FCC order. The Court issued a restraining order preventing start of commercial color on the CBS system until the Court had time to review the decision.

In the period that followed, RCA gave extensive demonstrations in Washington to industry, government, and the press. Receivers were shown with improved color tubes having 585,000 phosphor dots, new red and blue phosphors, and resolution and brightness (25 ft-L) about equal to black-and-white. Nevertheless, on May 28, 1951 the U.S. Supreme Court affirmed the FCC ruling in favor of the CBS system and authorized the start of color tv broadcasting on June 25.

Broadcasting on the CBS system standards never got underway because on November 20, 1951 the National Production Authority Order M-90 prohibited all manufacture of color tv components and receivers due to the war effort. The effect of this action was to give more time for sober thought on a compatible system. Indicating broad support of industry for such a system, the National Television Systems Committee held a meeting on June 18, 1952 to consider the subject of compatible color tv. After extensive deliberation the committee recommended a system of compatible color tv that was similar to but improved over that proposed by RCA. Approval was granted for the NTSC system by the FCC on December 17, 1953.

Although color broadcasting standards remained in doubt for a long period of time, there was no doubt about the utility of the shadow-mask tube, because it was suitable for either the CBS or RCA system. The major problem was how to mass produce the tube at a reasonable cost. Having to process a photographic plate and make a silk screen for each tube was expensive. The solution seemed to be traditional mass-production techniques making use of interchangeable parts. This would imply that the mask, first of all, should be made interchangeable so that interchangeable screens could be used. Looking ahead to this eventuality, RCA invested in a large three-color Vandercook printing press at Lancaster and undertook a research program with Lehigh University's National Printing Ink Research Institute. The program objective was to develop ink formulations for printing the relatively coarse phosphors on the flat glass screen plate that would then be mounted inside the color tube.

Progress was being made toward interchangeable masks, but it was accompanied by an enhanced appreciation of the geometric distortions that can be produced when the mask is mounted on a frame under highly stressed conditions.

Another nagging problem that increased cost was the slow heat cycling required in processing the tube because of the internal flat-glass screen plate. It heated and cooled mostly by radiation and was in danger of cracking if the cycling was too rapid.

In the midst of the struggle for mass production at RCA, a new technical development was announced at CBS-Hytron and later published.[2] Instead of using a flat mask and an internal screen plate, the mask was spherically curved and mounted close to the similarly curved faceplate of the tube. Phosphor was applied by means of the lighthouse to expose directly a photosensitive binder containing the phosphor on the inside of the faceplate. The exposed portion remained and the unexposed portion could be washed off. A repeat of the process made it possible to print successfully all three primary color phosphors.*

I was present in Toronto, Canada when Norm Fyler, a previous associate of mine at RCA Laboratories, delivered a paper describing the system. I had breakfast before the meeting with Norm and Rus Law, also at CBS-Hytron after leaving RCA in the early 50's. I was struck by the supreme confidence they had in the new system. Clearly it was not an interchangeable system, but it did not have to be. I was convinced of the approach's merit, but it was an important decision for RCA—to follow CBS or not.

*As was seen from the quotation from my 1948 notebook above, I had already proposed depositing phosphor in a photosensitive binder and suggested that it would work on a curved plate. A patent was applied for in my name by RCA on the process. Although I was first to conceive the invention, an interference was declared with another inventor. After extended litigation I prevailed and was granted Patent No. 3,406,068 in 1968.

Within a short time RCA, Lancaster, put together a curved-mask tube using photosensitive binder for phosphor deposition and confirmed the considerable advantages inherent in the system. One of the most obvious advantages to the viewer is the display of the picture on the tube face as in black-and-white picture tubes rather than on an internal screen. RCA adopted the system, which essentially opened a new era in the practical manufacture of the shadow-mask color tube and marked the end of the early development period.

Many of my colleagues and I continued on in color-tube work as a career. What followed were years of frustration at the slow progress of color television in the marketplace. How could color sets be sold when color telecasts were few and far between? Who would be willing to pay for programs in color when there was only a sprinkling of color sets among all the television sets in use? To top it off, color sets were expensive, and there was occasional publicity about work in progress on new color tubes that promised to be less complicated and cheaper than the shadow-mask color tube—both fostering the notion of waiting until color was "perfected" before buying a set. However, successful commercialization of another type of color-type display did not materialize. This was true partly because of continuing successful efforts to improve the performance and reduce the cost of the shadow-mask system and partly because this success, in a performance as well as business sense, provided a rapidly moving target for any potential competing system. From crude beginnings, the tube design and manufacturing processes today have been so developed and refined that the system constitutes perhaps the most sophisticated collection of high-technology procedures that is to be found anywhere in the mass production of such a bulky product. Some of these technical developments have been documented[3] and the history of color-tube development brought up to date,[4,5] but it is a continuing story as improvements in performance and reductions in costs are still being made.

It is hard to believe that those first few experiments could have led to a device that reached a cumulative production of over 100 million units worldwide.[5] It should now be abundantly clear, however, that although I performed the experiments, the basic design of the color system and tube were already there and my colleagues both here and worldwide have carried out a Herculean task, including the making of many ingenious inventions, to get us where we are today. Also, a key factor that cannot be too strongly emphasized was the vision and determination of General David Sarnoff, who provided the challenge, opportunity, and resources for this major effort. Without his leadership, color television, as we know it, would at least have been delayed.

Acknowledgment

I wish to thank Dr. E.W. Herold for his careful review of the manuscript and his many helpful suggestions.

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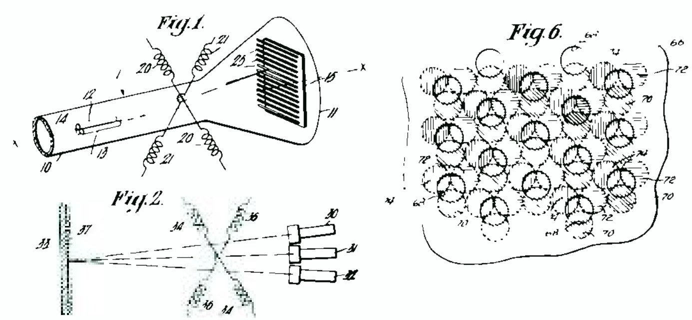
Appendix

As indicated in the text, the author chose the shadow-mask color tube idea described to him by A.C. Schroeder, and later patented by Schroeder, as the beginning point in a crash program to develop a single display tube for color television. Selected drawings from his patent are reproduced and the concepts in the patent made use of are given below as a matter of interest. However, unknown to Schroeder or the author until much later, a patent was applied for on July 11, 1938 by Werner Flechsig in Germany that appears to be the origin of several basic ideas along the same line. One year later the Flechsig appliction was filed in France and a French patent was issued on March 31, 1941. The drawings of this patent are also reproduced and a summary of the concepts disclosed are summarized below, also as a matter of interest.

A.C. Schroeder, Patent No. 2,595,548; filed February 24, 1947, issued May 6, 1952.

The first two patent drawings show three closely spaced beams that are deflected by a single deflection yoke with the beams coincident at the screen and penetrating a shadowing structure or mask.

The third drawing shows that when the mask has circular apertures arranged in a hexagonal pattern (solid circles), a nested array of phosphor dots can be formed back of the apertures. The array really consists of three interlaced arrays of different color-emitting dots. When used with a properly oriented delta gun cluster having correct dimensions, each beam will strike dots of only one color.



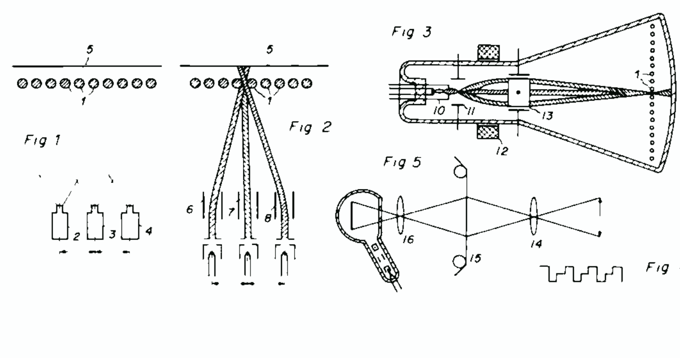
Selected figures showing three beams deflected by a single deflection yoke and the relative arrangement of mask apertures and phosphor dots that produces a nested phosphor-dot screen.

Werner Flechsig, French Patent No. 866,065; filed July 11, 1939, issued March 31, 1941.

Fig. 2 of the Flechsig drawing shows shadowing by a grill to obtain color selection at the screen. Fig. 1 indicates how the screen may be formed by evaporating luminescent material or color filter material through the grill from sources placed at the center of deflection of the beams. In Fig. 3 one beam is successively deflected to the three positions occupied by the beams in a three-beam embodiment and directed to a common point at the screen. A staircase switching voltage, which would accomplish this operation, is shown in Fig. 4. In Fig. 5 the same principles are applied to a camera tube.

The following concepts are contained in the Flechsig patent:

1) A shadowing structure that consists of a wire grill is used to permit excitation of a selected color at the phosphor screen.
2) Three electron beams converge at the grill and strike separate areas on a phosphor screen beyond the grill as a consequence of the grill's shadowing action.
3) The three beams are deflected with either individual or common deflection means from the same position along their respective paths.
4) The screen consists of phosphor lines, or color filter lines, prepared by causing the appropriate material to emanate as by evaporation from the points from which the beams are deflected. The material being evaporated at the screen is subject to the same shadowing action by the grill as are the electron beams.
5) The grill openings become cylindrical lenses for concentrating the electrons into narrow lines at the screen if the potential of the screen is made positive with respect to the grill.
6) If the electrons are sufficiently concentrated by cylindrical-lens action at the grill, the grill wires may be made very small in diameter and still perform their shadowing action. To deposit the screen the wires must then be temporarily enlarged, as by coating, to prevent the phosphor lines from being too wide and overlapping. The coating can be removed after the screen is made for normal operation of the tube.



Figures show shadow-mask color-tube principles in a grill-type tube.

The dimensional slide rule

A.B. Pikus

Interest in order and relationship between numbers and dimensions has turned a hobbyist into a crusader for a new tool—the dimensional rule, which is described in this paper.

Did you ever feel the need for assistance in checking dimensional properties of equations you work with or in mathematical manipulations of the many rules of nature to fit your specific objectives? It is for this and many other purposes that the author has developed a dimensional slide rule which will be described in this paper. His claim is that he can assist you in greatly speeding up the solution of your problems in this field and in assuring their accuracy. He also believes that this tool can assist those desirous of further probing the relationships of nature's rules, be it in professional pursuit or as a hobby.

Development

What prompted the author to develop the dimensional slide rule? — an interesting question, inasmuch as the slide rule is the result of a hobby rather than a professional assignment.

During the period of 1934-35, the author attended the University of Pennsylvania in Philadelphia, where in his course work he found he had developed a strong interest in the relationships of the laws of physics. From that time on, although engaged in different types of professional activities, he pursued the study of mathematics and physics as a hobby.

