RCA Engineer

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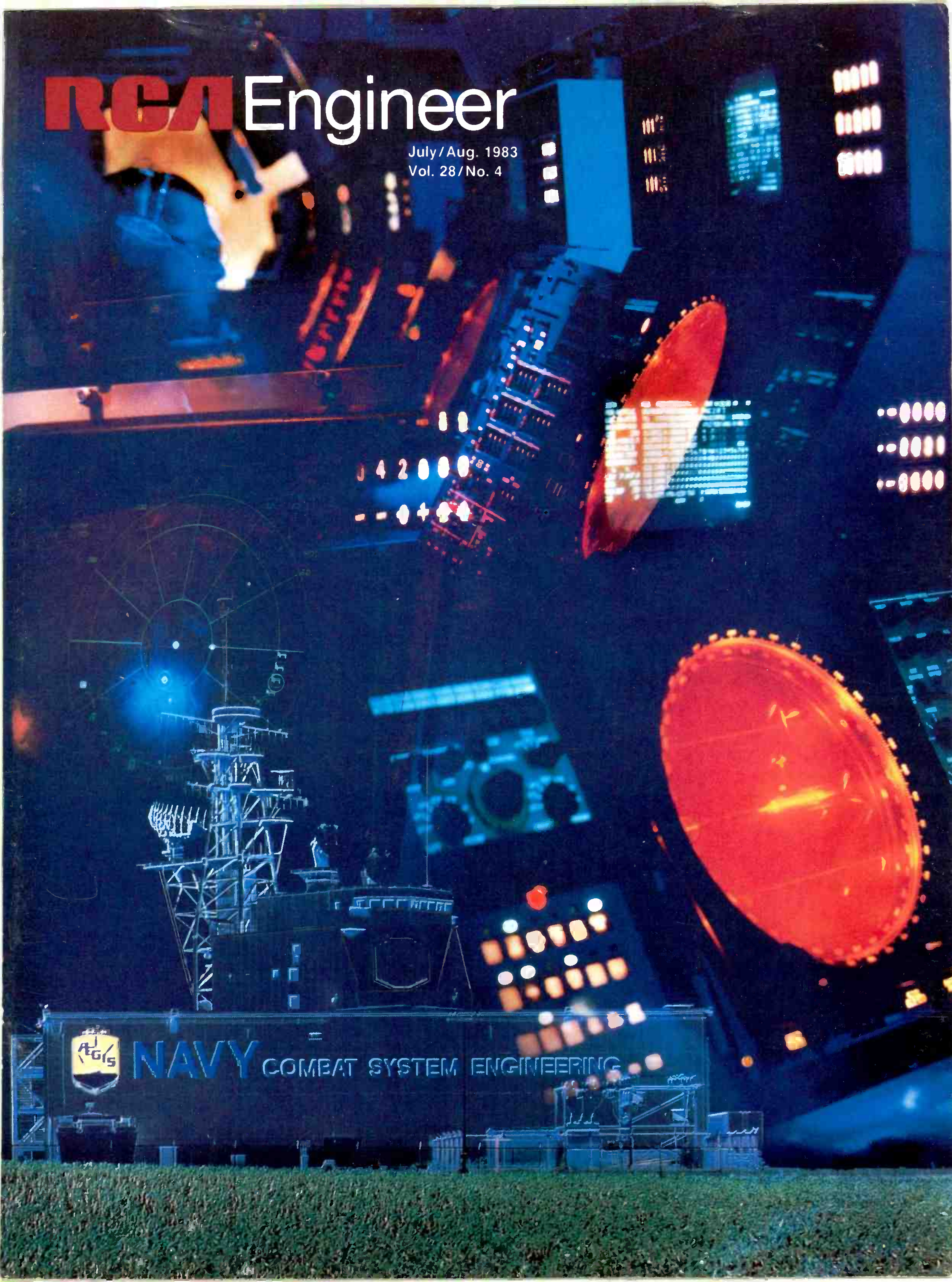
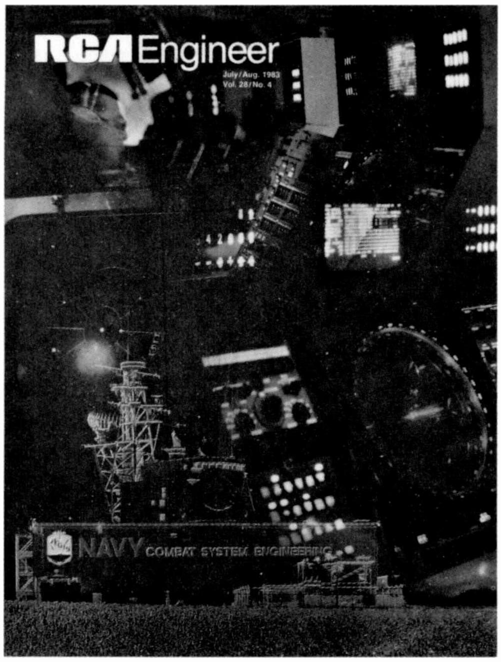


Cover photograph by Andy Whiting, Missile and Surface Radar

Back-cover photograph by Ron Elias, Ingalls Shipbuilding



Our cover symbolizes the RCA systems engineering efforts that led to a successful, sailor-operated AEGIS combat system aboard the Navy's CG-47 ships, which are now being put to sea. For our cover, Andy Whiting combined a specially processed photographic view of the Combat Systems Engineering Development (CSED) site at Missile and Surface Radar in Moorestown (at the bottom of the cover), with a montage of views from inside the facility (at the top). Here, engineers developed and tested the complex and interconnected systems for AEGIS. J.T. Threston's article (page 13) defines systems engineering in general, and describes the AEGIS Program in particular.

The 1983 David Sarnoff Awards for Outstanding Technical Achievement, presented on page 4, underscore RCA's increasing success as the architect of complex engineering projects that require teamwork, long-term planning, and multidisciplinary engineering talent. One such award-winning project, the COTY-29, is described in detail by Al Morrell, Video Component and Display Division. In addition, articles in this issue scrutinize office information technology systems, multi-satellite control systems, and factory information systems.

A vital component of the developing systems engineering discipline is written engineering communication. The guide for *RCA Engineer* authors included in this issue deals solely with *RCA Engineer* articles, but you may find useful idea-starters there for your other writing tasks as well. Please note that the *RCA Engineer*, part of the Technical Excellence Center, has the following new address (see page 23 for more information):

RCA Engineer
Technical Excellence Center
13 Roszel Road
P.O. Box 432
Princeton, N.J. 08540
(Internal Mail: RCA Laboratories-Roszel Road)
TACNET: 226-3090

—*MRS*

RCA Engineer

A technical journal published by
RCA Technical Excellence Center
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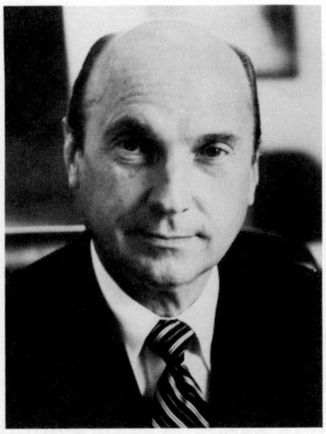
• To disseminate to RCA engineers technical information of professional value • To publish in an appropriate manner important technical developments at RCA, and the role of the engineer • To serve as a medium of interchange of technical information between various groups at RCA • To create a community 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.



R.R. Frederick

Systems thinking: A commitment to creativity and cooperation

One need only glance at the Table of Contents in this issue of the *RCA Engineer* to appreciate the diversity of technological experience that drives our company today. The fact that this technological diversity spans products, services, manufacturing processes, office automation, and systems management is of particular significance to our future growth.

As America's (or at least the investing public's) love affair with high-tech companies continues, it will become apparent that today's loose definition of high-tech is inadequate to identify true growth opportunities. More and more, the disparate technical disciplines are intersecting in the development of products and services. In my view, those companies that are able to put together the right mix of technological skills on a systems basis will be the winners.

RCA is well positioned to enhance its present system capabilities. In the first place, we're already a systems company in many areas and as such are recognized for our leadership. Second, we possess a respectable range of technological strengths. Third, our three areas of commitment—electronics, communications, and entertainment—require a high degree of technical and marketing integration.

Our *objective*, clearly, should be to use RCA's diverse talent in all its forms so that the sum of our efforts is greater than the parts. Our *challenge* is to make interdisciplinary, inter-divisional thinking, planning, and implementation an inherent part of our corporate culture.

There are those who seek the path to this worthy goal through organizational restructuring—bringing relevant technologies under one operational management. And, indeed, this is often necessary and desirable. But it is unrealistic to assume that RCA could take advantage of the many opportunities for system technological support and development through simple restructuring. Rather, it must be achieved through individual commitment to a way of thinking—creatively and cooperatively.

The technological strengths of RCA are substantial, and we intend to provide the necessary financial support to maintain or achieve leadership in the fields that we choose. Not only must we choose wisely, but we must also be able to use our strengths—wherever they exist in the company—to exploit our opportunities. This is a matter of attitude as well as organization.

If we keep our emphasis on enhancing the quality of products and services that we provide and, at the same time, develop new ways to use our systems strengths, we are unbeatable!

Bob Frederick

Robert R. Frederick
President and Chief Operating Officer

RCA Engineer

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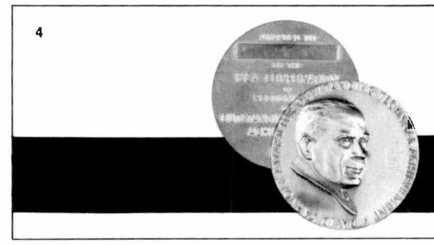
in this issue ...
systems engineering

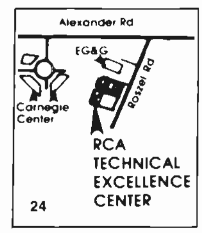


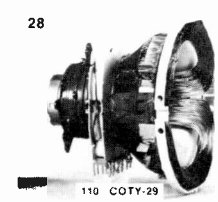
■ **Sarnoff awards:** *This year's awards to three teams and one individual show a systems engineering emphasis.*

■ **Threston:** *"What systems engineers do and how they do it are treated, with examples from MSR's recent experiences on the AEGIS Program."*

■ **Jenny:** *"The Technical Excellence Center is visible evidence of RCA's commitment to excellence in science and engineering."*

■ **Morrell:** *"[The COTY-29] is a system wherein all factors—the yoke, the tube, and the receiver interface—have been optimized for system cost and performance."*



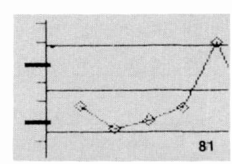


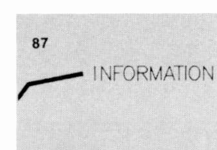
■ **Authors' guide:** *This special section features essays by RCA publications people, idea-starters, and guidelines for authors who want to tailor their information for the* RCA Engineer *audience and produce readable articles about high technology.*

■ **Stein/Rayl:** *"What's the difference between factory data and factory information? Let's walk through a factory, look at some of the processes and machinery, and talk to some of the people."*

■ **Freedman:** *"Even though information technology offers an enormous potential, its full benefits cannot be achieved without the awareness, direction, and support provided by management."*

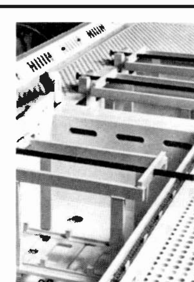
■ **Lewin:** *"A flexible approach toward facilitating expansion in ground-control systems is therefore a prudent objective, if disruption and cost are to be low."*