He was working as a supervisor in the Camden manufacturing activity of RCA when a paper in *Scientific American* (May 1963) titled "The evolution of the physicist's picture of nature," by P.A. Dirac, caught his attention. Here he found interesting relationships between fundamental constants resulting in a number with no dimensions:

> "There are some fundamental constants in nature: the charge on the electron (designated e), Planck's constant divided by 2π (designated $\hbar$) and the velocity of light (c). From these fundamental constants, one can construct a number that has no dimensions: the number $\hbar c/e^2$. That number is found by experiment to have the value 137, or something very close to 137. Now, there is no known reason why it should have this value rather than some other number. Various people have put forward ideas about it, but there is no accepted theory. Still, one can be fairly sure that someday physicists will solve the problem and explain why the number has this value. There will be a physics in the future that works when $\hbar c/e^2$ has the value 137 and that will not work when it has any other value."

The author set out to find the reason why this nondimensional value was 137—a task he is still pursuing today.

However, this led him towards the development of the dimensional slide rule. He reasoned that, starting with the electron as his building block, he could develop specific numbers associated with each dimension. Then by arranging the dimensions according to their specific numbers in a slide rule scale, he was able to construct a dimensional slide rule.

Starting with the electron, and using MKS units, we know that:

- Mass $M = 9.108 \times 10^{-31}$
- Charge $Q = 1.602 \times 10^{-19}$
- Velocity $v = 2.998 \times 10^{8}$ $= c$ (velocity of light)
- Permittivity $\epsilon_0 = 8.854 \times 10^{-12}$.

Now using

$$r = l = q^2/4\pi\epsilon_0 m V^2$$
$$= 2.818 \times 10^{-15}$$

- Length $l = 2.818 \times 10^{-15}$

and
$$T = \frac{L}{c} = \frac{2.818 \times 10^{15}}{2.998 \times 10^{8}}$$

Thus
- Time $T = 9.4 \times 10^{-24}$ s.

Then proceeding to the values of voltage and current:

$$V = ML^2T^{-2}Q^{-1}$$
- Voltage $V = 5.108 \times 10^{-5}$

$$I = T^{-1}Q$$
- Current $I = 1.704 \times 10^{4}$

In this manner, around a hundred numbers were assembled.

On the slide rule, all the dimensions are shown, along with the exponent of their number.

The tool is now capable of

1) Obtaining the dimensional meaning of complicated algebraic expressions using physical quantities,
2) Being able to identify unknown symbols in formulas,
3) Being able to recall and reconstruct formulas with the assistance of the slide rule,
4) Being able to check equations dimensionally in a quick and efficient manner,
5) Being able to find algebraic errors when solving problems, and finally
6) Being able to solve directly many dimensional problems.

Would you believe that manipulations taking an expert half an hour to do by hand can be completed with the dimensional slide rule in seconds? Let's find out how.

Description

As shown on Fig. 1, the construction of the dimensional slide rule is pretty much like that of a conventional one. The *body* consists of an upper and lower folded part which holds the *slide* and allows it to be moved back and forth as required. The *indicator* is a transparent piece which may be moved over the *face* of the rule. The indicator carries a *hairline* shown as a vertical line. The hairline extends over and onto the *reverse face* of the slide rule for the *D sq rt* and the *D sq scales*.

Alfred B. Pikus attended the University of Pennsylvania and City College of New York. He was employed by RCA Victor Division, Camden, N.J., for 29 years, after which he retired in 1971. His major responsibility at RCA was the production of government equipment. He holds one patent.

Left to right: author Al Pikus with associates K. Pikus and Dr. L. Gagliardi.

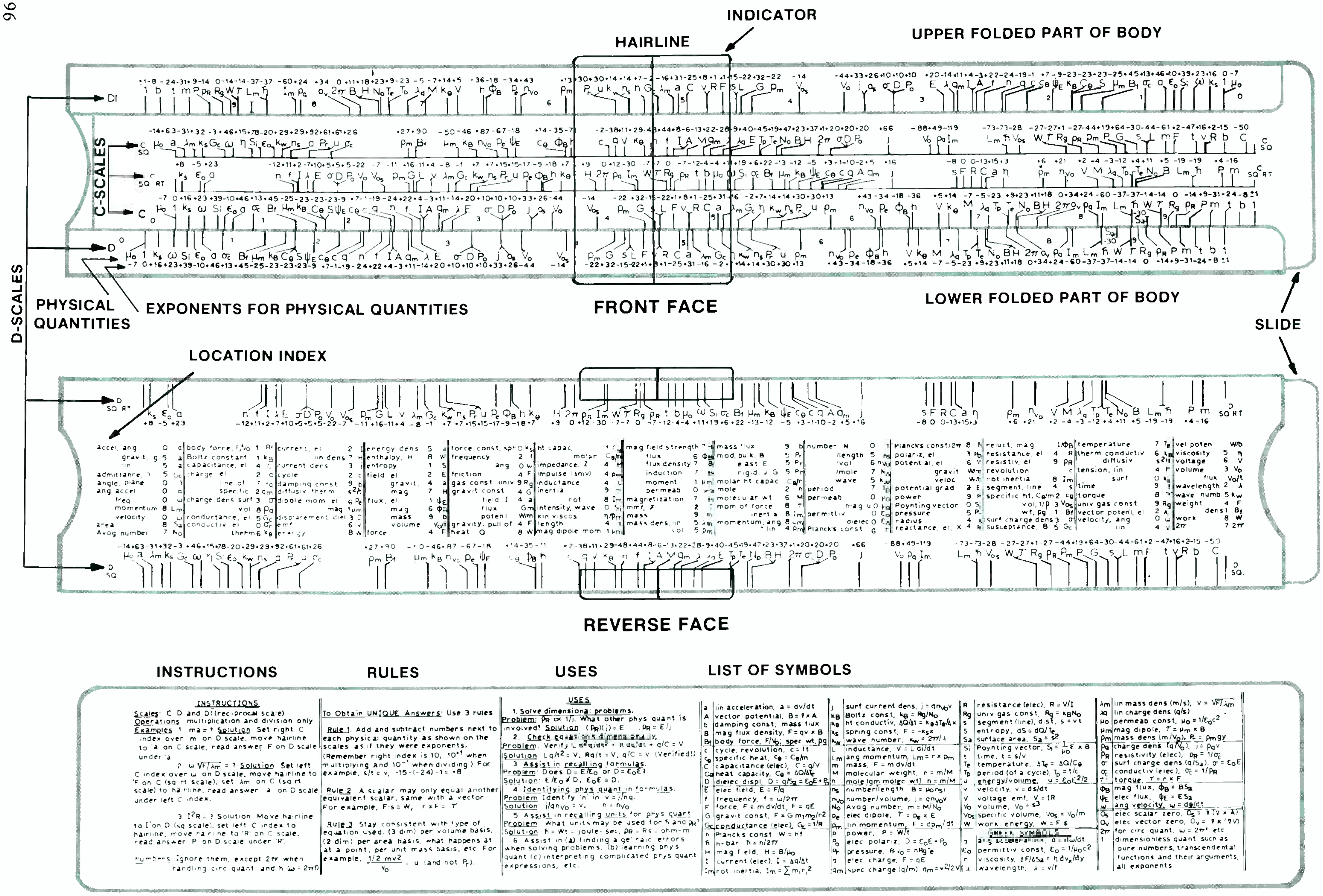


Fig. 1 — Dimensional slide rule.

Table I — Description of slide rule (see Fig. 1).

1 72 *physical quantities* with a symbol for each, plus electrical scalar and vector zeros, 2π (for circular quantities) and 1 (for dimensionless quantities).

2 *Exponents* or "powers of 10," as in $3.0 \times 10^{+8}$, where +8 is the exponent under v (velocity). Every symbol (in all the scales) has a number or exponent either above or below the symbol. These exponents are used to obtain "unique" answers.

3 *C-scales*: 3(a) C, physical quantities to the 1st power,
(b) C sq rt, physical quantities to the ½ power,
(c) C sq, physical quantities squared.

4 *D-scales*: 4(a) D, physical quantities to the 1st power,
(b) DI, the inverse of the D-scale 1st power,
(c) D sq rt, physical quantities to the ½ power,
(d) D sq, physical quantities squared.

5 *Index* of physical quantities (with their location numbers and their symbols).
For example, electrical charge has q for its symbol and the location 2 means that q is located in the interval between 2 and 3.

6 *Instructions*. (Reverse face of slide.)
Simple instructions are shown on the slide rule for easy recall.

7 *Three rules*. (Reverse face of slide.)
These rules are used (mentally) to obtain "unique" answers on the dimensional slide rule.

8 *Uses*. (Reverse face of slide.)
Six (6) uses suggested for the dimensional slide rule.

9 *Alphabetical list of symbols*. (Reverse face of slide.)
The list gives the physical quantity represented by the symbol (plus an identifying formula).

The front and reverse faces show the *C-scales* (1st power, square root, and square scales), and the *D-scales* (1st power, inverted *DI scale*, square root, and square scales) for a total of seven scales. A summary of features is given in Table I.

Use

We shall now show examples of the following uses for the dimensional slide rule:

A. As a "dictionary" of complicated algebraic expressions, (which, in turn, makes for easier reading of mathematical periodicals, papers and texts);
B. To pinpoint algebraic errors;
C. To solve "dimensional-type" problems;
D. To identify unknown symbols in formulas; and
E. To help reconstruct formulas.

The slide rule is easy to use, since the only operations performed are multiplication and division and these operations are performed in the same way as on a numerical slide rule. This is because the dimensional slide rule uses numbers to represent physical quantities. For example, v (velocity) is located on the slide rule where the significant figures 2998 are located, and the number +8, below the v represents the exponent or "power of 10". Therefore, v (velocity) is represented by the number 2.998×10^8. In a similar way, E (electric field) is represented by 1.813×10^{20}; R (universal gas constant) is represented by 8.310×10^0; etc. To insure "unique" answers, exponents are (mentally) added when physical quantities are multiplied; exponents are substracted when physical quantities are divided. (Observe that this is the same as multiplying and dividing numbers on a numerical slide rule.) For example, in ohms law,

$$\frac{V}{R} = \frac{5.108 \times 10^5}{2.998 \times 10^1} = 1.704 \times 10^4 = I \text{ (current)}.$$

The answer is I (current) and not A (vector potential), since the exponent for I is +4, whereas the exponent for A is −3. Another important rule that is employed, when using the slide rule, is "A scalar can only equal another scalar; a vector can only equal another vector." For example, where F = force, s = displacement (a length) and r = radius vector (a distance), $F \cdot s = W$ (work), a scalar, since it is the result of a dot product. $r \times F = \tau$ (torque), a vector, since it is the result of a cross product. In this way, W and τ are separated, even though they are represented by the same number. Thus, the basis of the rule is an ordered set of numbers, insuring complete consistency in mechanical, gravitational, thermodynamic, electrical, and strong and weak nuclear dimensional quantities. The dimensional slide rule is designed in the MKS system of units.

A. Dictionary of complicated expressions

To determine the "meaning" of $L\omega^2 kT$, where L = inductance, ω = angular frequency, k = Boltzmann's constant and T = temperature, the slide rule is used as follows:

Step 1. Set left C-index (1, Fig. 1) to L on D-scale.
Step 2. Move hairline to ω on the C-square scale.
Step 3. Set left C-index under hairline.
Step 4. Move hairline to k_B on C-scale.
Step 5. Set right C-index (1) under hairline.
Step 6. Move hairline to T on C-scale.
Step 7. Read answer V^2 (voltage squared) on D-square scale.

Observe that only C and D scales are used, and the answer may appear on any of the D-scales, 1st power, square root or square scales. Also note that when adding the exponents, the right C-index (1) is actually 10, (since it follows 9 on the numerical rule). When this index is used for multiplication, an extra 1 must be added. (When dividing, the 1 is subtracted.)

The answer, V^2 (voltage squared), represents the "Johnson noise" associated with thermal fluctuations.

B. Pinpoint algebraic errors

Given:

$$\epsilon_0 c^2 \nabla^2 A + (1/\mu_0)\nabla(\nabla \cdot A) + \partial\nabla\phi/\partial t) + \epsilon_0(\partial^2 A/\partial t^2) = j.$$

As one of the steps in the solution of a problem, the slide rule can detect an error in this step. (Remember, each term must have the same dimension as every other term.) Using the slide rule,

$$\epsilon_0 c^2 \nabla^2 A = \epsilon_0 c^2 (A/s^2) \text{ (dimensionally)} = j;$$

$$1/\mu_0 \nabla(\nabla \cdot A) = A/[(\mu_o)(s)(s)] \text{ (dimensionally)} = j;$$

$$(\partial \nabla \phi/\partial t = \phi/ts \text{ (dimensionally)} \neq j; \text{ and}$$

$$\epsilon_o \partial^2 A/\partial t^2 = \epsilon_0 A/t^2 \text{ (dimensionally)} = j.$$

Therefore, since

$$(\partial \nabla \phi/\partial t) \neq j$$

the error is pinpointed to be in this term. Reviewing the mathematics in the previous steps, a correction is made to

$$\epsilon_o (\partial \nabla \phi/\partial t)$$

and using the slide rule to check,

$$\epsilon_0 (\partial \nabla \phi/\partial t) = \epsilon_0 \phi/ts \text{ (dimensionally)} = j.$$

The solution of the problem may now be completed with reasonable assurance of no algebraic errors up to and including this step.

C. Solve dimensional-type problems

Problem 1: The square of the noise voltage produced by thermal agitation of the molecules in an input grid impedance (considered as a two terminal network) is

$$V^2 = 4kT\int_0^\infty R(\omega)\, d\omega,$$

where V = voltage, k = Boltzmann's constant, T = absolute temperature, R = resistance, and ω = angular frequency. The network diagram is shown in Fig. 2. What effect has the capacitance and shunt resistance on the square of the noise voltage?

The solution is as follows:

Step 1. Since, in the given circuit,
$R(\omega) = R/[1 + \omega^2 C^2 R^2]$,
then
$V^2 = 4kT\int_0^\infty \{R/[1 + \omega^2 C^2 R^2]\}\, d\omega$.

Step 2. Obtain the "meaning" of the quantity on the right hand side of $\int$. The quantity $\omega^2 C^2 R^2$ must be dimensionless since it is added to 1; thus only $R\omega$ remains.

Step 3. Using the slide rule to obtain the "meaning" of $R\omega$, set left C-index to R on D-scale, move hairline to ω on C-scale, read answer $1/C$ (reciprocal of capacitance) on DI scale.

Step 4. Since the quantity on the right hand side of the integral is multiplied by kT, $V^2 \propto kT/C$ (dimensionally), and the square of the noise voltage is inversely proportional to the capacitance C; the resistance in the circuit has no effect since it does not appear in the dimensional solution. Observe that problems of this type are solved with the slide rule without calculus.

Problem 2: Determine the "meaning" of

$$\epsilon_o c^2 \nabla^2 A \quad + (1/\mu_o)\nabla(\nabla \cdot A) + \epsilon_0 \partial\phi/\partial t) + \epsilon_0(\partial^2 A/\partial t^2)$$

where ϵ_o = permittivity constant, c = velocity of light, A = vector potential, μ_o = permeability constant, t = time, and ϕ = scalar potential, it is only necessary to obtain the meaning of one term (since each term must equal every other term because only identical 'things' may be added). Selecting the term $\epsilon_o\, \partial^2 A/\partial t^2$, which is dimensionally equivalent to $\epsilon_o A/t^2$,

Step 1. Set left C-index to ϵ_0 on D-scale.

Step 2. Move hairline to A on C-scale.

Step 3. Set t on C-square scale under hairline.

Step 4. Read answer j (current density) on D-scale, under right C-index.

Therefore,

$$\epsilon_0 c^2 \quad {}^2 A + (1/\mu_0) \quad (\quad \cdot A) + \epsilon_0(\partial \quad \phi/\partial t) + \epsilon_0(\partial^2 A/\partial t^2) = j.$$

D. Identify unknown symbols in formulas

Identify the symbol n in

$I = nqvA$,
where I = electrical current in a wire, q = charge, v = average drift of the carriers, and A = cross section of the wire. The slide rule is used as follows:

Step 1. Solve for n in the given formula. Since $I = nqvA$, $n = I/qvA$.

Step 2. Identify I/qvA. Move hairline to I on D-scale; set q on C-scale under hairline; move hairline to left C-index; set v on C-scale under hairline; move hairline to right C-index; set S_a (surface area) on C-scale under hairline; and read answer n_{Vo} (number/volume) under right C-index, on D-scale.

Therefore,
n = number (of charges)/volume.

E. Reconstruct formulas

Reconstruct a formula from ω, μ, B, and L, where ω = angular frequency (of precession of a particle about the direction of a magnetic field because of the action of a magnetic torque); μ = magnetic dipole moment (of the particle), μ_m on the slide rule; B = magnetic induction; and L = angular momentum (of the "spinning" particle), L_m on the slide rule.

The slide rule is used as follows to relate ω, μ, B and L:

Step 1. Move the hairline to ω on the D-scale.

Step 2. Set μ_m on C-scale under hairline, forming the ratio ω/μ_m.

Step 3. Move the hairline to B on D-scale and observe the ratio B/L_m.

Therefore, $\omega/\mu_m = B/L_m$. Solving for ω, $\omega = \mu_m B/L_m$.

Outlook

It is the author's belief that the dimensional slide rule has great potential both for learning expert manipulation of known laws of nature (mechanical, electrical, nuclear) as well as for plowing of new areas.

In 1967, Keuffel & Esser Co. brought out the "Analon" dimensional slide rule under license to the author. This slide rule contained 30 physical quantities. Since then, the author has developed his own version including over 70 quantities and has carried out a pilot production run. He is presently pursuing the use of this slide rule in educational institutions.

Considering today's technology, it would appear that a cost effective dimensional calculator may soon become a reality. However, today the low cost dimensional slide rule is ready to carry out many divergent tasks. Those further interested in this topic may contact the author at:

501 Oaklawn Ave., Oaklyn, N.J. 08107
Tel.: 609-854-1628

Acknowledgment

The author gratefully acknowledges the assistance of Dr. L.J. Gagliardi and Kenneth Pikus in the pursuit of the applications of the dimensional slide rule.

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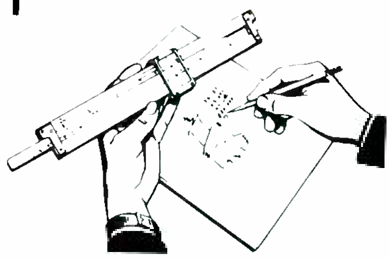
Engineering and Research Notes



Automatic black-level set

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The black-level signal setting of video cameras for outdoor use and surveillance operations in general can be improved by the circuit shown in Fig. 1, which reduces the time required to set the black-level bias and eliminates the bias ripple voltage for a video signal that is unchanging from frame to frame, thus virtually eliminating shading from the viewed picture.

In operation, an uncontrolled video signal V_{in} is applied to a noninverting summing amplifier and coupled to adjustable comparators V_{T1} and V_{T2}. The V_{T1} drive signal causes the bias drive integrator to ramp. The negative going bias control drive, which is coupled to the inverting input of the summing amplifier, drives the output video signal toward the V_{T1} and V_{T2} threshold band. When V_{T1} is reached, the retriggerable one-shot fires, decoupling the input drive to the bias drive integrator, which in turn stops the bias control drive. If the black-level signal peak stays above the V_{T1} threshold at least once per field, no further action occurs to change the bias control drive and resulting black-level operating bias point.

If the input video signal goes more black and exceeds the V_{T2} threshold, the V_- drive ramps the integrator in the opposite direction only for as long as the threshold is exceeded. Because the V_{T2} threshold is normally exceeded only a small fraction of the total time of a field, the V_- drive is chosen to be 100 to 1000 times the V_+ drive, which results in a system transient recovery time that is comparable in the two directions.

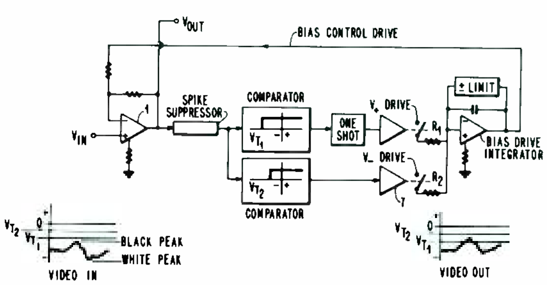

Fig. 1 — Circuit used to establish black level automatically.

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Inrush current reduction in triac-switched inductive loads

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In the ac power-control system of Fig. 1, the inrush current of a triac-switched inductive load (such as a motor) is reduced by initially firing the triac when the ac voltage is at its peak, and then changing the firing point to the load-current zero crossings.

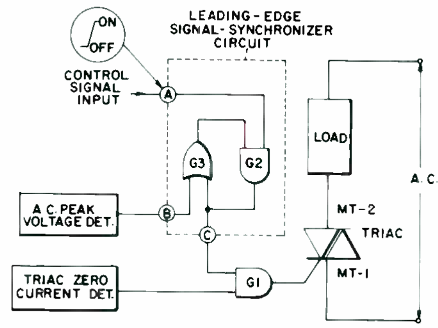

Fig. 1 — AC power control system.

Initially, when the triac is *off* and the control signal is low, output C of the leading-edge signal synchronizer circuit is low, thereby inhibiting triggering of the triac via gate G_1. Gate G_1 is primed, however, by the triac zero-current detector to trigger the triac whenever terminal C becomes high. This happens when the first peak of the ac voltage occurs subsequent to a positive transition of the control signal. Specifically, when the control signal is high, *and* gate G_2 is primed. When the ac voltage reaches a peak, the ac peak voltage detector applies a pulse to terminal B that enables *and* gate G_2 via the *or* gate G_3. Thus, the triac is triggered immediately at the first peak of the ac signal subsequent to a positive transition of the control signal.

Positive feedback around *and* gate G_2 via *or* gate G_3 maintains output C high after the termination of the peak-voltage-detector pulse. Accordingly, the triac is triggered thereafter by the detector via gate G_1 at each axis crossing of the load current. When the control signal is low, *and* gates G_2 and G_1 are disabled immediately. The triac subsequently self-commutates *off* when the load current reverses.

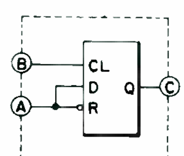

Fig. 2a — Synchronizer circuit with leading edge synchronized.

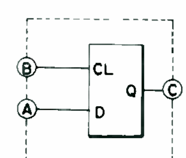

Fig. 2b — Synchronizer circuit with leading and trailing edges synchronized.

The synchronizer circuit may be implemented in a number of ways, such as with *nor* or *nand* gates or with a D flip-flop, as shown in Fig. 2(a). While it is necessary that the circuit synchronize the leading edge of the signal at A with the signal at B, it is not necessary that the trailing edge be synchronized. Fig. 2(b) is an example of a synchronizer in which both the leading and trailing edges of the signal at A are synchronized with the signal at B.