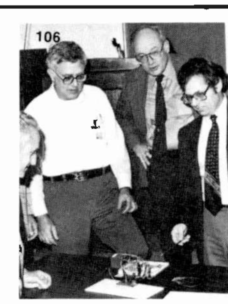




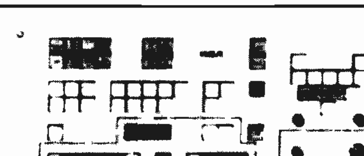
■ **Kern:** *"The present paper traces the historical development of the process since its origin in 1961, notes the supporting data from radioactive-tracer studies, and summarizes the essential facts underlying the procedures."*

■ **Poletti:** *"... members of the Microcomputer Club of RCA Missile and Surface Radar (MSR) at Moorestown can be found at home extending their work environment into their new-found hobby."*



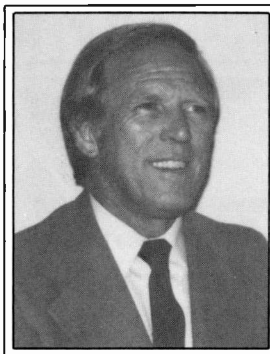


in future issues...
digital broadcast,
software

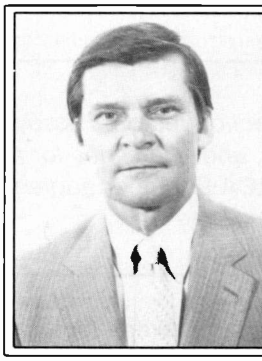


The 1983 David Sarnoff Awards for Outstanding Technical Achievement

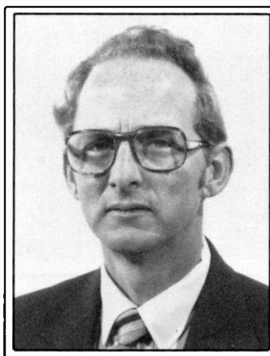
CITATION: For team achievement in the design and development of a highly manufacturable and reliable color television receiver.



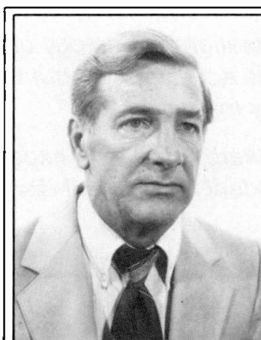
James R. Arvin
Manager, Manufacturing Engineering
RCA Consumer Electronics



Robert E. Fein
Manager, Manufacturing Planning and Services
RCA Consumer Electronics



Perry C. Olsen
Director, Product Design Engineering
RCA Consumer Electronics



Paul C. Wilmarth
Manager, Project Engineering
RCA Consumer Electronics

ACHIEVEMENT

This team contributed to the successful design, development, and introduction into production of a highly manufacturable and reliable color television receiver at RCA Consumer Electronics (CE). The heart of this receiver is the CTC120 chassis and the entire design and development program is commonly referred to as the CTC120 program.

The CTC120 program represents the first time that manufacturability and reliability have been the highest priority items (after safety)—above performance improvement, feature enhancement, or cost reduction—during chassis design and development. In recent years, CE has been developing and applying new assembly and test technologies to its manufacturing operations. To reach the desired objectives for manufacturing yields and field reliability levels, a receiver had to be designed to specifically take advantage of these technologies and other new technologies that could be mastered on the production floor.

The CTC120 program has generated a product design that has enhanced the efficiency of well-established technologies such as automatic test and alignment, automatic component insertion, and automatic soldering of electrical parts heretofore unattained within CE. New technologies—such as radial component insertion, and active and passive clinch of component leads—were fundamental to this new chassis design. The entire design effort was directed at obtaining full value from each of these technologies so as to achieve greater manufacturing yields and improved reliability in the customer's home.

The CTC120 chassis is a direct replacement for the CTC110. The CTC120 chassis now runs with a 25- to 45-percent yield improvement over the CTC110 after only eight months in production. Chassis labor content has been reduced by 20 percent.

Final instrument assembly has benefited from the CTC120 program. Many models profited from the design enhancements and improved manufacturing techniques initiated by the program in major components such as tuners, control assemblies, yokes, and cabinets. These components are used over a wide range of models, and they therefore have tended to raise the yield level of instrument production. These yield improvements have resulted in increased productivity reflected by a 5 percent increase in instrument line rates.

High reliability was a prime design objective for the CTC120. The 1980 service call rate of the comparable product was cut by almost 50 percent to establish the CTC120 goals. These figures represent only the earliest production; the rate will be further reduced.

The CTC120 program has established a new, higher level of expectation in television design and in the application of manufacturing technologies. It is now the standard by which other designs are being measured and by which other systems are expected to perform in the production environment.

BUSINESS IMPLICATIONS

The fundamental objective of Consumer Electronics is to increase its market share by producing instruments at maximum cost effectiveness commensurate with good performance, quality and reliability. This strategy is fueled by and dependent upon product designs that blend the strengths of television circuit and mechanical design with the strengths of manufacturing technology. The CTC120 design program is directed toward this objective and will contribute significantly to RCA's position in the industry.

The direct cost of the CTC120 product is lower than the CTC110 it replaced. Warranty costs have been lowered because of lowered warranty service calls.

In addition to the considerable monetary value of the CTC120 program, the increased reliability of the product in the field enhances the RCA image and builds confidence in RCA products in the minds of dealers, servicemen, and consumers.

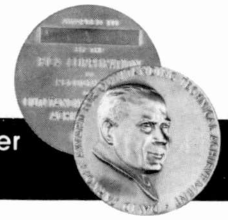
INDIVIDUAL CONTRIBUTIONS

James Arvin properly applied the various manufacturing technologies required for chassis production and directed the overall manufacturing engineering effort at the chassis assembly and test level. His contribution was vital in extracting all of the potential manufacturing efficiencies designed into the CTC120 chassis. He contributed heavily in ensuring that established techniques were applied at the highest level of efficiency and that new techniques were thoroughly prepared for production.

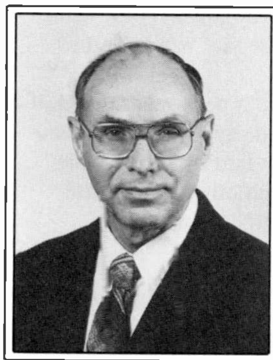
Robert Fein directed the configuration of the entire manufacturing system and was specifically instrumental in gaining management approval for including radial component insertion in the CTC120 program. He gave direct input into the design effort on a continuous basis concerning the availability and application of all manufacturing technologies and provided detailed manufacturing design guidelines to ensure the greatest manufacturing benefit from various design features. He was the prime coordinator for technical information between the design organization and the manufacturing plants.

Perry Olsen was responsible for the overall organization and management of the program. He led a task force with representatives from each manufacturing plant and each organization in Operations. All problems in assembly, reliability, quality, and purchasing were itemized and individually addressed. The layout of the chassis and instrument was driven by the inputs from the manufacturing teams. Dedicated vendors were selected based on good quality performance. Specifications were changed to reflect the new expected levels of quality; reliability goals were assigned to each component in the set to assure that this would be the most reliable set RCA had ever produced. The successful management of this newly developed, in-depth, broad-based program has resulted in record yields in the manufacturing plant and has demonstrated a new standard of performance for RCA in terms of reliability in the marketplace.

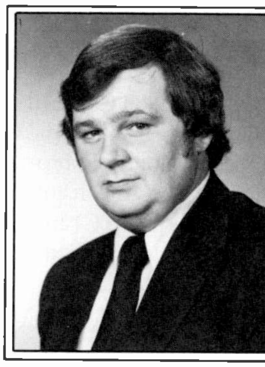
Paul Wilmarth was the Project Manager on the CTC120 program. He initiated an in-depth analysis of component failure mechanisms, set up more than 75 specific projects for component and manufacturing improvement, and formulated an electrical step-stress program for the instrument. He coordinated the project with all the various disciplines involved.



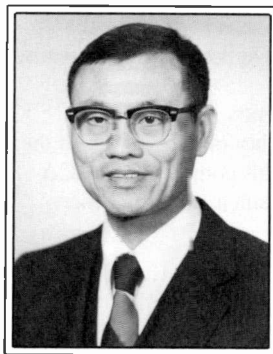
CITATION: For team effort leading to the first commercial solid-state microwave power amplifier in space.



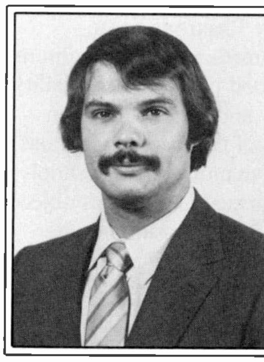
E. Aaron Boyd
Principal Member
Technical Staff
Electrical Design
RCA Astro-Electronics



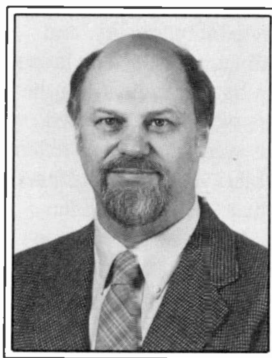
Brian R. Dornan
Member Technical Staff
Microwave Technology
Center
RCA Laboratories



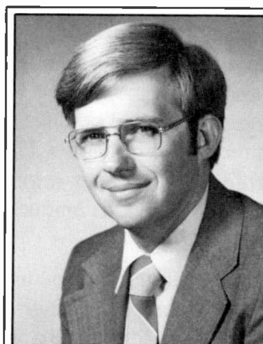
Ho-Chung Huang
Head, Microwave
Process Technology
Microwave Technology
Center
RCA Laboratories



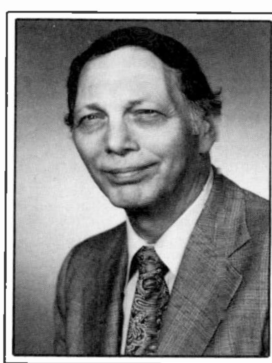
J. Nicholas LaPrade
Member Technical Staff
RF Equipment
Development
RCA Astro-Electronics



Robert M. Schuster
Principal Member
Technical Staff
Electrical Design
RCA Astro-Electronics



Walter J. Slusark
Member Technical Staff
Microwave Technology
Center
RCA Laboratories



Herbert J. Wolkstein
Manager, Space and
Countermeasure Programs
Microwave Technology
Center
RCA Laboratories

ACHIEVEMENT

The team has conceived and implemented over a period of five years the RCA solid-state power amplifier (SSPA). SSPAs have been space-qualified and placed into operation on-board the advanced RCA Satcom commercial communications satellite as the first solid-state replacement for TWT amplifiers deployed for commercial communications satellite use.

The SSPAs offer improved linearity, higher reliability, and lighter-weight performance with respect to travelling-wave tubes of comparable power. The team achievement included a series of technical innovations:

Gallium-arsenide field-effect transistor (GaAs FET) evaluation and development. The electrical, mechanical and reliability performance of the FET devices was evaluated and specified. A device and amplifier qualification test facility was established for the evaluation of device and circuit reliability. The transistor vendors were guided in making necessary design and process improvements needed to support the SSPA's performance and reliability requirements.

Breadboard, engineering model and prototype model development. The development and integration of electrical, mechanical, and microwave-integrated-circuit (MIC) aspects of the design evolved through several increasingly sophisticated versions of the SSPA. An initial engineering model amplifier convinced RCA management of the viability of the GaAs FET amplifier as a travelling-wave-tube amplifier replacement. The final optimized manufacturable product required many improvements in the design, assembly, test, quality and configuration control areas.

Circuit design developments. Technical innovations were made in the microwave circuit design, hybrid microwave-integrated circuit (MIC), and packaging areas. Computer-aided design (CAD) developments included use of the RCA-generated microwave circuit analysis and optimization program (COSMIC) for designing and evaluating microwave circuit parameters. The final design resulted in a power amplifier with 55-dB gain and 8.5-watt power output. Six stages of microwave FET amplifiers are used in cascade. Interdigitated combiners and splitters allow the efficient power combination of four parallel output power stages.