Fig. 3 illustrates a practical circuit for implementing the system of Fig. 1. The circuit includes an integrated-circuit timer for providing timed control of the load current. In Fig. 3, the *on* time period is determined by selection of resistors R_1 and R_2 and capacitor C_1. Circuit operation is as previously described with regard to Fig. 1. In Fig. 3, the synchronizer circuit is composed of a type-CA3083 transistor array; the peak-voltage detector is composed of a diode-resistor network. The functions of *and* gate G_1 and the zero-current detector are performed by the combination of the type-CA3059 and CA3086 integrated circuits.

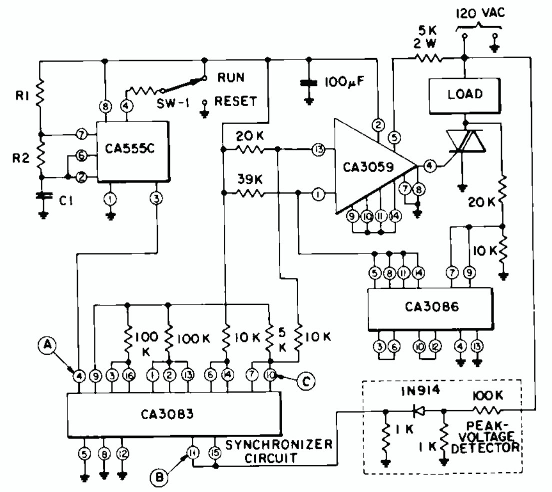

Fig. 3 — Practical example of system shown in Fig. 1.

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Improved method and apparatus for measuring capacitance as a function of voltage

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Measurement of the small-signal differential capacitance of an MIS (metal-insulator-semiconductor) device as a function of the applied quasi-dc bias voltage can be used to derive information about the interface properties at the IS (insulator-semiconductor) interface and the doping of the underlying semiconductor. This investigative technique is known as the MIS capacitance method. However, the MIS capacitance method has some severe limitations. It has been shown[1] that because the MIS capacitance consists essentially of the insulator capacitance C_I in series with the semiconductor space-charge capacitance C_S, there is a practical upper limit on the magnitude of C_S that can be measured with reasonable accuracy; *viz.*, $C_S \lesssim 10C_I$. This leads to a restriction on the region of the forbidden energy gap in which interface states may be studied by the MIS capacitance method, as well as an upper limit on the thickness of the insulating layer beyond which no useful information may be obtained. In order to overcome these limitations, a modified MIS capacitance method has been developed, which allows the accurate determination of C_S when the ratio C_S/C_I becomes very large. In fact, the inherent limit using the modified method is no longer directly dependent on this ratio but rather on the noise level in the capacitance measurement.

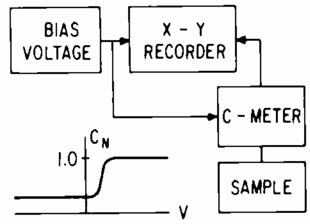

Fig. 1 — Conventional high frequency C - V measurement.

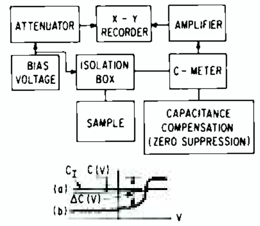

Fig. 2 — Modified high-frequency C-V measurement.

There is also, in some cases, an instrumental limitation to the application of the MIS capacitance method. This occurs when, due to a thick insulating layer, a very large bias voltage is required to span the capacitance range of interest. Commercially available C meters, (capacitance meters) which typically have applied bias capabilities of ±600 V or less, may be inadequate.

Conventional high-frequency MIS capacitance measurements are usually carried out using the type of system shown in Fig. 1. The bias voltage is applied to the sample through the C meter and is simultaneously displayed on the x axis of the recorder. The sample capacitance is continuously measured by the C meter, which provides a quasi-dc analog signal to the y axis of the recorder. The sensitivity is typically limited by a minimum full scale value of about 10^{-12} F, and the magnitude of the bias voltage is typically limited by a maximum value of 600 V or less.

The C-meter sensitivity and/or the recorder y-axis sensitivity are then adjusted so that C_I is exactly full scale. The normalized capacitance $C_N = C/C_I$ can then be plotted versus applied bias voltage V. This is shown schematically in the inset in Fig. 1. The value of C_I and the plot of $C_N(V)$ may be used to evaluate $C_S(V) = [C_IC_N(V)]/[1-C_N(V)]$.

If, however, $C_S >> C_I$ then the accuracy with which U_S can be determined is diminished. As C_N approaches 1, the maximum relative error in the determination of C_S becomes very large.[1]

The error and bias-voltage limitations may be significantly mitigated by modifying the measurement system. A functional block diagram of such a modified system is shown in Fig. 2. It can be seen that there are four additional parts in the system; their functions are as follows. The isolation box[2] allows the bias voltage to be applied to the sample while keeping it out of the C meter; at the same time, it isolates the bias-voltage supply from the high-frequency (usually 1-MHz) test signal being used by the C meter to measure the sample capacitance. This removes the previously mentioned bias-voltage limitation. The capacitance compensation box is connected to the differential terminals of the C meter in order to "cancel out" most of the sample capacitance (thereby suppressing the zero level) and allowing the output of the C meter to be amplified without going off the y-axis scale of the recorder. The precise value of the compensation capacitance is not critical. The attenuator is used to diminish the bias voltage to a level that can be accommodated by the recorder.

The measurements are carried out in the following sequence. The capacitance versus voltage measurement is carried out in the usual way. This gives the type of curve shown schemaβcally and designated as (a) in the inset in Fig. 2. The maximum value is the insulator capacitance C_I. The output signal of the C meter (the y-axis signal to the recorder) is reduced to nearly zero by adjusting the capacitance compensation box at the differential terminals of the C meter. The gain is then raised by either raising the amplifier gain or increasing the sensitivity of the y axis at the recorder.

The magnitude of the variation in the capacitance from its maximum value C_I is $|C - C_I| = C_I - C \equiv \Delta C(V)$. This can now be plotted and is shown schematically as (b) in the inset in Fig. 2.

The value of C_S may then be obtained from the relation $C_S = C_I[(C_I/\Delta C) - 1]$. An analysis[3] shows that the value of C_S obtained in this way can be far more accurate than the value obtained by the conventional MIS capacitance method when $C_S/C_I > 1$. The method and apparatus described in this note are treated in more detail in Ref. 3.

Two important applications of this modified MIS capacitance method have emerged:

1) Characterization of the interface between Si and a thick glass layer used to passivate it.[3]
2) Characterization of epitaxially deposited Si on sapphire and the Si-sapphire interface.[4]

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Combination bulb spacer and glass particle trap

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A substantial percentage of color television tubes require scrapping and/or rebuilding because mask apertures become clogged by particles. These particles sometimes originate during final tube processing. A major source of such particles, however, is produced by regunning of the tube. A hole is made in the neck of the tube to relieve the internal vacuum and the neck is then cracked off, generating a substantial amount of glass powder or particles in the gun region, which are swept into the tube particularly during the initial opening to air.

The electron gun structure of conventional television tubes comprises a plurality of aligned electrodes including a convergence cage mounted on a plurality of insulator members, see Fig. 1. According to typical prior art structures, the gun is centered in the neck and held in place by a series of leaf spring spacers, which are in contact with a conductive coating on the inside of the televison tube. Such conventional structures make it very difficult to prevent all the particles from migrating to the mask and blocking the apertures.

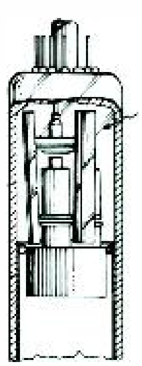

Fig. 1 — Electron gun structure.

As an improvement, the present gun includes a continuous coil spring which, as shown in Fig. 1, is placed in the general area of the convergence cage and spans the gap between the outside diameter of the convergence and the conductive coating on the inside diameter of the glass neck of the picture tube. The coil, which serves as a centering spacer, can be directly fastened to the cage by welding or held in place by clips. The coil spring also acts as a filter during the inrush of air in the "airing" operation and is removed with the gun after the "cracking off" operation to sweep out substantially all glass particles produced during the "airing" and "cracking off" processes.

The coil spring thus acts as a combination spacer for the convergence cage from the bulb and a glass particle trap, eliminating blocked apertures produced during the "airing" or "cracking off" processes.

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Limited signal-seeking AFT system

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Carlson

George

A varactor controlled uhf television tuner (see Fig. 1) is tuned by a 70-position detent, which is coupled to a switch having as many voltage dividers (not shown) as positions. The voltage dividers provide different voltages to establish the desired tuning. To eliminate the necessity for manual fine tuning, a low-cost limited signal-seeking AFT system is provided.

The limited signal-seeking system incorporates a shorting switch coupled to the 70-position detent. The shorting switch is operative to provide a closed circuit across the capacitor in between each of the detented positions. When the uhf tuner is set at a particular detented position, the switch is open and the capacitor is caused to charge to a quiescent voltage level provided at the output terminal of a conventional AFT circuit. The charging of the capacitor causes the frequency of the local oscillator in the tuner to sweep through a narrow band of frequencies. If a television carrier is received, the AFT loop action takes over and locks the tuner onto the desired frequency. Subsequent channel change causes the switch to discharge the capacitor in preparation for the charging cycle that occurs at the next selected detent position.

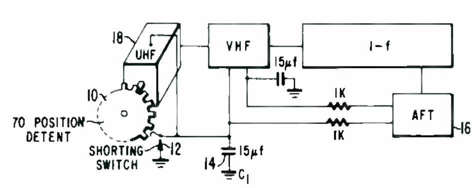

Fig. 1 — Limited signal-seeking AFT system.

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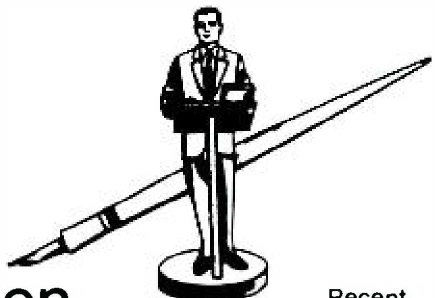

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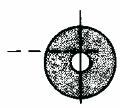

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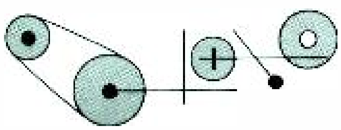

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Injection laser modulator — H. Kawamoto, D.J. Miller (Labs, Pr.) U.S. Pat. 3953809, Apr 27, 1976.

Wave-energy imaging technique — D.H. Vilkomerson (Labs, Pr.) U.S. Pat. 3953822, Apr 27, 1976.

Signal pickup return mechanism — M.A. Leedom (Labs, Pr.) U S. Pat. 3954272, May 4, 1976.

Microwave delay line — L.C. Upadhyayula, M. Nowogrodzki (Labs, Pr.) U.S. Pat. 3955158, May 4, 1976.

Surface acoustic wave device — M.T. Duffy (Labs, Pr.) U.S. Pat. 3955160, May 4, 1976.

Metal plated or platable article — G.S. Lozier (Labs, Pr.) U.S. Pat. 3956535, May 11, 1976.

Picture Tube Division

In-line electron guns having consecutive grids with aligned vertical substantially elliptical apertures — J. Evans, Jr. (PTD, Lanc.) U.S. Pat. 3952224, Apr 20, 1976.

CRT comprising strontium metal getter films and method of preparation — J. C. Turnbull (PTD, Lanc.) U.S. Pat. 3952226, Apr 20, 1976.

Special Contract Division

Adjustable spring mount for a cathode ray tube yoke — T M. Shrader, U.S. Pat. 3950720, Apr 13, 1976.

Diphenyl continuous form dyeing with fabric running over rolls in foam bath — B.M. Childers, C.D. Fesperman, Jr. (Cor Ind., Dalton, Ga.) U.S. Pat. 3954404, May 4, 1976.

Pickup arm apparatus — B.K. Taylor (Sel. Proj., Indpls.) U.S. Pat. 3956581, May 11, 1976.

Process for non-destructive inspection — E.L. Crosby, Jr. (Sv Co., Pat. AFB) U.S. Pat. 3956631, May 11, 1976.

Advanced Technology Laboratories

Zero crossover detector — R.L. Pryor (ATL, Cam.) U.S. Pat. 3944936, Mar 16, 1976.

Missile and Surface Radar Division

Magnetic disc coder-decoder — V.A. Schlenker (MSRD, Mrstn) U.S. Pat. 3937880, Feb 10, 1976 (Pat. assigned to U.S. Gov't).

Digital interpolator for reducing time quantization errors — H. Urkowitz, R.P. Perry, L. Weinberg (MSRD, Mrstn) U.S. Pat. 3943346, Mar 9, 1976.

Data processor recorder random access memory — L.W. Martinson (MSRD, Mrstn) U.S. Pat. 3943347, Mar 9, 1976.

Sidelobe lock-on discriminating method for search-track monopulse radar — D.J. Dempsey (MSRD, Mrstn) U.S. Pat. 3943512, Mar 9, 1976.

Avionics System Division

Altitude coding for collision avoidance system — J.J. Lyon (ASD, Van Nuys) U.S. Pat. 3947845, Mar 30, 1976.

Gain-controlled amplifier — J.R. Hall (ASD, Van Nuys) U.S. Pat. 3950708, Apr 13, 1976.

Astro-Electronics Division

Replaceable solar array panels — A. Anchutin (AED, Htstwn) U.S. Pat 3948468, Apr 6, 1976.

RCA Limited

Timing technique for NRZ data signals — K. Feher (RCA Ltd., Montreal) U.S. Pat. 3944926, Mar 16, 1976.

RCA Records

Start-up power supply for a television receiver — R.J. Giger, J.M. Lawrence (RCA Records, Indpls.) U.S. Pat. 3947632, Mar 30, 1976

Distributor and Special Products Division

Constant temperature control for transferred electron devices — D.D. Mawhinney, T.E. Walsh (DSPD, Har.) U.S Pat. 3953878, Apr 27, 1976.

Solid State Division

Use of aluminum for bonding silicon-germanium type alloys to graphite — R.V. Eggemann (SSD, Har.) U.S. Pat. 3931673 assigned to U.S. Gov't., Jan 13, 1976.

Fluid flow measuring system — J.A. Olmstead (SSTC, Som.) U.S. Pat 3931736, Jan 13, 1976.

Fluid flow measuring system — J.A. Olmstead (SSTC, Som.) U.S. Pat. 3942378, Mar 9, 1976.

Keyed comparator — D.K. Morgan, R.C. Heuner (SSD, Som.) U.S. Pat. 3943380, Mar 9, 1976.

LSI array using field effect transistors of different conductivity type — G.E. Skorup, (SSTC, Som.) U.S. Pat. 3943551, Mar 9, 1976.

Bridge-balance detection circuit — M.V. Hoover (SSD, Som.) U S. Pat. 3944859, Mar 16, 1976.

Side pincushion correction circuit — W.F. Dietz (SSD, Som.) U.S. Pat. 3946274, Mar 23, 1976.

Transistor amplifier — A.J. Leidich (SSD, Som.) U.S. Pat. 3946325, Mar 23, 1976.

Timer circuits — A.C. Sheng, M.V. Hoover (SSD, Som.) U.S. Pat. 3950657, Apr 13, 1976.

Current proportioning circuits — O.H. Schade, Jr. (SSD, Som.) U.S. Pat. 3952257, Apr 20, 1976.

Method of electrolessly depositing nickel phosphorus alloys — A.F. Arnold (SSTC, Som.) U.S. Pat. 3953624, Apr 27, 1976.

Ground fault detection apparatus — A.A. Ahmed (SSD, Som.) U.S. Pat. 3953767, Apr 27, 1976.

Current amplifier — O.H. Schade, Jr. (SSD, Som.) U.S. Pat. 3953807, Apr 27, 1976.

Method and apparatus for determining the average size of apertures in an apertured member — F.R. Ragland, Jr. (SSD-Lanc.) U S. Pat. 3954337, May 4, 1976.

Method and apparatus for determining the average size of apertures in an apertured member — G.S. Gadbois, F.R. Ragland, Jr. (SSD, Lanc.) U.S. Pat. 3955095, May 4, 1976.

Self-fusing transcalent electrical device — S.W. Kessler, Jr. (SSD, Lanc.) U.S. Pat. 394629, Mar 23, 1976.

Erasing method for storage tube employing raster scan — E.M. Smith (SSD, Lanc.) U.S. Pat. 3950669, Apr 13, 1976.

Method for preparing supplemental filter for lighthouse — T.L. Chase, D. Duranti, R. Sassoli, (SSD, Lanc.) U.S Pat. 3952586, Apr 27, 1976.

Consumer Electronics

Retrace pulse generator having improved noise immunity — M.L. Henley, L.E. Smith (CE, Indpls.) U.S. Pat. 3944883, Mar 16, 1976.

Channel number memory for television tuners — D.E. Christensen (CE, Indpls) U.S. Pat. 3947773, Mar 30, 1976.

Multi-layer toroidal deflection yoke — I.F. Thompson (CE, Indpls) U.S. Pat. 39477993, Mar 30, 1976.

Method of tuning a tunable microelectronic LC circuit — L.A. Olson (CE, Indpls.) U.S. Pat. 3947934, Apr 6, 1976.

Gating circuit for television SCR defleciton system — R.J. Gries (CE, Indpls.) U.S. Pat. 3950673, Apr 13, 1976.

D.C. Reinsertion in video amplifier D.H. Willis (CE, Indpls.) U.S. Pat. 3955047, May 4, 1976.

Transistor amplifier stage with device in its temperature compensated bias network used as preliminary amplifier — J.B. Beck (CE, Indpls.) U.S. Pat. 3955108, May 4, 1976.

Commercial Communications System Division

Circlarly polarized antenna system using a combination of turnstile and vertical dipole radiators — O. Ben-Dov (CCSD, Cam.) U.S. Pat 3943522, Mar 9, 1976.

Protection circuit for insulated-gate field-effect transistors — R.G. Stewart (CCSD, Som.) U.S. Pat. 3947727, Mar 30, 1976.

Reference signal generator for tape tension servomechanism — A.M. Goldschmidt (CCSD, Cam.) U.S. Pat. 3949244, Apr 6, 1976

Metal spray forming of waveguide for phase shifter case — W A Dischert (CCSD, Cam.) U.S. Pat. 3952267, Apr 20, 1976 (Pat. assigned to U.S. Gov't).

Amplitude modulation system — W.L. Behrend (CCSD, MdwLnds) U.S. Pat. 3955155, May 4, 1976.

Amplitude modulation system — W.L. Behrend (CCSD, MdwLnds) U.S. Pat. 3956715, May 11, 1976.

SelectaVision Project

Pickup arm cartridge apparatus — J.A. Allen (SV, Indpls.) U.S. Pat. 3952145, Apr 20, 1976.

Automated Systems Division

Power test means and method for internal combustion engines — R.E. Hanson, T.E. Nolan, Jr. (ASD Burl.) U.S. Pat. 3942365, Mar 9, 1976.

Determining engine compression from starter motor current — R.E. Hanson, T.E. Nolan, Jr. (ASD, Burl.) U.S. Pat. 3952186, Apr 27, 1976.

Dates and Deadlines

Calls for papers
—be sure deadlines are met

Ed. Note: Calls are listed chronologically by meeting date. Listed after the meeting (in bold type) are the sponsor(s), the location, and deadline information for submittals.

NOV. 9-11, 1976 — **IEEE Int. Pulsed Power Conf.,** Hilton Inn, Lubbock, TX **Deadline Info: (abst) 8/15/76 (papers) 10/15/76 to** Dr. T.R. Burkes or Dr. M. Kristiansen, Dept. Elec. Engrg., Texas Tech. University, Lubbock, TX 7409.

DEC. 6-10, 1976 — **Submillimeter Waves and Their Applications** (IEEE, OSA, ICO) San Juan, Puerto Rico **Deadline Info: (ms) 8/1/76 to** K.J. Button, MIT, Nat. Magnet Lab., Cambridge, MA.

JAN. 30 - FEB. 4, 1977 — **Power Engineering Society Winter Meeting (IEEE)** Statler Hilton Hotel, New York, NY **Deadline Info: (ms) 9/1/76 to** IEEE Office, 345 E. 47 St., New York, NY 10017.

MARCH 28-31, 1977 — **IEEE 1977 Int. Semiconductor Power Converter Conf.** Walt Disney Contemporary Hotel, Orlando, FL **Deadline info: (ms) 11/5/76 to** R.G. Hoft, Univ. of Missouri, Columbia, MO 65201.

May 9-11, 1977 — **Acoustics, Speech & Signal Processing Int. Conf.** (ASSP) Sheraton Hartford Hotel, Hartford, CT **Deadline Info: (100 wd. abst) 10/15/76 (4-pg. ready paper) 1/14/77 to** Dr. N. Rex Dixon, T.J. Watson Res. Ctr., POB 218, Yorktown Heights, NY 10598.

MAY 24-27, 1977 — **1977 Power Industry Computer Application Conf. (PICA X)** (IEEE) Toronto, Ont., Canada, **Deadline Info: (150-200 wd. abst) 10/8/76 (ms) 1/3/77 to** IEEE Technical Conference Services Office, 345 E. 47 St., New York, NY 10017.

JUNE 20-24, 1977 — **Int. IEEE/AP Symp. & USNC/URSI Meeting,** (IEEE, USNC/URSI) Palo Alto, CA **Deadline Info: (papers) 1/77 to** K.K. Mei, Dept. of EE&CS, Univ. of Calif., Berkeley, CA 94720.

JUNE 1-23, 1977 — **Int. Microwave Symp.** (IEEE) San Diego, CA **Deadline Info: (papers) 1/77 to** G. Schaffner, 6320 Elmcrest Dr., San Diego, CA 92119.

JULY 17-22, 1977 — **Power Engineering Society Summer Meeting** (IEEE) Mexico City, Mexico **Deadline Info: 1/1/77 to** IEEE, 345 E. 47 St., New York, NY 10017.

AUG. 24-26, 1977 — **Product Liability Prevention Conf.** (IEEE, *et al*) Newark College of Engrg., Newark, NJ, **Deadline Info: 11/1/76 to** R.M. Jacobs, Newark College of Engrg., 323 High St., Newark, NJ 07102.