Computer-aided test (CAT). Detailed characterization of FET device power and efficiency performance was obtained using the RCA-developed computer-controlled load-pull system. A complete microwave production test facility was developed. Multiple stations tied to a central computer feature CRT terminals, measuring equipment, and printers controlled via special test software.

Electronic power conditioner (EPC) development. Each group of seven SSPAs used on the spacecraft requires conditioned dc power from one EPC. The EPC requirements were particularly severe because the unit had to be small, lightweight, and efficient, yet it had to have a very low output impedance and wide bandwidth so that there would be no cross-talk between the multiple SSPAs being powered from the same EPC. In addition, the EPC had to provide exceptional attenuation of ripple from the spacecraft bus relative to the conditioned dc outputs.

All of these goals were attained. In the process, several circuit innovations were attained, including a unique transformer anti-saturation circuit, and the first known use of hexagon-structure MOS power transistors (Hex FETs) in space.

Manufacturing support. The timely development of a cost-effective, highly reliable manufacturing process required technical guidance and quick-reaction support from the design team.

The final SSPA hardware product meets the RCA commercial communications satellites needs and provides RCA with a competitive edge in the power-amplifier area. The timely delivery and successful use in space of the SSPA was made possible by many individual technical achievements supporting a team effort.

BUSINESS IMPLICATIONS

The investment in the development of the C-band SSPA has allowed RCA to be the first commercial-communication-satellite manufacturer to be able to offer a space-qualified, all-solid-state communications transponder. The use of the SSPA with its longer life expectancy and increased channel capacity contributes to the profitability of the RCA advanced Satcom satellites.

The capability of building all-solid-state communication satellites creates a significant competitive edge for RCA. This capability contributed to increased interest in RCA as a supplier of communications satellites. Examples of recent new business include: Southern Pacific Communications Company (SPCC), General Telephone and Electronics (GTE), and American Satellite Company. Building upon the technical base developed for the C-band 8.5-watt SSPA, a new 12-GHz, 40-watt K-band SSPA is in the development phase.

INDIVIDUAL CONTRIBUTIONS

Brian Dornan did the circuit design of the solid-state power amplifier (SSPA), optimized the various stages, performed all necessary tests, designed and refined the interstage networks, developed the mechanical design of the engineering model, and assisted in the environmental testing of the first units. During the technology transfer phase, he assisted in the training of Astro-Electronics engineering, manufacturing, and test personnel and contributed his skills toward the evolution of the final design of the SSPA.

Ho-Chung Huang was the Group Head in charge of the SSPA development program. His expertise and knowledge in FET device physics were instrumental in the development of viable performance-acceptance specifications for the transistors, definition and execution of the device selection and proof-of-reliability program, and final amplifier circuit configuration. His managerial skills contributed materially to the smooth conduct of the development program phase.

Walter Slusark was involved in the reliability program since the early days of the product. Working with the Astro-Electronics engineers, he developed the reliability projections and trade-off analyses that demonstrated the superiority of the SSPA for the intended application; designed, instrumented, and implemented a unique reliability test facility; and established a pilot fabrication facility for the manufacture of SSPA components that could not be obtained from outside vendors.

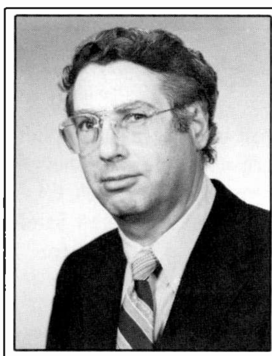
Herbert Wolkstein acted as the Microwave Technology Center program manager for the SSPA and was the principal link, both technical and programmatic, between RCA Laboratories and Astro-Electronics during both the development and the technology-transfer phases of the program. In addition, he made numerous technical contributions to the design and integration of the amplifier and to its eventual production design. Without his indefatigable energy in solving numerous design and fabrication problems, his insight into the minutiae of amplifier and system operation, and his trouble-shooting skills, the project could not have been completed on schedule.

Nick LaPrade acted as the lead engineer on the entire SSPA development project. As such, he coordinated the activities within the RF Engineering activity, and the interaction of the SSPA/EPC design groups. He carried out the product design of the microwave-integrated-circuit (MIC) design, and during the technology-transfer phase, he was instrumental in expediting manufacturing-design problems. He also contributed his skills toward the final product design of the SSPA by his use of computer-aided testing methods.

Aaron Boyd was one of the two principal circuit designers for the electronic power conditioner (EPC) portion of the SSPA. He performed the detailed electrical design, test, and analysis for both the high-power and low-power converter sections. In the process, he also designed and developed a unique anti-saturation circuit that allowed the use of a small ungapped transformer. All of Aaron's efforts resulted in an overall EPC design that attained the conflicting requirements of small size, light weight, high efficiency and good reliability, while maintaining good SSPA power-supply isolation.

Robert Schuster was lead engineer and one of the principal designers for the SSPA/EPC. Bob was instrumental in defining the 4/3 redundancy configuration and power-switching matrix that resulted in the reduced EPC package size, and weight. In addition to performing designs of various EPC control and power-monitoring sections, Bob was instrumental in locating and resolving an extremely difficult vendor part problem involving parasitic elements in the primary power-switching devices. It is also through his efforts that the manufacturing of the SSPA/EPC flight production units continues to flow smoothly with a minimum of EPC debug/test problems.

CITATION: For contributions to improvement in the reliability of solid-state devices.



George L. Schnable
Group Head
Device Physics
and Reliability
RCA Laboratories

ACHIEVEMENT

Dr. Schnable has a 12-year record of continuous, outstanding contributions to reliability improvements of the solid-state devices manufactured by RCA, or used in the electronic equipment manufactured by RCA.

Since joining RCA Laboratories in 1971, his extensive patent and publication record clearly has established Dr. Schnable as a recognized authority on solid-state device fabrication and reliability. In this role he is often consulted by RCA personnel relative to solid-state component reliability. His principal interaction is with Solid State Division (SSD) although he has often helped the systems divisions, particularly Consumer Electronics (CE) and Government Systems Division (GSD), when they have encountered solid-state device reliability problems.

For example, in late 1981 and continuing into 1982, Dr. Schnable worked with RCA Astro-Electronics and Fujitsu to help solve a major reliability problem on gallium arsenide field-effect transistors (GaAs FETs) supplied by Fujitsu for the solid-state power amplifiers (SSPAs) manufactured by Astro-Electronics for the advanced Satcom V satellite . The Fujitsu FETs were sole source, highly selected, and extensively tested devices that were critical to the performance of the SSPA. When a discrepant rf performance problem with the devices was uncovered, Dr. Schnable analyzed the devices and suggested to Fujitsu that they add an aluminum line-resistance measurement as an additional screen to ensure adequate metal coverage on the device gates. This additional screen, along with 100-percent scanning electron microscope inspection and bias life tests, provided the necessary improvements to the device reliability so that the SSPA was included on Satcom V.

In this case, as on other occasions, Dr. Schnable directly assisted the major operating unit (MOU) to obtain components from outside suppliers that would meet the reliability requirements of the electronic systems that the MOU was manufacturing. This was accomplished by providing specific fabrication-process or test-sequence changes to the outside supplier so that the supplier could deliver the devices with the required reliability.

Beyond assisting CE and GSD with specific solid-state device reliability improvements, Dr. Schnable has directed most of his work toward SSD. This work has ranged from the selection of specific device reliability problems to participation in several reliability improvement task-force efforts to improve the integrated circuit (IC) manufacturing methods used in SSD. Although it is difficult to separate individual contributions in a task-force effort, which is by nature the collective contributions of many individuals, Dr. Schnable's demonstrated ability to develop practical, commercially-viable processes along with his demonstrated skill at liaison, and his excellent written and verbal skills, have enabled him to be a key contributor to each task force.

Two particularly noteworthy efforts were the joint CE/SSD bipolar IC reliability improvement task force and the closed-cell logic (C^2L) reliability improvement task force. The dramatic reliability improvement achieved by the CE/SSD bipolar task force, a factor of 5.6 in 1981 over the 1980 baseline, is attributable, in large part, to the improved over-metal passivation techniques that were incorporated in the bipolar manufacturing line in Findlay, Ohio, along with improved packaging techniques and burn-in screening processes in the Far East. Dr. Schnable is recognized as the principal contributor to the improvement in passivation. He recommended the deposition of a 3-percent phosphosilicate glass (PSG) as the passivation glass. The 3-percent phosphorus concentration is high enough for adequate alkali ion gettering and low enough to avoid excessive cathodic corrosion of the aluminum metal in plastic-encapsulated integrated circuits. Furthermore, he led the effort to refine the PSG depostion process to produce low-tensile-stress films that result in the reduction of over-metal cracks and pinhole defects.

A similar success was achieved by the C^2L reliability improvement task force. In 1977, when the task force was formed, it was necessary to package the C^2L devices in the more costly hermetic package since the devices packaged in the low-cost plastic package exhibited a *p*-channel transistor slow-hole-trapping instability. Dr. Schnable is co-inventor of the C^2L process change that uses a high-temperature deposited Si_3N_4 as a barrier against the slow-hole-trapping and incorporates a 6-percent PSG steam-aided reflow process to improve step coverage. This technique is of fundamental importance to SSD since it enables the devices to be reliably packaged in plastic. The use of this technique has been extended to include devices fabricated in CMOS/SOS, CMOS I, CMOS II, and our most advanced process, CMOS III.

Since joining RCA Laboratories in 1971, Dr. Schnable has received seven U.S. patents, has four patents pending, and has an additional 14 patents disclosed in the areas of reliability and quality improvement of solid-state devices. He has also published or presented forty-five papers on device reliability as author or co-author and already has four papers accepted for publication in 1983.

BUSINESS IMPLICATIONS

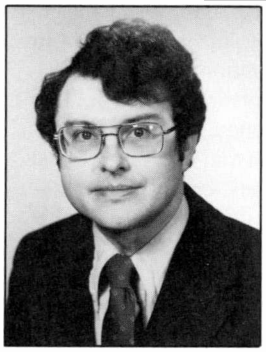
It is difficult to document, in detail, the economic benefits derived from improvements in solid-state device reliability. However, for the case of integrated circuits manufactured by SSD for CE, this has been done.

In late 1980, CE supplied a listing of ICs used in TV receivers, the percentage of failures per 1000 hours, and the burden cost per unit based on TV warranty costs. As a result of the CE/SSD task-force efforts, the reliability of integrated circuits manufactured by SSD for CE increased by a factor of approximately 5.6. Substantial savings in warranty costs were thus achieved.

The benefits of the C^2L reliability task force have been considerable. The IC fabrication technique, which was developed by the task force, has since been extended to all silicon-gate CMOS ICs manufactured by SSD in Palm Beach Gardens, Florida. It should be emphasized that the incorporation of the high-temperature Si_3N_4 layer is the only method that, as yet, has been shown at RCA to consistently eliminate the slow-hole-trapping instability effects on devices that are packaged in plastic. Since it is absolutely essential that SSD provide reliable products in low-cost plastic packages to compete in the commercial marketplace, this effort has had a profound positive effect on SSD.

The reliability problem encountered with the Fujitsu GaAs FET was one of potential negative business impact. The devices were sole sourced and there was no way to distinguish "good" from "high-risk" devices until the additional reliability screen was developed and shown to be effective. The questionable device reliability, in turn, placed the schedule for the manufacture of the solid-state power amplifiers at risk, which could have jeopardized the Satcom V launch date. Fortunately, the device reliability problem was solved in an effective and timely manner, and Satcom V was launched on schedule.

CITATION: For team effort in the development of the COTY family of picture tubes and yokes.



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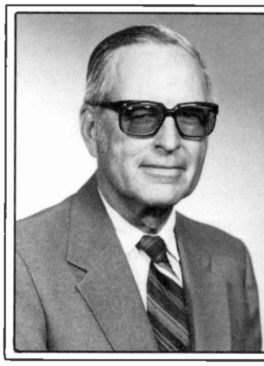

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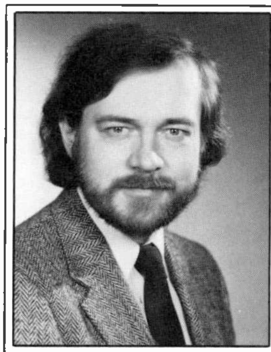

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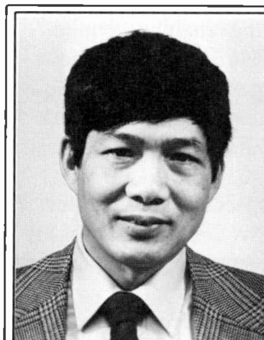

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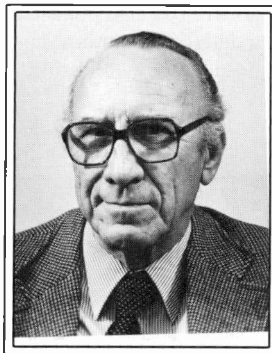

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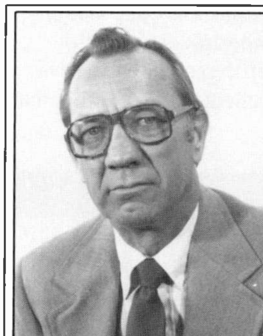

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ACHIEVEMENT

As the COTY acronym (Combined Optimized Tube and Yoke) indicates, in this system the tube and the yoke have been mutually optimized to improve resolution and convergence as well as to provide the basis for a lower cost TV system. RCA achieved these gains through the use of radically new electron-optic designs, including full three-dimensional main lenses and greatly shortened yoke fields. This work was completed quickly and has allowed RCA to be competitive in the timing of the introduction of the COTY. For example, from the first formulation of the COTY concept in January of 1981, the system was demonstrated and sampled to customers within 18 months, including 13V and 19V products with 90° deflection, and 19V and 25V products with 110° deflection. The most important technical innovations in this system are in electron guns and in deflection yokes.

Electron guns. The COTY system incorporates significant changes in electron gun design. A high-quality electron focussing main lens departs from the cylindrically symmetric electron optics and enters the realm of fully three-dimensional electron optics. The advantage of this new extended lens, designated the XL lens, is that it improves color convergence through substantial reduction in the spacings between the three guns, and simultaneously reduces the aberrations of the guns. In conventional cylindrical optics a reduced spacing between the guns resulted in smaller, higher-aberration lenses. The COTY XL lens was used to reduce the gun spacing by 25 percent, and resulted in 25- to 40-percent reductions in convergence errors. The technical dimension of this achievement can be measured from the fact that there does not even exist a textbook on the subject of three-dimensional electron optics: many of the designs involved collaboration between conventional gun designers and computer simulation experts.

A second innovation in gun design is a high-quality, six-element electron gun called the DB (Double Bipot). This six-element gun provides the improvement in the electron optics near the cathode that will further improve resolution at both the centers and the corners of the wide angle 110° tubes in the COTY system. Again, the proveout of the basic concepts in this gun and the tailoring of the basic design to optimize performance was a full hardware/software collaboration involving RCA's computer-aided-design (CAD) capability in electron optics.

Deflection yokes. The major innovation in the COTY yoke is the reduction in the size of the yoke, particularly in the 110° designs. This small-yoke concept is a radical departure from that in the traditional 29-mm neck sizes and required a breakthrough in the understanding of yoke fields to achieve it. The primary measure of this achievement is that the smaller yokes reduce the weight, including the copper and the ferrite, of our RCA yoke line by 35 percent on the average, and they do so with no degradation in the quality of convergence. In fact, due to the smaller gun spacing, the convergence is actually improved in the COTY system. A secondary gain in the COTY system is the reduction in the stored energy needed to achieve deflection. This reduction, amounting to about 20 percent in the 90° products and the 19V110°, results in reduced deflection-circuitry costs, compared to earlier RCA designs. The full development from short-yoke concept to final design involved extensive collaboration among the yoke design groups at both RCA Laboratories and CE.

BUSINESS IMPLICATIONS

The trend in the television receiver business has been toward progressively lower, real-dollar prices over the past several years. This has been fueled both by reduced circuit cost and increased competition from foreign competitors. This reduced-cost progression was extended into picture tubes with the introduction of the mini-neck system. This is a reduced neck-diameter tube in which reduced yoke size (and therefore reduced yoke cost) are obtained at the sacrifice in resolution that results from the smaller gun/neck diameter. This mini-neck challenge developed concurrently with the need for higher resolution tubes for high-end TV receivers and the data-display market, and these two developments were beginning to drive a wedge between lower-cost systems for the low end of the consumer market and higher-performance systems for high-end consumer products and for data display.

The COTY system has emerged as a solution to this cost dilemma. The COTY yoke is nearly identical in size, cost, and stored energy to the mini-neck yoke, but COTY does not suffer the degradation of the smaller gun required by the mini-neck. Through the use of the XL lens, COTY produces improved resolution and will be the basis for much of RCA 's color TV consumer line and for higher-resolution displays.

In short, the COTY line has emerged as the strongest U.S. response to the international challenges in this area in many years. It has been enthusiastically received by customers here and abroad and is slated for inclusion in RCA's K-line receiver product. Beyond the cost savings that the COTY yoke provides, another important consideration for the system is its impact on RCA's position in the television community: RCA has re-emerged as the technical leader in picture tube and yoke design among domestic manufacturers and as a major force within the international community.

INDIVIDUAL CONTRIBUTIONS

Roger Alig has been responsible for the computer-aided-design work that went into the development of XL lenses with the aberration, astigmatism, and convergence required for use in color tube guns. He developed computer programs to interface between the existing general electron-optics simulator and the particular gun geometry, and he used these programs to collaborate with Mr. Hughes in running through many generations of three-dimensional lens designs to develop product-quality lenses.

William Barkow initiated the COTY short-yoke concept when he recognized and demonstrated the feasibility of using mini-neck-sized yokes on tubes with a 29-mm neck. He then led the effort to establish the geometry—ferrite and coil lengths and diameters—that serves as the basis for the entire line of COTY yokes.

Dennis Bechis contributed the theoretical and experimental expertise that led to the demonstration of the DB gun as an improved resolution design. He played a key role in taking the DB from a basic concept to a component optimized for performance in 110° deflection systems.

H.Y. (Jim) Chen was the key person who promoted the concept of combining an asymmetrical beam-forming region to an asymmetrical open main lens (XL), which resulted in the balanced center-corner spot performance of COTY tubes (both Hi-PI and DB). Dr. Chen also provided the hands-on gun hardware expertise that resulted in a cost- and process-optimized DB gun.

Richard Hughes was the prime mover in the invention and development of low-cost XL lens designs. Mr. Hughes demonstrated that an extended lens could be designed that satisfied the low-cost requirements of consumer tubes. He then worked with Dr. Alig in achieving a large number of designs with progressively improved aberration and deflection compatibility.

Ira Thompson, working from the basic geometry of Mr. Barkow's reduced-size yoke, developed winding distribution and final product designs for the 19V110° yoke and contributed key technical advances that led to the design of a 25V110° product.

Schade's book available at no charge

Image Quality—A Comparison of Photographic and Television Systems, by Otto H. Schade, Sr., gives a technical overview of the concepts developed by the author, and now in universal use, that permit a quantitative evaluation of image quality. Dr. Schade describes in some detail the three basic parameters that determine image quality: the intensity-transfer function, which is a measure of the gray scale; the modulation-transfer function, which is a measure of sharpness and definition; and the particle or quantum density that can be stored in the sensor of the camera, which is a measure of granularity, or noise.

A unique feature of the book is a series of 54 unusually high-quality reproductions of photographic and television images that dramatically illustrate the effects of various parameters on image quality. For example, the same subject is shown as reproduced by television systems having 525 lines, 4.25 MHz; 625 lines, 5 MHz; 525 lines, 7 MHz; 625 lines, 9 MHz; and 1760 lines, 60 MHz. Another set of reproductions shows photographic images of a subject made with films of different speeds and with formats requiring different magnifications. The story told by these illustrations will be readily perceived by the expert and the layman alike.

Most of the reproductions measure 8½ by 6¼ inches. Some have appeared in various of Dr. Schade's papers scattered throughout the technical literature (although usually in a much smaller format and with less detail) and others have not been published before. Here, for the first time, they are brought together in a single volume.

Otto Schade has been active in the field of television for more than thirty-five years. His pioneering work in the 1940s and 1950s led to the concept of Modulation Transfer Functions and Noise Equivalent Pass Bands, which can be applied equally to amplifiers, lenses, and the human eye. He made the first measurements on the human visual system in terms of these parameters. Dr. Schade's work has received worldwide acclaim.

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J.T. Threston

Managing the future— The expanding role of systems engineering in a high-technology society

The systems engineer is the architect of a new race of huge, sophisticated, socially oriented systems that characterize technology application in the late 20th century. No firm involved in high-technology systems today can function without strength in systems engineering.

USS *Ticonderoga*, the first of the new class of guided missile cruisers, has joined the U.S. Atlantic Operating Forces. As a warship, *Ticonderoga* represents a major technological achievement, an example of a modern, powerful combat system. Her effectiveness unquestionably derives in part from the sophistication of her systems—sophistication that would have been impossible to handle a few years ago. In that sense this new ship is futuristic. Indeed, she *is* the future in large-scale combat systems.

In terms of its development, the AEGIS Ship Combat System is a textbook example of a successful systems engineering project, albeit rather grander in scope and complexity than most. The successful harnessing of so much advanced technology and sheer complexity in a single system that *works* and can be fought by sailors stands as a truly significant systems engineering achievement. The fact that it was accomplished by a national systems engineering team led by RCA is significant for three reasons: (1) our systems engineering skills made it possible; (2) the scope and breadth of the work provided a fertile environment for further growth and expansion of our systems engineering capability; (3) the existence of this systems engineering kernel creates opportunities for RCA in undertaking other major systems programs.

Abstract: *The growing complexity and scope of modern systems—both military and commercial—create a demand for a special engineering resource, with a depth and breadth of understanding and capability that embrace virtually every known field of technology. "Systems engineering" is the name commonly applied to such a resource, and the creation and development of a strong systems engineering team can be seen to reflect the demands imposed by the system under development. This paper describes the evolution and maturation of systems engineering, and treats the development of a major systems engineering resource at Missile and Surface Radar in Moorestown that was derived from the complex demands of the AEGIS Ship Combat System. Application of systems engineering tools is discussed briefly, and a projection is made of increasingly wider application of systems engineering approaches to meet the growing complexity of society's future needs.*

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This paper traces systems engineering from its roots and from its formal beginnings in the 1950s. What systems engineers do and how they do it are treated, with examples from MSR's recent experiences on the AEGIS Program. The paper concludes with a discussion of the future in a high-tech society that places a premium on systems engineering strength.

Systems engineering—Origins and evolution

Systems engineering can best be considered a result of the evolution of technology in society. Originally our machines were simple (at least in hindsight), either discovered or created as a means of multiplying our strength or saving our bodies from harm or pain. Later we created machines that also supplied the power; to these we applied our intelligence and motor capabilities for control and direction. Today, as technology provides ever broader opportunities, we are evolving machines that do the work, provide the power, and also include the motor reflexes and logical thought actions previously supplied by people. The man in the

What is systems engineering and how does it work?