SEPT. 18-21, 1977 — **American Ceramic Society Fall Meeting** (IEEE, ACS) Queen Elizabeth Hotel, Montreal PQ, Canada **Deadline Info: (abst.)** 1/77 to Hank O'Brien, Bell Labs., Murray Hill, NJ 07974.

SEPT. 37-OCT. 1, 1976 — **Underground Transmission & Distribution** (IEEE) Convention Hall, Atlantic City, NJ **Prog Info:** P.H. Ware, Alcoa Conductor Pdts. Co., 510 One Allegheny Sq., Pittsburgh, PA 15212

SEPT. 29-OCT. 1976 — **Ultrasonics Symp.** (IEEE) Annapolis Hilton Hotel, Annapolis, MD **Prog. Info:** L.R. Whicker, Code 5250, Naval Res. Lab., Washington DC 20375.

OCT. 10-15, 1976 — **Int. IEEE/AP Symp. & USNC/URSI Meeting** (IEEE USNC/URSI) Univ. of Mass., Amherst, MA **Prog Info:** R.E. McIntosh, Dept. of Elec. & Computer Engrg., Univ. of Mass., Amherst, MA 01002.

OCT. 11-14, 1976 — **Industry Applications Society Annual Meeting** (IEEE Chicago Section) Regency Hyatt O'Hare, Chicago, IL **Prog Info:** G.R. Griffith, Atlantic-Richfield, Harvey Tech. Ctr., 400 E. Sibley Blvd., Harvey, IL.

OCT. 13-15, 1976 — **Display Conf.** (IEEE, SID) Statler Hilton Hotel, New York, NY. **Prog Info:** Frederick Kahn, Hewlett Packard Lab., IU, 1501 Page Mill Rd., Palo Alto, CA 94304.

OCT. 13-15, 1976 — **Software Engineering Conf.** (IEEE ACM, NBS) Jack Tarr Hotel, San Francisco, CA **Prog Info:** R.T. Yeh, Dept. of Computer Sci., Physics Bldg. 3.28, Univ. Texas, Austin, TX 78712.

OCT. 21-22, 1976 — **Canadian Communications & Power Conf.** (Canadian Region, Montreal Section) Queen Elizabeth Hotel, Montreal, Quebec, Canada **Prog Info:** Jean Jacques Archambault, CP/PO 958, Succ. "A" Montreal, Quebec H3C, 2W3 Canada.

OCT. 25-26, 1976 — **Joint Engineering Management Conf.** (IEEE, EIC *et al*) Hyatt Regency Hotel, Toronto, Ont., Canada **Prog Info:** K.L. Couplan, Ministry of Colleges & Univ., 60 Sir Williams Lane, Islington, Ont., Canada M9A IV3.

OCT. 25-27, 1976 — **Foundations of Computer Science** (IEEE) Warwick Hotel, Houston, TX **Prog Info:** J.W. Carlyle, 4531 Boetter Hall, UCLA, Los Angeles, CA 90024.

OCT. 25-27, 1976 — **High Speed Computation Symp.** (IEEE) Univ. of Illinois, Urbana, IL **Prog Info:** Duncan Lawrie, Dept. of Computer Sci., Univ. of Illinois, Urbana, IL 61801.

Dates of upcoming meetings
—plan ahead

Ed. Note: Meetings are listed chronologically. Listed after the meeting title (in bold type) are the sponsor(s), the location, and the person to contact for more information.

AUG. 24-27, 1976 — **Parallel Processing** (IEEE, Wayne State Univ.) Walden Woods Resort & Conf. Ctr., Walden Woods, MI **Prog Info:** T. Feng, Dept. of Elec. & Computer Engrg., Wayne State Univ., Detroit, MI 48202.

AUG. 25-27, 1976 — **Product Liability Prevention Conf.** (IEEE *et al*) Newark College of Engrg., Newark, NJ, **Prog Info:** R.M. Jacobs, Newark College of Engrg., 323 High St., Newark, NJ 07102.

SEPT. 7-10, 1976 — **European Conf. on Circuit Theory & Design** (Region 8, N. Italy Section *et al*) Univ. of Genova, Genova, Italy, **Prog Info:** Ing. Giuseppe Biroci, Instituto di Elettrotecnica, Viale F. Causa 13, 16145 Genova, Italy.

SEPT. 8-10, 1976 — **Technology for Selective Dissemination of Information** (IEEE *et al*) Palazzo Dei Congressi, San Marino, Italy **Prog Info:** Giorgio Valle, Univ. Degli Studi Di Bologna, Instituto Di Electronics, 40136, Bologna, Italy.

SEPT. 12-17, 1976 — **Intersociety Energy Conversion Engrg. Conf.** (IEEE *et al*) Sahara Tahoe, Stateline, Lake Tahoe, NV **Prog Info:** E.J. Cairns, Gen'l Motors Res. Lab., 12 Mile & Mound Rds., Warren MI 48090.

SEPT. 14-17, 1976 — (WESCON) (L.A. & S.F. Councils, ERA) Los Angeles Conv. Ctr., Los Angeles, CA. **Prog Info**: W.C. Weber, Jr., WESCON, 999 N. Sepulveda Blvd., El Segundo, CA 90245.

SEPT. 20-24, 1976 — **Int. Broadcasting Conf.** (EEA, IEE, IEEE UKRI Section) Grosvenor House, Park Lane, London, England **Prog Info:** IEE Savoy Place, London WCZR OBL, England.

SEPT. 23-24, 1976 — **Broadcast Symp.** (BCCE) Washington, DC **Prog Info:** IEEE Office, 345 E. 47th St., New York, NY 10017.

SEPT. 26-29, 1976 — **Electronic & Aerospace Sys. Convention** (EASCON) (AES, Washington Section) Stouffers Inn, Washington, DC.

Engineering News and Highlights

Sarnoff Awards presented

PLAUDITS FOR PICTURE TUBES— Anthony L. Conrad, RCA Chairman and President (left) presents a 1976 David Sarnoff Award for Outstanding Technical Achievement to Albert M. Morrell, RCA Picture Tube Division, Lancaster, Pa. Mr. Morrell received the award "for his continuing technical contributions to the design of color picture tubes." Dr. James Hillier, RCA Executive Vice President and Senior Scientist is on right.

CREDIT FOR COLORTRAK — Anthony L. Conrad, RCA Chairman and President (left) presents the 1976 David Sarnoff Awards for Outstanding Achievement to Dr. J Peter Bingham, Walter G. Gibson, Marvin N. Norman, Dr. Chandrakant B. Patel, Robert L Shanley II, and Bernard Yorkanis. "for outstanding team cooperation in bringing certain revolutionary video concepts from research to commercial product in the ColorTrak system." Mr. Gibson and Dr. Patel are with RCA Laboratories, Princeton, N.J. Dr. Bingham and Messrs. Norman, Shanley and Yorkanis are with RCA Consumer Electronics. Mr. Yorkanis is located in Somerville, N.J.; the others are in Indianapolis. Mr. Jack Avins of RCA Laboratories was also honored with the team, but was unable to attend the ceremonies.

MERIT FOR MICROPROCESSORS—Anthony L. Conrad, RCA Chairman and President (left) presents 1976 David Sarnoff Awards for Outstanding Technical Achievement to Joseph A. Weisbecker and Dr. Robert O. Winder, both of RCA Laboratories, Princeton, N.J. They were cited "for excellence of team effort leading to the development and marketing of an advanced microprocessor." Dr. James Hiller, RCA Executive Vice President and Senior Scientist is on right.

COMMUNICATIONS COMMENDATIONS—Anthony L. Conrad, RCA Chairman and President (left) presents 1976 David Sarnoff Awards for Outstanding Technical Achievement to Dr. John E. Keigler, RCA Astro-Electronics Division, Hightstown, N.J., and Lorne Keyes, RCA Limited, Montreal. They received a team award "for outstanding contributions to the development of a highly cost effective communications satellite, the RCA Satcom series." Dr. James Hillier, RCA Executive Vice President and Senior Scientist (right) looks on.

Professional Activities

RCA Laboratories

Dr. David E. Carlson, Process and Applied Materials Research Laboratory has received the American Ceramic Society's 1976 Ross Coffin Purdy Award "in recognition of his outstanding contribution to ceramic literature in the year 1974." Dr. Carlson was honored for his paper, "Ion depletion of glass at a blocking anode: I, theory and experimental results for alkali silicate glasses."

Dalton H. Pritchard has been elected a Fellow of the Society for Information Display. He was cited for contributions to the NTSC color television system, color tv magnetic recording and innovations in associated tv equipment including the RCA VideoDisc system.

The IEEE Princeton Section for 1976-77 has elected **Lubomyr S. Onyshkevych** Chairman and **Jules D. Levine** Vice Chairman.

Solid State Division

Dr. Ralph Engstrom, Senior Engineer, Electro-Optics and Devices, Lancaster, Pa., recently received a letter of appreciation from students who completed the twelve session RCA Minorities in Engineering Program at that facility. The Lancaster program is one of twelve MEP projects at RCA facilities around the country.

Awards

ATL honors Authors, Speakers, Inventors

A reception was held on April 18 to recognize members of Advanced Technology Laboratories who had increased their professional stature and added to RCA's prestige by having had a paper published, having presented a paper, or being granted a patent. Those honored were:

G. J. Ammon	M.L. Levene
D. Benima	A.A. Litwak
A. Boornard	T.J. Lombardi
W.A. Borgese	E.P. McGrogan
G.M. Claffie	R. Noto
W.A. Clapp	S.E. Ozga
S.L. Corsover	J.I. Pridgen
G.J. Dusheck	R.L. Pryor
N.H. Farhat	P.W. Ramondetta
R.T. Fedorka	C.W. Reno
A. Feller	J.E. Roddy
J.E. Friedman	J.E. Saultz
D.A. Gandolfo	R.D. Scott
W.F. Gehweiler	B. Shelpuk
W.F. Heagerty	B.W. Siryj
E. Herrmann	A.M. Smith
D.G. Herzog	C. Strasberg
K.C. Hudson	D.J. Woywood
H.W. Kaiser	H.J. Zadell
R.F. Kenville	

Government Communications Systems Division

Ray Chicalo, Digital Equipment Engineering, has received the Technical Excellence Award for his outstanding work on the TENLEY KVG. Ray was required to develop a complex digital data-processing system using custom static CMOS LSI arrays to replace the dynamic PMOS LSI arrays used in an earlier design. The required maintenance of an equivalent or smaller physical size than the predecessor equipment was a considerable task due to the larger size of CMOS arrays.

Ray Chicalo (left) demonstrates his system to (left to right) Ed Mozzi (Leader), Charley Schmidt (Manager, TENLEY Program), and Jim Fayer (Activity Manager).

GCSD hold 1975 Authors' and Inventors Reception

Government Communications Systems Division honored 68 technical staff members at an Authors' and Inventors' Reception at the Camden Plant Cafeteria, recently. Each of those honored had authored a paper, prepared an invention disclosure or had a patent issued in his name in 1975.

Host for the reception was **Joseph B. Howe,** Chief Engineer. Guests included **Dr. J. Vollmer,** Division Vice President and General Manager, GCSD; **R. Trachtenberg** acting for Vice President, Government Engineering; **H.K. Jenny,** Manager, Technical Information Programs; **J. C. Phillips,** Editor, *RCA Engineer*; and **F. Strobl,** Editor, *Trend*.