Like all projects undertaken by civilized man, the systems engineering process can be viewed as a *task* to be performed by *people* who use some set of *tools*. It is from this perspective that systems engineering might best be explained.

The task

In many large systems engineering projects, the tasks seem virtually boundless. Admiral Rickover described the scope of systems engineering when he spoke of creating a strategic ballistic-missile capability for the fleet. He classified the task as analogous to creating a national automotive capability. Not only must one design and produce a car; one must also create a national highway system, establish a rubber industry, develop a petroleum industry, and so on.

The systems engineering process can be essentially boundless in the time domain, also. In most cases the process must embrace all phases of the system's existence, from creation through its life and into retirement.

But the resources are *not* boundless. Much as the systems engineer would like to believe that he has a blank sheet of paper to start from and endless resources to apply to the task, in reality the time, people, and money are all limited. This fact of life manifests itself in many ways, and one of the first responsibilities of the systems engineer is to bound the task.

First, the systems engineer needs to know the constraints that apply to the program. These include a definition of the bounds of his system (for example, is he assigned the task of creating an automotive capability or just that of establishing the petroleum industry?). In addition, he needs constraints on the choice of elements for the system composition (any customer would naturally prefer to use an element already bought and paid for rather than create a new one). One of the first steps in the process, therefore, is to define the boundaries of the system and establish the constraints to be applied. In fact, if no constraints are given initially, the systems engineer must seek them.

Beyond this, the system engineering process can be broken down into six phases: *synthesis, design, execution, integration, test,* and *maintenance.* These are described below to indicate the variety and complexity of the systems engineering process. With minor variations, most texts on the subject use a similar breakout.

- **Synthesis** includes a most important first step: fully understanding what is really required of the system. This information is often masked by a number of subrequirements not necessarily relevant to the real problem. It is difficult for the customer of a major system to fully articulate his wishes at the beginning of a development effort. A dialogue is necessary between user and designer. Beyond that, synthesis of a major system involves two basic tasks: (1) allocating functions to various system elements depending on performance requirements and element capabilities, and (2) specifying performance and design of equipment and computer programs.

man-machine combination is withdrawing from direct functional participation and becoming a policy maker and provider of high-level instruction.

We see this more and more, not only in weapons systems, but also in our day-to-day conduct of communications and commerce. Today's machines, or systems, often replace a segment of society and therefore are organized on societal lines. Such an organization means that the systems are very large and complex. Coping with this level of complexity is beyond the reasonable limits of any single scientific or technological discipline; hence the evolution of a combination of disciplines under the broad label of systems engineering.

Historically, systems engineering derives from two principal sources. The first of these was a conscious effort to organize and develop commercial communications on a national—and international—scale. From the formation of the Bell Telephone Laboratories in 1925 came a gradual realization of an explicit new discipline. Indeed, the term "systems engineering" was coined in Bell Labs in the 1940s, although its formalization as part of the Laboratories' R&D structure did not occur until after World War II.

The second major force contributing to the origin of a systems engineering discipline was operations research, which originated in Great Britain during World War II as a means of optimizing employment of military equipment. (An example is the Manhattan Project, which qualifies as a classic systems engineering project, completed before the term was defined.) Other factors that contributed to the emergence of systems engineering were the discovery in 1947 of linear programming, the development of information theory, and the growing availability of digital computers.

Precise definition of systems engineering is elusive. Sage[1] calls it a "branch of management technology whose aim is to assist and support policy making and planning for decisions which result in resource allocation or action deployment." Encyclopedic definitions tend to descriptions of technical specialties, referring to systems engineering as the last logical step in the process of specialty proliferation, but not to be confused with any of the other fields. These non-definitions at least avoid the narrowness of small system developers who think in terms of specialties, for example, aircraft "systems engineering" or radar "systems engineering."

- **Design effort** for systems engineers involves extensive trade-offs to balance design margins against limitations among the system elements to assure that the system as designed will perform to the level specified.
- **Execution** is a period of building equipment and computer programs. The systems engineering role during this phase is primarily that of troubleshooting unexpected problems.
- **Integration effort** places major demands on systems engineers, who must resolve the myriad interface problems that arise the first time large, complex system elements are interconnected.
- **Test operations** also require close systems engineering attention. Special interdisciplinary teams are required to perform the types and levels of testing necessary to verify system performance against the specified function and performance.
- **Maintenance** involves all aspects of system operation and long-term maintenance support after the system is delivered to the customer. It is a task of enormous scope, ranging from equipment maintenance, to operating and maintenance documentation, to training, to systems for providing spare parts.

The people

Essentially any engineer can be a systems engineer, simply because no single discipline can perform all the functions set down under the umbrella of systems engineering. It takes a vast array of skills to carry out a large program. Recently in considering a large systems engineering task, we identified no fewer than 43 skill requirements, ranging from theoretical aerodynamics and fluid mechanics through library sciences.

Attitude is everything. The systems engineer is identified more by attitude and approach to life than by formal training or specialty. The first requirement is to be a team player. This characteristic is essential because the job skill requirements are invariably beyond the capabilities of a single individual. A second trait is an insistence on looking into and questioning all aspects of the problem to better understand it and the available options for solution. An inclination for an ordered approach is also invaluable, as is uncompromising attention to detail. The systems engineer is an avid believer in the precise statement—*in writing*—of performance requirements and system characteristics in specifications. In the systems era the "back of the envelope" documentation is as useless as is the passing on of history by word of mouth. Above all others, two prime traits stand out as most important: *discipline* and *responsibility*.

The tools

Over the years the systems engineering process has evolved a set of tools for accomplishing the tasks required. Some of these are used regularly on all programs; others are used only rarely, to meet specific requirements of special tasks. An excellent treatment of tools for combat system development was contributed by Nessmith more than 10 years ago.[3]

If we can't have a precise definition, we can at least find something descriptive. M'Pherson[2] refers to systems engineering as "an organic process that has to be conceived, organized, and managed as a whole," indicating that its essence lies "in its emphasis on the whole-system and life-cycle concepts."

In fact, "systems engineering" is a cover word for a traditional, basic function that has endured in some form through all civilization—that of the architect: the one who must be familiar with all the disciplines associated with the synthesis, design, construction, and use of the project. It should be noted here that the systems engineering we are discussing in this paper is not the purists' "Systems Engineering," involving esoteric analysis in a special laboratory of a prestigious university. Rather our systems engineering calls for a man (or woman) for all seasons, who could well be labeled a human factors engineer, or reliability engineer, or radar engineer.

The systems engineer, then, is the architect of a new race of huge, sophisticated, socially organized machines or systems that characterize technology application of the late 20th century. No industrial firm involved in high-technology systems today can function without strength in systems engineering.

Systems engineering and the AEGIS program

The development of the systems engineering organization and capabilities in Moorestown can best be expressed in terms of the development history of AEGIS. Unfortunately, to give the reader a complete understanding of the process would require a detailed description of the entire AEGIS Weapon System and Combat System, a task not attempted here. Both system description and development history are treated in the literature.[4-7]

The system

It is sufficient to say that AEGIS is a surface-to-air weapon system for area defense of the Navy's battle groups. The AEGIS Weapon System Mark 7 contains a large, phased-array radar and a computer-controlled combat direction system to fire standard missiles (Fig.1). The other elements of the system are fire-control illuminators, missile launchers, and missiles. Also included in the AEGIS Weapon System are the Operational Readiness Test System (ORTS) and the AEGIS Display System to support operational command. RCA has both design and production responsibility for the AEGIS Weapon System.

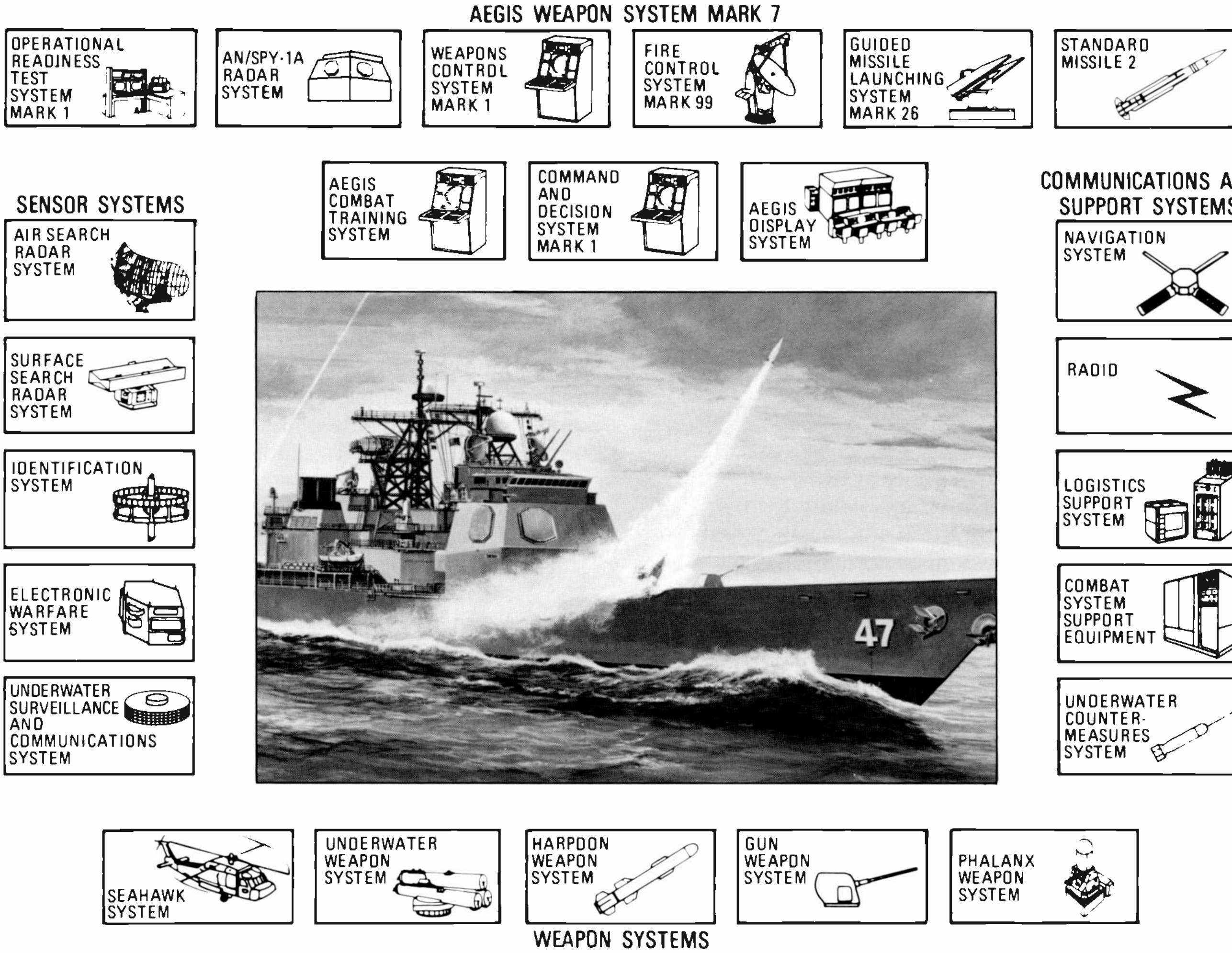

Fig. 1. The AEGIS Ship Combat System integrates a complex of 25 elements: sensors through the Command and Decision System, weapons through the Weapons Control System, and off-ship information through the communications links. The AEGIS Weapon System Mark 7, the Combat System's primary defense against aircraft and missile attack, is considered the most advanced antiair warfare system in existence.

The weapon system is a subset of the AEGIS Ship Combat System. RCA also serves as the Navy's design agent for the Combat System. In this role we are responsible for installation, test, and integration of all Combat System elements in the ship. The size and scope of this job are illustrated in the statistics in Table I.

Short history

At Moorestown the AEGIS Program began in 1963 with our involvement in the Advanced Surface Missile System, ASMS. After several years of study and delay the program got into full swing with the beginning of a competitive Contract Definition Phase in October 1968. RCA won the Engineering Development competition in December 1969, over two other industry teams led by General Dynamics and Boeing.

The early years of the program were occupied with the synthesis of the weapon system architecture and in particular with the design of the heart of the system, the AN/SPY-1 radar system. The first missiles were successfully fired from the first engineering development model aboard the Navy's test ship *USS Norton Sound* in May 1974.

The next major phase started with work on the second engineering development model, including an improved version of the AN/SPY-1, the AN/SPY-1A radar system. Perhaps more important in this phase was the assignment of Combat System Design Agent responsibility to RCA. This second model, complete with most of the rest of the combat system, is installed at

Table I. *The integration challenge.*

• *Equipment*	
• Unique pieces	840
• Computers	19 bays AN/UYK-7 20 units AN/UYK-20
• Units requiring 400 Hz power	251
• Units requiring liquid cooling	166
• Units requiring dry air	20
• *Cables*	4,900
• *Computer Programs*	
• 18 tactical programs	1.2 million words
• Support programs	1.9 million words
• Disk data base	2.2 million words
• Programming agencies	14
• *Digital Interfaces*	
• Unique	55
• Intercomputer protocols	6

Fig. 2. The Combat System Engineering Development Site, and more recently the Production Test Center, provide a land-based facility for the installation (or simulation), test, and verification of all AEGIS Combat System elements.

the AEGIS Combat System Engineering Development (CSED) site at Moorestown (Fig. 2).

The CSED Site serves as the focal point for the integration, test, and evaluation of all Combat System elements with the real-time, tactical, shipboard computer programs. Except for the underwater systems, missiles, and guns (which are represented by simulators), all sensors, weapon control equipment, computers, computer peripherals, displays, and communications equipment have been successfully installed, checked out, integrated, and tested through a series of milestones to demonstrate increasing levels of combat system operational capability and compliance with performance specifications.

The third phase began with the authorization of AEGIS Weapon System production in April 1978. During this period much of the training, logistics, and grooming activity is taking place. We are now in the full-scale production and product improvement phase, awaiting the next step in what is truly an exciting technological adventure.

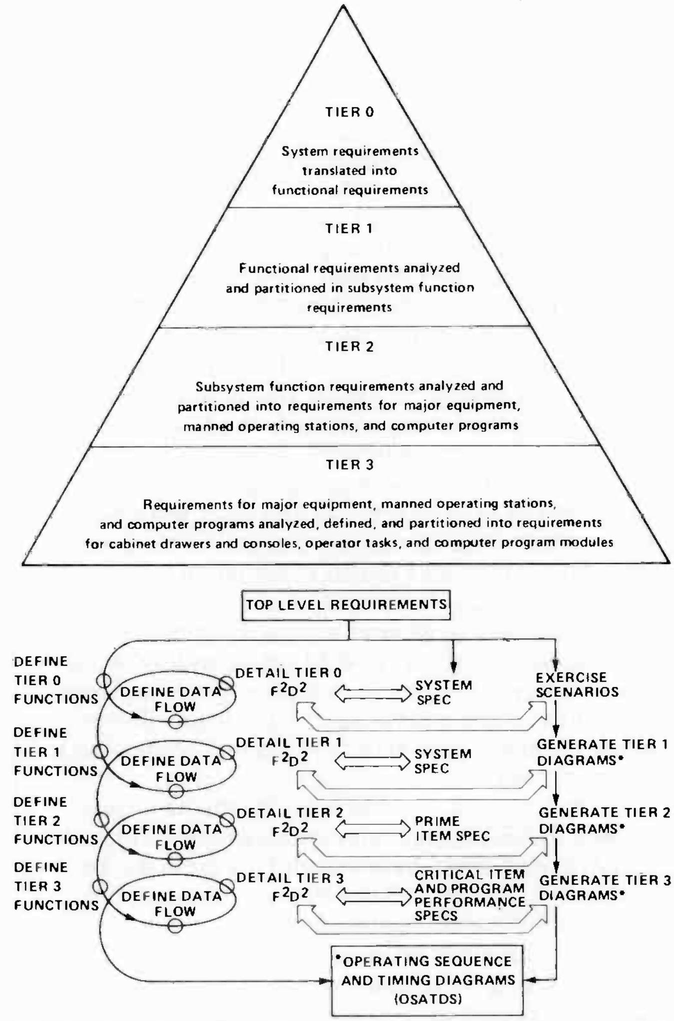

Fig. 3. Functional flow diagrams and descriptions are developed in tiers, as shown in the pyramid above. The actual development flow shows how the functions are detailed, and then included in specifications for equipment or computer programs and in the Sequence and Timing Diagrams of system-usage scenarios.

Applying the tools

Many of the systems engineering tools used in the AEGIS Program were developed or refined on the job at Moorestown. When the program began, application of formal systems engineering methodologies was not widely practiced or even well understood throughout much of industry (although radar system engineering and computer system engineering organizations were in place at MSR). At that time there was no institutionalized process in the Navy. The Air Force Systems Command had made an ambitious attempt some years before with its AFSC 375 series of Systems Engineering Standards, but these had largely died from overinterpretation, misunderstanding, and the weight of their own complexity.

What follows is an account of the major tools assembled for use in the AEGIS Program, their purpose, and their effectiveness.

Computer models—an absolute necessity for any systems organization is the ability to build, maintain, and use large-scale, high-level models of the system under development.

One of the first items developed was a large-scale computer model of the radar and weapon system. This model was used to perform initial tradeoffs and evaluate overall performance. Called SPECTRM, it was very thorough from a system-performance point of view, but worked on a single engagement reference. Later we developed a larger, more operations-analysis-oriented program called MEDUSA,[8] which modeled the entire ship in a multi-target environment reference. Recently we completed a program called PROTONS[9] to model the entire force. In total, these three programs include more than 75,000 FORTRAN statements, and all run in the DEC-System 20 machines in MSR's Naval Systems Department computer center.

Functional analysis—fundamental to the process of allocating function and performance to the system elements are established and institutionalized techniques for functional analysis. The methodology developed at Moorestown for system functional analysis is a simplified version of one developed earlier by the Air Force; we labeled it F^2D^2 for Functional Flow Diagrams and Descriptions.[10,11] This technique is invaluable as a tool for completing system functional analysis (Figs. 3 and 4). With this technique, all system functions are identified and eventually allocated within the system to either a piece of equipment, a computer program, or a human operator.

Specifications—specifications are cornerstones of the system design, because they represent, at the top level, a mutual under-

The AEGIS ships today

The Navy's current plans call for 24 *Ticonderoga*-class cruisers. At the time this article was written, RCA had contracted for 10 AEGIS Weapon Systems and was also serving as Combat System ship integration contractor for all ships. The USS *Ticonderoga* was at sea with the fleet; *Yorktown* (CG48), christened in April, 1983, had AEGIS Lightoff scheduled for July, the AEGIS Weapon System for CG 49 was installed and operating in the Production Test Center, and the CG 50 AEGIS Weapon System was in the process of being installed. The CG 49 and 50 hulls were nearing completion at Ingalls shipyard, and Bath Iron Works was readying facilities for fabrication of CG 51. The first CG 51 arrays were being assembled, while fabrication of water coolers, cabinets, and cables was ahead of schedule for the CG 52 and 53 AEGIS Weapon Systems.

Development work was also well underway for the new AEGIS destroyer DDG 51 class, with RCA serving as the Navy's combat system engineering agent. Long-term plans call for up to 60 of these *Burke*-class warships, with ship construction scheduled to begin in 1986.

At Moorestown, the first array for the new radar system of AEGIS Engineering Development Model 4 (EDM-4) was being assembled. This array will be part of the AN/SPY-1B development model of the AEGIS Weapon System Mark 7 Mod 5 for *Ticonderoga*-class cruisers beginning with CG 59 and the AN/SPY-1D radar system for the *Burke*-class destroyers.

The AN/SPY-1B radar system array will incorporate the very latest producible technology and will use new phase shifter and beamforming techniques to achieve very low sidelobes. The AN/SPY-1B signal processor will use a distributed microprocessor system.

Once assembled, the array will be tested in the ANFAST II (AEGIS Near Field Antenna System Test facility), which was specifically designed to test and align the EDM-4 high performance array as well as subsequent production arrays for the AN/SPY-1B and -1D radar systems. This developmental array will later be evaluated as part of the total model when EDM-4 is installed in the CSED Site.

standing of requirements reached with the Navy; at the lower levels they become the actual requirements placed on the designers.

We were given a set of top-level system requirements by the Navy, and it was necessary to complete this specification and other supporting specifications a few tiers (and in some cases several tiers) lower as part of the systems engineering process. Over the course of the program we have written and are maintaining more than 300 individual specifications. In general, the format used for the specifications is MIL-STD 490, the hierarchy of which is depicted in Fig. 5. A special Navy standard, SECNAVINST 3560.1, is used for the computer programs.

Fig. 4. The F^2D^2 Room becomes the systems engineering control center during the synthesis and early design phases of a new system, providing complete, current status of *all* system functions.

Budgets—to support the specification effort it is necessary to set up several budgets to govern allocation of function and performance to the various elements of the system. In addition to the obvious budgets (weight, space, power), we established error budgets, Reliability/Maintainability/Availability (RMA) budgets,[12] system reaction-time budgets, maintenance man-hour budgets, and a number of others. In the computer program area we established core and time budgets for all programs and computers.[13] These budgets have proved to be indispensable as a method of control over the course of the program. An example is shown in Fig. 6.

Standards—a systems effort of this magnitude demands a standards program. The initial effort was to properly interpret the Navy-imposed environmental and construction standards. This effort eventually led to a complete standards program, including standard rules for parts selection, an AEGIS Standards Manual, a standard parts list,[14] and construction and installation standards. The AEGIS system is not only the most sophisticated weapon system of its time, but also the first required to be designed from the ground up to withstand the electromagnetic pulse (EMP) from a nuclear burst. The obvious potential for electromagnetic interference and EMP hazards required very special attention to detail in grounding. New methods were developed and a new double-shielded cable was specified as a standard for the system. This cable subsequently became a Navy standard.