Special recognition was given **E.J. Nossen** for seven papers and six invention disclosures; **D. Hampel** for six papers; **E. VAn Keuren, H. Rubenstein, E.R. Starner, S. Yuan** for five papers each and **H.H. Chapman** for five invention disclosures.

(Left to right) R. Trachtenberg acting for Vice President, Government Engineering viewing the "Order of Prolificacy" lists with H. Rubenstein, five papers; H.H. Chapman, five invention disclosures; and E. Van Keuren, five papers.

Division Vice President and General Manager, Dr. J. Vollmer (left) congratulates E.J. Nossen for his seven papers and six invention disclosures.

J.B. Howe, Chief Engineer (left) and D. Hampel.

One team, four individual achievement awards presented at Broadcast Systems, engineering conference

One Team Achievement and four Individual Achievement awards were presented at the fourth annual Broadcast Systems Engineering Conference recently.

Attending were about 300 employes from technical, manufacturing, and product management activities, and representatives of Corporate Staff, G&CS, Somerville, Princeton Labs and Meadow Lands.

The program was divided into a series of addresses during the afternoon, followed by discussion groups and dinner.

Individual Achievement Awards went to: **Alan Crego** for outstanding contributions to the Kish Island program; **Edward Swientisky** for outstanding engineering contributions to color camera production; **Oded Ben-Dov** for outstanding contributions to the Turnstile II development; and to **Donald Van Horne** for outstanding contributions to customer technical service.

The Team Achievement Award for outstanding contributions to the TK-76 program went to: **John Adison, Morris Bardock, Lucas Bazin, Sidney Bendell, Richard Boyland, Robert Brookes, William Bryan, Joseph Bulinkis, Louis Ciarrocchi, John Clarke, William Cosgrove, Raymond D'Andrea, Frank DiLeo, Raymond Dixon, Maurice Gallagher, Edward Haugh, Donald Herrmann, Harry Holroyd, Clifford Hoffer, Cydney Johnson, Robert Johnson, Raymond Jungclaus, Albert Kaiser, Robert Levins, Stephen Martorana, James McAdara, James McCormac, Dominic Mignone, Miles Moon, Henry Nasielski, Mark Nelson, William Parker, Fred Pfifferling, Vincent Renna, Dennis Schneider, Harry Schellack, Martin Schoettler, Furman Sherlock, Aleyis Shukalski, Rusling Slawter, Dale Smith, John Stevens, Sidney Sykes, Edwin Tatem, Z.N. (Nick) Trivelis, Louis Troilo, Wei Tsien, James Ward, Robert Weatherford, Fred Weber, Leonard Welsch, James Whisonant, Harry Wright** and **Guido Zappasodi.**

Employes were recognized for attending training seminars, after-hours and university courses; for patent disclosures; and for papers presented or published.

TK-76 team award winners.

J. Cassidy, A. Crego, N. Vander Dussen.

J. Ulasewicz, D. Van Horne, N. Vander Dussen, A Luther.

J. Ulasewicz, O. Ben-Dov, N. Vander Dussen, A. Luther.

J. Ulasewicz, E. Swientisky, N. Vander Dussen, A. Luther.

G&CS Canada — Technical Excellence Award Winners

At a Technical Awards Dinner held April 8, 1976, three teams were recognized. **G. Dziub, E. George, M. Altman, B. Dinsdale,** and **C. Kudsia** received a team award for the development of the GFEX Multiplex Assemblies for the RCA Satcom 24-channel transponder. The team of **R.C. Baxter, N. Whittaker, P. Oldfield,** and **J.M. Keelty** received an award for the development of the 2-GHz ranging transponder for CTS. **L. A. Mora, J. Labelle, Dr. S.C. Acharyya,** and **A. Grosswindhager** received a team award for the development of modular design earth-station ground communications equipment utilizing MIC techniques.

(Left to right) G. Dziub, E. George, M. Altman, J.R.G. Cox (Chief Engineer), B. Dinsdale and C. Kudsia. This team was awarded for developing the GFEC Multiplex Assemblies for Satcom's 24 Channel Transponder.

(Left to right) J.R.G. Cox (Chief Engineer), R.C. Baxter, N. Whittaker, P. Oldfield, and J.M. Keelty. This team was awarded for developing the 2 GH Ranging Transponder for CTS.

(Left to right) L.A. Mora, J. Labelle, J.R.G. Cox (Chief Engineer), Dr. S.C. Acharyya, and A. Grosswindhager. This team was awarded for developing Modular Design Earth Station Ground Communications Equipment usino MIC Techniques.

RCA President A.L. Conrad elected Chairman of the Board

The Board of Directors of RCA Corporation, has elected Anthony L. Conrad, President and Chief Executive Officer, to the additional position of Chairman of the Board of RCA. Mr. Conrad, who is 55 years old and who completed 30 years of service with RCA this past April, became President and Chief Operating Officer of the Corporation on August 1, 1971. He became Chief Executive Officer on November 5, 1975. Mr. Conrad becomes the third person in the 57-year history of RCA to occupy the dual positions of Chairman and President. The previous occupants were General David Sarnoff and his son, Robert.

Missile and Surface Radar Division

Don Thomson and **Maurice Timken** have received Technical Excellence Awards for the First Quarter. Their efforts in widely diverse areas were significant factors in RCA's recent success in capturing two major contract awards. Mr. Thomson is cited for his innovative system engineering performance in developing a successful configuration for the HR-76 Fire Control Radar System. Mr. Timken is being honored for outstanding technical leadership in the development of special signal processing system architecture.

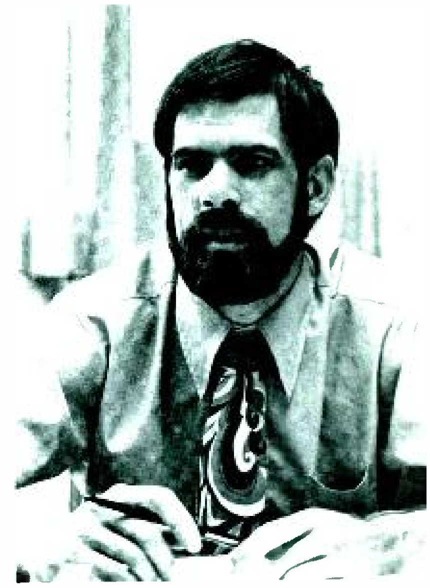
Hurst appointed to Broadcast Systems Training Group

Robert N. Hurst has been appointed to the staff of the RCA Broadcast Systems training department, **John W. Wentworth,** Manager, Broadcast Technical Training announced today. In his new assignment, Mr. Hurst will develop advanced technical educational material for users of RCA radio and television broadcast equipment, and for RCA technicians and engineers.

Degree Granted

Astro-Electronics Division

Victor K. Sapojnikoff, of Mission Planning Group, has been awarded the PhD in mathematics from Princeton University.



Lauffer appointed to Engineer Staff

William D. Lauffer has been appointed Coordinator, Technical Publications, and Assistant Editor, *RCA Engineer*.

Bill holds a BSE with honors in mechanical engineering from Princeton and an MS in Engineering Design from Tufts University. His engineering experience has been as a marine engineer and with Sperry's Marine Systems Div., where he did mechanical design work on gyrocompass and radar equipment. His previous communications experience was as Assistant Editor of the engineering magazine *Design News*.

"TETHERED BALLOON REFUELING SYSTEM," Patent #3,834,655, got a patent plaque for E.L. Crosby (center), Aerostat Systems Technical Staff, RCAS. Awarding Crosby are Dr. E. Mertens, Project Manager (left) and R.P. Murkshe, Project Administrator (right). The patent relates to an Air Force contract for tethered balloon systems R&D.

Crowley appointed Manager, Communications Products Engineering.

George J. Mitchell, Manager, Mobile Product Operations, announced the appointment of **Lee F. Crowley** as Manager, Communications Products Engineering, a newly created position for RCA Mobile Communications Systems, Meadowlands, Pa.

Mr. Crowley has been responsible for design and development for RCA's line of portable, mobile and base station two-way radio communications equipment. In his new position he retains these activities and assume responsibility for advanced development products.

Mr. Crowley was a 1975 recipient of the David Sarnoff Award for Outstanding Technical Achievement, the company's top technical honor, for his contributions to the design and development of RCA's TACTEC series of hand-held portable radios. He has been with the RCA two-way radio activity since 1961.

Promotions

RCA Alaska Communications, Inc.

G.H. Brennan from Sr. Engrg. Assoc. to Supervisor, Field Installation (E.S. Mack, Construction Engrg.)

D. Stewart from Technician to Supervisor, Field Installation (F.E. Tinch, Field Installation)

R.M. Schilling from Sr. Engr. to Mgr., Traffic Facilities (F.C. Bolsinger, Traffic)

Consumer Electronics

Vernon Morton from Sr. Mbr. Engrg. Staff to Mgr. Ferrite Engrg. (Eugene Lemke, Display Systems).

Astro-Electronics Division

L. Scholz from Sr. Engr. to Mgr. (Specialty) Engrg. (G. Barna)

A. Sheffler from Sr. Engr. to Mgr., (Specialty) Engrg. (W. Metzger)

N. Huffmaster from Engr. to Mgr. (Specialty) Engrg. (J. Staniszewski)

L. Gomberg from Mgr. (Spec.) Engrg. to Mgr. Project (M. Sasso)

Solid State Division

R. Kleppinger from Sr. Mbr. Tech. Staff to Ldr. Tech. Staff (J. Litus, Jr., MOS Design Engrg.)

Missile and Surface Radar Division

J. Hobson from Mbr. Engrg. Staff to Sr. Mbr. Engrg. Staff (G. Rogers, Support Systems)

L. Humphrey from Mbr. Engrg. Staff to Sr. Mbr. Engrg. Staff (L. Nelson, Tradex Press)

J. Markunas from Assoc. Mbr. Engrg. Staff to Mbr. Engrg. Staff (H. Inacker, Circuits Design)

M. Riggle from Assoc. Mbr. Engrg. Staff to Mbr. Engrg. Staff (E.T. Hatcher, Space Applications)

D. Webdale from Mbr. Engrg. Staff to Sr. Mbr. Engrg. Saff (P. Derickson ORTS Data Base Application)

RCA Service Company

C. F. Griffin from Mgr., Support Instrumentation to I & M Engr. (W. Tubell, AUTEC Project, Andros Island, Bahamas)

J.J. Cain from Ldr. Instrumentation Sys. — Ships to Assoc. Ships Instrumentation Engr. (W. N. Leonard, USNS Arnold, West Coast)

C.E. Jacobson from Ldr. Instrumentation Sys. — Ships to Assoc. Ships Instrumentation Engr. (USNS Arnold, West Coast)

W.D. May from Ldr., Instrumentation Sys. — Ships to Assoc. Ships Instrumentation Engr. (W.M. Leonard, USNS Arnold, West Coast)

T.D. Petty from Engr. To Mgr., Control Center (M.D. Sweetin, MADOS, Lanham, Md.)