Computer programming tools—the heart of virtually every large system is its real-time computer programs. As the AEGIS Program moved into its execution phase we developed new tools and skills to accommodate the need. The design of the computer system and the architecture for the real-time computer programs had been laid out early, and working tools for the program development were crafted. With the help of our subcontractor, Computer Sciences Corporation, our programming standards were defined and imposed. A set of programming support programs was defined and prepared. The standard compiler was installed and checked out.[15,16]

In addition to all these activities, the generation of large-scale, real-time computer programs requires a facility for compilation and testing of the programs. This facility was initially defined and established at a Computer Sciences Corporation facility in 1970, and expanded over the years until today it comprises more than 20 computers, 2.5 billion bytes of disk storage capacity, and a complete program library with more than 10,000

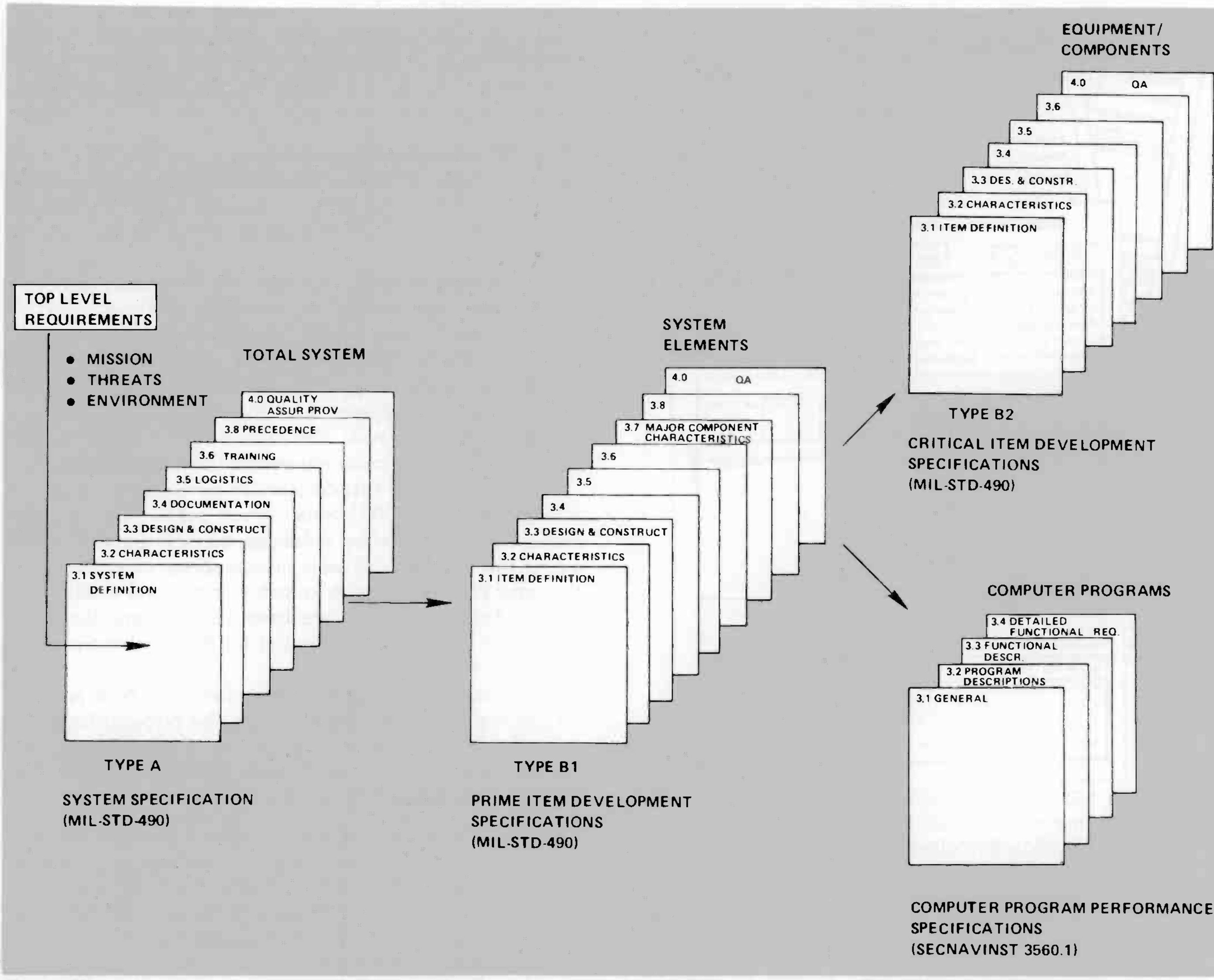

Fig. 5. This structure, or hierarchy, for specification development on major systems begins with Top-Level Requirements, which specify broad mission requirements and threat environment. From these comes a series of documents that specify performance of the system, its elements, and their equipments and computer programs. This structure is rigorously defined for military systems in a variety of Military Standards.

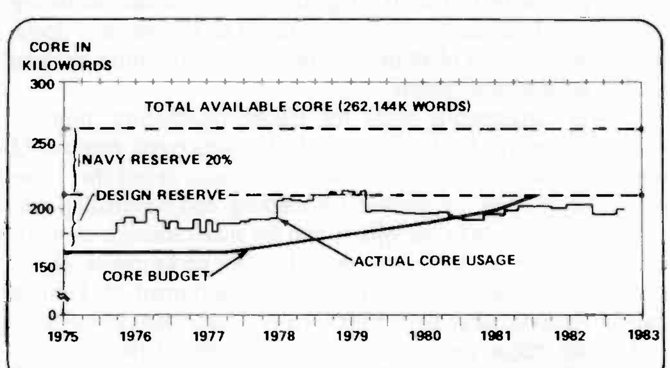

Fig. 6. Management of computer program resources (core and time) is critical to achieving successful large-scale real-time programs. Shown here is a carefully recorded status history of core use for a major AEGIS system element program. Note that a substantial Navy reserve is built into the core-management process to allow for changes and additions when the programs become operational.

tapes on file in addition to numerous other facilities. More than 1100 people from five companies work at this Program Generation Center and the Computer Program Test Center.

As the programming effort got underway a feedback mechanism was set up to allow a formal dialogue between programmer and systems engineer. This mechanism consisted of a set of specific requests called SDRs (System Definition Requests). Over the years more than 8600 of these have been processed. In addition to the questioning it was also necessary to monitor problems as the programming work proceeded. This monitoring process employs the CPPR (Computer Program Problem Report). Over the years more than 15,000 CPPRs have been formally issued and processed. Figure 7 shows a sample of the computer program monitoring forms. In the equipment area similar institutionalized methods were set up for systems engineering to communicate with and monitor the activities of the designers.

Integration tools—the integration of a large system takes place over a period of years. It must be integrated a small piece at a time, and the system engineers must do it; they are the only ones

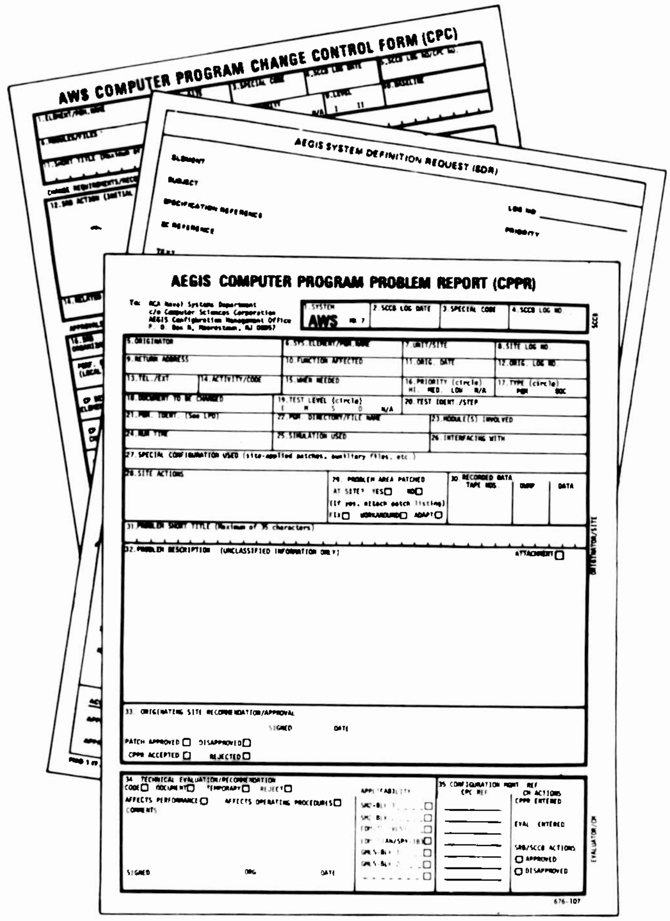

Fig. 7. The AEGIS System Definition Request form (center) provides a formal means by which programmers may request and receive specific information from the systems engineers. The Computer Program Problem Report and Computer Program Change Control forms are used to monitor and maintain control over programming problems throughout the development process.

who understand the final objective.[17] Furthermore, no one engineering group has the breadth to do the whole thing.

A semipermanent integration structure was established. Ad hoc groups were then established that operate within the structure, charged with specific phases of the integration. These groups are staffed with the specific talents required for those tasks. Once a task is completed the group is dissolved and a new one set up tailored for the next step. Group leadership changes frequently, not only because of the various skill requirements but because the physical and mental stress of the intense integration activity cannot be tolerated indefinitely. This approach not only prevents staff "burnout," but also results in the creation of a sizable group of extremely competent and experienced systems integration managers.

Test tools—system testing is carried out concurrently with integration. The initial test requirements were defined at the same time the specifications were written. An institutionalized process was then set up, first to translate these into a set of test requirements to verify all aspects of the system performance. These requirements were then integrated into a system test program, one level at a time, until the full system was under test. Much systems analysis is required to devise these tests and produce an outcome that can be evaluated against accept/reject criteria.

Part of the systems engineering test effort was the creation of a computerized data reduction system that operated on the computer data tapes taken from the system during test. The data reduction system with its associated programs was made interactive with the test analysis so that detailed and specific reports could be prepared automatically.

Ship integration tools—the assignment to act as the Combat System Design Agent meant that RCA has to represent the AEGIS Combat System to the shipbuilders and to the shipbuilding community. This called for the creation of an additional set of tools.

A large computerized data base was established that contained the physical data on the more than 1500 separate components of the Combat System. This data base includes not only dimensions and weight, but also such information as electrical and cooling requirements. This listing has become the Master Combat System Equipment List from which RCA, the Navy, and the shipbuilders work. The physical data is used to prepare compartment arrangements and interface control drawings.

Another large data base contains the wiring interconnect data for the more than 4900 combat system cables. With this data base and automatic drafting techniques, the cable drawings, wiring interconnection lists, and cable running sheets are produced for the entire combat system in formats common and usable by all parties. These two large data bases have become the major instrument of configuration control for the Combat System as installed in the ships.

In addition, several special publications have been prepared for the shipbuilding community; RCA also prepared large portions of the specification used to select the shipbuilders. Systems engineers even prepared the Combat Systems Alignment Plan for shipboard alignment and alignment verification.

Lifetime support tools—lifetime support is built into the basic AEGIS Weapon System architecture in the form of the Operational Readiness Test System (ORTS).[18] ORTS is a system designed to automatically perform fault detection and fault isolation within the system. More than 30,000 test points are built into the system to monitor its operation. This is in addition to automatically scheduled operational performance tests run in background on the real-time tactical computer programs to perform both fault detection and fault isolation. A disk data base of more than 2 million words is used to aid fault isolation. ORTS is closely tied to the logistics considerations, including manuals and documentation; the more ORTS, the less documentation. The sum of all these elements, however, must become a total maintenance system.

Systems engineering tools for failure monitoring must be established early. First we established a structured method of reporting equipment failures. This process was called the Trouble Failure Report—a method for tracking and eliminating reliability weak points in the system and for maintaining a continuous, up-to-date assessment of the reliability performance of the system. Over the 13 years since the establishment of Trouble Failure Reports, more than 19,000 reports have been processed.

Another major item in the lifetime support of the system is training. RCA developed 20 full-scale training courses for the AEGIS Weapon System, taught the first classes, and trained the Navy teachers.

Logistics—finally, and most important in the lifetime support area is the item of logistics. RCA systems engineers have developed a revolutionary method of defining on-board spares for the ship, designed not only to be responsive to the need for continuous availability, but also to the characteristics of the systems architecture. The system, called SEASCAPE, is now being considered for wider application throughout the Navy.[19]

This brief review covers only a small portion of the total count of systems engineering tools applied to the AEGIS Program. The organization itself contains several hundred technical professionals. The bottom line is the tremendous amount of background and experience that must be accumulated in an organization for it to lay claim to true large-scale systems engineering capability.

How did it happen?

Today RCA Missile and Surface Radar has in its Naval Systems Department a kernel of highly developed systems engineering skills for combat system conception and development that is probably unmatched in the world. Indeed, the Moorestown Systems Engineering capability has been characterized by RADM Wayne E. Meyer, AEGIS Shipbuilding Project Manager, as a national asset.