Obituary

Dr. William C. Curtis, Manager, System Simulation, Automated Systems Division, Burlington, died May 22. He received the BS and MS in Electrical Engineering from the University of Illinois in 1934 and 1935 respectively. Dr. Curtis was then an instructor of electrical design at Tuskegee Institute, where he became Director of its School of Mechanical Industries in 1940. He received the MS in Communications Engineering in 1945 and the PhD in Engineering Sciences and Applied Physics in 1949, both from Harvard University. Dr. Curtis became Dean of the School of Engineering at Tuskegee Institute in 1949. He joined RCA in 1945 where he has been responsible for the direction of theoretical and experimental analysis of new radar techniques. His work at RCA included the Black Cat Weapon System, the MG-3 Fire Control Radar, the 300-A Weapon System Radar, Airborne Interceptor Data Link, the Lunar Module Rendezvous Radar and Transponder, and Radar Data Processing for high resolution radar.

Staff Announcements

RCA Electronics and Diversified Businesses

Joseph W. Curran, Vice President, Marketing has announced that the Marketing Research activity is transferred to the Marketing organization, RCA Electronics and Diversified Businesses. **Beryl Goverman** and **Irwin Lesser,** Managers, Marketing Research will report to **Marilyn S. Watts,** Staff Vice President, Marketing Services

Edgar H. Griffiths, President, RCA Electronics and Diversified Businesses has announced that **Rocco M. Laginestra,** Staff Vice President, Operations Analysis and Business Planning will assume responsibility for the RCA Real Estate activity. **Herbert A. Semler** is appointed Staff Vice President, Real Estate, and will report to Mr. Laginestra.

Consumer Electronics Division

Eugene Lemke, Manager, Display Systems has announced the organization as follows: **Jerrold K. Kratz,** Manager, Magnetics Engineering; **James A. McDonald,** Manager, Deflection and Power Supply Engineering, and **Vernon Morton,** Manager, Ferrite Engineering.

RCA Staff

Charles C. Ellis, Senior Vice President, Finance has announced that the RCA Policy, Procedures and Records Management organization is transferred to the staff of Management Information Systems.

Joseph R. Kiernan, Director, RCA Policy, Procedures and Records Management, will report to **DuWayne J. Peterson,** Staff Vice President, Management Information Systems. Mr. Peterson will continue to report to the Senior Vice President, Finance.

Solid State Division

James C. Miller, Director, Product Marketing — Power, announced the appointment of **Leonard H. Gibbons** as Manager, Applications Engineering — Power.

Carl R. Turner, Division VP, Solid State Power Devices, announced the appointment of **Donald E. Burke** to the new post of Manager, Device Development Engineering.

Bernard V. Vonderschmitt, Vice President and General Manager, Solid State Division, has announced the organization of the Solid State Division is as follows:

Robert M. Cohen, Director Quality and Reliability Assurance; **Walter B. Dennen,** Manager, News and Information; **Edward K. Garrett,** Division Vice President, Finance; **Ben A. Jacoby,** Division Vice President, Systems, Services and Strategic Planning; **Donald W. Ponturo,** Division Vice President, Industrial Relations; **Richard A. Santilli,** Division Vice President, Sales and International Operations; **Ralph E. Simon,** Division Vice President, Electro-Optics and Devices; **Philip R. Thomas,** Division Vice President, Solid State MOS Integrated Circuits; **Edward M. Troy,** Division Vice President, Solid State Bipolar Integrated Circuits; **Carl R. Turner,** Division Vice President, Solid State Power Devices.

Industrial Relations

George H. Fuchs, Executive Vice President, Industrial Relations announced that **George A. Fadler,** Vice President, in addition to his present duties, will assume responsibility for the following: **David A. Eckhardt,** Director, Architecture and Construction and **Kenneth D. Lawson,** Staff Vice President, Facilities.

Corporate Engineering

Raymond E. Simonds, Director, RCA Frequency Bureau, has appointed **Edward E. Thomas** as Manager, Divisional Liaison, RCA Frequency Bureau.

RCA Laboratories

Emil V. Fitzke, Manager, Technological Services, has announced the organization as follows: **Austin J. Keeley, Jr.** continues as Manager, Instrument Center; **Paul J. Messineo** continues as Manager, Process Technology; **Jack F. Otto** is appointed Manager, Device Technology.

Dr. Paul Rappaport, Director, Process and Applied Materials Research Laboratory, has named **Dr. Jon K. Clemens** Group Head, Signal Systems Research, RCA Laboratories, Princeton, N.J.

Thomas O. Stanley, Staff Vice President, Research Programs, has appointed **George C. Hennessey** as Director, Marketing and Technical Information Services.

George C. Hennessy, Director, Marketing and Technical Information Services, has announced the organization as follows: **Paul Brown, Jr.,** Manager, Technical Relations; **Richard L. Foley,** Manager, Market Development; **Charles C. Foster,** Manager, Scientific Publications; **Richard S. Gawlik,** Manager, Market Development; **Forrest L. Grimmett,** Manager, Government Contract Administration; **Paul J. McGinley,** Manager, Procedures and Contracts; **Al Pinsky,** Administrator, Scientific Information Services; **William C. Schneider,** Manager, Market Development; and **David G. Weir,** Manager, Market Development.

RCA Americom

Philip Schneider, President, RCA Americom Communications, Inc., announced the appointment of **A. William Brook,** Chief Engineer; **Carl J. Cangelosi,** General Counsel; **Dennis W. Elliott,** Director of Finance; **Donald E. Quinn,** Director, Public Affairs; and **Charles H. Twitty,** Director, Public Relations.

A. William Brook, Chief Engineer, has announced the organization of Satcom System Engineering as follows: **James M. Walsh,** Director, Systems, Facilities, and Construction Engineering; **John M. Christopher,** Director, Space Systems Engineering; **Edward F. Doherty,** Manager, Terrestrial Design Engineering; **Jack L. Ray,** Manager, Traffic and Switching Engineering; **Lloyd A. Ottenberg,** Manager, Transmission Engineering; **Karl W. Ekeland,** Manager, Plant Extension Engineering; **Donald L. Lundgren,** Administrator, Project Administration.

James M. Walsh, Director, Systems, Facilities, and Construction Engineering; **John M. Christopher,** Director, Space Systems Engineering; **Edward F. Doherty,** Manager, Terrestrial Design Engineering; **Jack L. Ray,** Manager, Traffic and Switching Engineering; **Lloyd A. Ottenberg,** Manager, Transmission Engineering; **Karl W. Ekeland,** Manager, Plant Extension Engineering; **Donald L. Lundgren,** Administrator, Project Administration.

Consumer Electronics

David D. Eden, Plant Manager, Monticello Plant, announced the appointment of **David L. Roach** as Manager, Manufacturing Engineering.

Picture Tube Division

Robert E. Salveter, Manager, Marion Resident Product Engineering, has announced the organization as follows: **Robert E. Benway,** Manager, Product Development; **Richard W. Osborne,** Manager, Applications, Reliability and Safety; **Robert E. Salveter,** Acting, Process Development; and **James A. Stankey,** Manager, Materials Development.

Hill named Ed Rep

Harry Anderson, Division Vice President Manufacturing Operations, Consumer Electronics Manufacturing, Indianapolis, announced the appointment of **Cortland P. Hill** as Editorial Representative for the *RCA Engineer*.

Mr. Hill holds BME and MME degrees from Cornell University in the field of machine design and an MEA degree from Syracuse University. With IBM for 11 years, he worked in various micro-electronic packaging assignments including printed-circuit-board design, connector design, heat transfer, and special product design. At Quasar Electronics he held positions in new business development and plant management. Now with RCA's Consumer Electronics Division in Indianapolis, he is Director, Manufacturing Technology and Services.

Upcoming issues

Your next *RCA Engineer* is going to emphasize **automotive electronics,** including:

Electronic ignition
Microcomputer spark advance
Electronic brake control
Automotive radar
Automotive engine diagnosis

Further ahead, future issues will cover:

RCA Records
Electro-optics
Microprocessors
Advanced communications
Radar
SelectaVision

Editorial Representatives

The Editorial Representative in your group is the one you should contact in scheduling technical papers and announcements of your professional activities.

Government and Commercial Systems

Astro-Electronics Division — I.M. SEIDEMAN* Engineering, Princeton, N.J.

Automated Systems Division — K.E. PALM* Engineering, Burlington, Mass.
A.J. SKAVICUS Engineering , Burlington, Mass.
L.B. SMITH Engineering, Burlington, Mass.

Commercial Communications Systems Division

Broadcast Systems — W.S. SEPICH* Broadcast Systems Engineering Camden, N.J.
K. PRABA Broadcast Systems Antenna Equip. Eng., Gibbsboro, N.J.
A.C. BILLIE Broadcast Engineering, Meadow Lands, Pa.

Mobile Communications Systems — F.A. BARTON* Advanced Development, Meadow Lands, Pa.

Avionics Systems — C.S. METCHETTE* Engineering, Van Nuys, Calif.
J. McDONOUGH Equipment Engineering, Van Nuys, Calif.

Government Communications Systems Division — A. LIGUORI* Engineering, Camden, N.J.
H.R. KETCHAM Engineering, Camden, N.J.

Government Engineering — M.G. PIETZ* Advanced Technology Laboratories, Camden, N.J.

Missile and Surface Radar Division — D.R. HIGGS* Engineering, Moorestown, N.J.

Research and Engineering

Corporate Engineering — H.K. JENNY* Technical Information Programs, Cherry Hill, N.J.

Laboratories — C.W. SALL* Research, Princeton, N.J.

Solid State Division

J.E. SCHOEN* Engineering Publications, Somerville, N.J.
H.R. RONAN Power Devices, Mountaintop, Pa.
S. SILVERSTEIN Power Transistors, Somerville, N.J.
A.J. BIANCULLI Integrated Circuits and Special Devices, Somerville, N.J.
J.D. YOUNG IC Manufacturing, Findlay, Ohio
R.W. ENGSTROM Electro-Optics and Devices, Lancaster, Pa.

Consumer Electronics

C.W. HOYT* Engineering, Indianapolis, Ind.
R.J. BUTH Engineering, Indianapolis, Ind.
P.E. CROOKSHANKS Television Engineering, Indianapolis, Ind.
C.P. HILL Manufacturing Technology, Indianapolis, Ind.

SelectaVision Project

F.R. HOLT SelectaVision VideoDisc Engineering, Indianapolis, Ind.

RCA Service Company

J.E. STEOGER* Consumer Services Engineering, Cherry Hill, N.J.
R. MacWILLIAMS Marketing Services, Government Services Division, Cherry Hill, N.J.
R.M. DOMBROSKY Technical Support, Cherry Hill, N.J.

Distributor and Special Products Division

C.C. REARICK* Product Development Engineering, Deptford, N.J.
J.N. KOFF Receiving Tube Operations, Harrison, N.J.

Picture Tube Division

E. K. MADENFORD* Engineering, Lancaster, Pa.
N. MEENA Glass Operations, Circleville, Ohio
J.I. NUBANI Television Picture Tube Operations, Scranton, Pa.

RCA Communications

W.S. LEIS* RCA Global Communications, Inc., New York, N.Y.
P. WEST* RCA Alaska Communications, Inc., Anchorage, Alaska

NBC, Inc.

W.A. HOWARD* Staff Eng., Technical Development, New York, N.Y.

RCA Records

J.F. WELLS* Record Eng., Indianapolis, Ind.

RCA Ltd

W.A. CHISHOLM* Research & Eng. Montreal, Canada

Patent Operations

J.S. TRIPOLI Patent Plans and Services, Princeton, N.J.

Electronic Industrial Engineering

J. OVNICK* Engineering, N. Hollywood, Calif.

*Technical Publications Administrators (asterisked * above) are responsible for review and approval of papers and presentations

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