How did we get there? How did we develop this apparently unique capability? The answers to these questions lie in the chain of events dating back to the early 1960s. In fact, AEGIS systems engineering is a child of necessity, born and brought up in an environment that demanded an organization with the full range of modern systems engineering skills.

First was a level of system complexity that precluded simplistic approaches and solutions. The system began as one of the most complex ever developed; it grew moreso over a decade of added scope. We were especially fortunate in starting with a small cadre of mature, experienced, systems-oriented engineers who understood the systems problems at the beginning and thereby created an opportunity to formulate requirements, to staff the project, and to evolve and adjust the systems under development over a period of years—a special and rare learning experience.

A second, and major contributor to the development of this staff was very strong, consistent Navy leadership that demonstrated not only competence, but vision. Since the summer of 1970 there has been only one Navy Project Manager, RADM Wayne E. Meyer. Admiral Meyer brought both wide experience and great knowledge to the program. We became what he demanded of us.

We were also blessed with an understanding of systems engineering within RCA management. All three of the Naval Systems Department vice-presidents who have served over the course of the program had previous assignments as systems engineering managers.This kind of support nurtured an employment environment that allowed us to attract a consistently high level of talented people to staff the program.

Finally, although there were setbacks along the way, the program enjoyed a degree of continuity in national priority and support that promoted a stable climate in which the team could flourish.

What of the future?

It would seem that the late 20th Century is the time of the systems engineer in terms of where technology and society are taking us. It would seem that the systems engineering capability in Moorestown is the right instrument at the right time in history. The effective use of this capability for the common good is a grave responsibility placed on both RCA management and the U.S. Government.

For the time being this organization is fully dedicated to the AEGIS cruiser and destroyer programs for the Navy. The responsibility to serve the AEGIS Program is one that is fundamental to the organization and will continue to be our prime objective as long as the Navy sees a need for our services.

Nonetheless, the techniques, methods, disciplines, and approaches have permeated all of MSR engineering, thereby enabling us to seriously consider undertaking tasks of very broad scope. Some of these that come immediately to mind include working with the FAA on modernization of the entire federal airways system, or undertaking for the Army and/or Air Force a series of linked command and control systems of national and international coverage.

Where will systems engineering at large go? The horizons outside the military sphere are virtually limitless: new transportation systems, attacks on pollution, reconstruction of urban areas—these are all problems of immense scope and complexity that literally demand systems engineering solutions.

And what of systems engineering as a discipline? It seems clearly on a path of growth and development that parallels or exceeds the growth of technology generally. Every day we find a new way of automating the things we do—a new way of writing a computer program to solve our problems, or print our reports, or write our specifications, or do our functional allocations. We at MSR will move in that direction because we will be forced to by the technology and the competition. We need not, however, worry over rendering ourselves obsolete or expendable in the process. Neither complex computer programs nor massive "thinking machines" will replace the systems engineer, whose essential tasks involve, in addition to intellect and discipline, a level of judgment, responsibility and experience that simply cannot be built into a machine.

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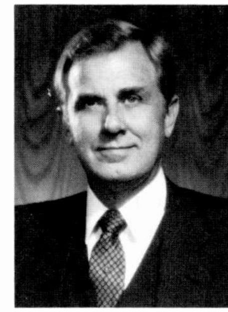

Joe Threston began his systems engineering career at the Hughes Aircraft Company's Guided Missile Laboratory in 1957 as a participant in the development of the Falcon missile. Since joining RCA in 1959, he has held increasingly responsible engineering and management positions in systems engineering organizations. His direct involvement with the AEGIS Program began in 1968, and in July 1981, he was appointed to his present position of Division Vice-President, Naval Systems Department.
Contact him at:
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Moorestown, N.J.
TACNET: 224-2235

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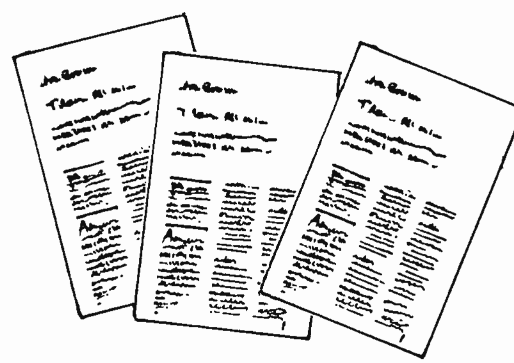

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Microcomputer Index, 1980 to present— *a subject and abstract guide to magazine articles from 21 micro-computer journals, including* Byte, Interface Age, InfoWorld *and* Personal Computing.

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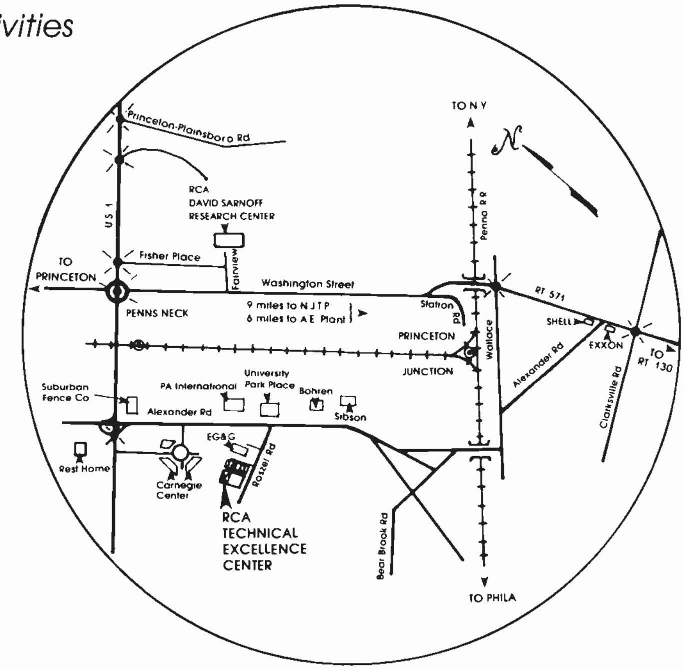
H.K. Jenny

RCA Technical Excellence Center established in Princeton

The Technical Excellence Center supports activities contributing to corporate-wide engineering viability.



On July 1, 1983, the RCA Technical Excellence Center was opened at 13 Roszel Road, Princeton, New Jersey. The objective of the Center is to assist the RCA business units in their efforts to develop and maintain a highly competitive and viable technical work force. This effort had previously been carried out by the Engineering Professional Programs activity at the Cherry Hill location.

The need

Thornton Bradshaw, RCA's Chairman and Chief Executive Officer, recently pinpointed RCA's corporate goals this way in a 25-year-service award luncheon address:

> "The RCA of the future will emphasize three primary areas of operations: Communications, Electronics and Entertainment. We are going back to the roots . . . .
>
> "Beyond specific strategic, product and profit objectives, I have set an overriding goal: to reaffirm RCA's long-established reputation as a profitable, forward-looking, quality enterprise with international stature."

Abstract: *The goals and activities of the Technical Excellence Center, now established in Princeton, are described and placed in the framework of the Corporation's objectives. The approach is to use networks throughout the Corporation to maintain the technical excellence and interests of the engineering community. The services are broad-based and are being successfully used by a large portion of the RCA engineering population.*

Final manuscript received June 30, 1983.
Reprint RE-28-4-3

Technology is moving at a dizzying pace. Whereas years ago leaders in technology could choose and pursue areas of interest and expertise that they could dominate relatively unchallenged, today they find themselves confronted by extremely fierce worldwide competition. To succeed, they must innovate to stay ahead, use advanced technologies and facilities, and be fully aware of and leapfrog competitors' technological achievements. Operating with yesterday's technologies and methods is not good enough. Sensitivity to and rapid pursuit of new and better ways to do business is vital. Thus, the technical excellence of a company will bear heavily on its successful business conduct.

Approach

The measure of technical excellence is determined by RCA's technical work force. RCA has always strongly supported its scientists and engineers. Although this is done mainly in the engineering departments located throughout the corporation, RCA's Corporate Staff provides and coordinates additional services through its Technical Excellence Center.

Attainment and upkeep of technical excellence require above all a challenging and motivating environment. This includes stimulating job assignments and up-to-date facilities as major attributes. Many supportive attributes such as the availability of current and useful information, education in state-of-the-art techniques and technologies, productive interaction with relevant colleagues, and recognition of outstanding achievements condition this atmosphere as well. It is in these latter activities that the Technical Excellence Center supports RCA's technical employees.

How does the Technical Excellence Center work?

The Technical Excellence Center's approach is to:

• Determine professional needs	through interacting networks with the engineering activities, and through the Technical Excellence Committees
• Develop approaches/programs	to meet specific needs
• Stimulate/recommend	programs to meet these needs
• Support new and ongoing programs	by assisting in startups and coordinating corporate-wide efforts
• Directly present engineering ideas and successes in educational and publications settings	to recognize engineering effort, foster cross communication, and encourage continuing engineering education

In these efforts, the members of the Technical Excellence Center work with the various involved engineering departments by use of appropriate networks that include managers, engineers and support personnel, and especially RCA's Technical Excellence Committees (Fig. 1). The services supplied by the Technical Excellence Center are usually implemented in cooperation with the engineering groups. Table I summarizes the ongoing activities of the Technical Excellence Center and shows the range of its responsibilities.

Much of the effort of this modestly sized group centers on specific products/services delivered throughout the corporation: production of videotape courses, Corporate Engineering Education course material distribution, videotape lending library, *RCA Engineer* magazine, *TREND* news digest, *Technical Abstracts* bulletin (TAB) and Technical Abstracts Database (TAD).

The RCA Technical Excellence Center and the technical employee: A successful partnership

When technology changes as rapidly as it does in RCA's businesses, technical professionals face the continual problem of how to keep up. The issue of technical obsolescence and how to combat it has

Table I. *The activities of the Technical Excellence Center.*

Technical Education

Develops course needs and plans. Develops complete video course packages that are made available for delivery at RCA locations for the continuing education of RCA's technical staff. Develops and administers a videotape library covering general technical subjects, plant orientations, video course previews, technical symposia and seminars, and RCA Laboratories colloquia. Provides educational consultation and services.[1,2]

Technical Publications

RCA Engineer—Offers in-depth technical articles for RCA's multidisciplinary engineering audience. Published bimonthly, this engineering magazine contains papers authored by RCA engineers on specific engineering themes that cross divisional lines.

TREND (The **R**esearch and **E**ngineering **N**ews **D**igest)—Alerts RCA's engineers each month to the Corporation's latest technical and business advances.

Technical Information Systems

Publishes the *RCA Technical Abstracts* bulletin each month. The bulletin references RCA-authored papers, reports, presentations, and patents. This information is also available in an on-line data base for computer searching. Provides coordination of the RCA technical library system and publishes catalogs of library holdings.[5,6,7]

Engineering Manpower and Resources

Provides an engineering head count, engineering statistics, the Engineering Resource Directory, and carries out engineering productivity studies.

Technology Symposia

Convenes technical personnel in specific disciplines for presentation and discussion of state-of-the-art developments.

Technical Excellence Program

Sponsors and coordinates Technical Excellence Committees (TECs) composed of engineers at various RCA locations. Members of the TECs address issues of maintaining technical competence and provide programs helpful to engineers.[3,4]

Minorities in Engineering Program

Coordinates the corporate-wide program, which is an in-depth orientation to the engineering profession for promising young students.[8]

been a popular subject. One aspect that has been debated is who is responsible for assuring technical viability—the employer or the technical employee? Obviously, it is important to each.

RCA deals with this aspect as a partnership. It expects technical professionals to be committed to maintaining "field" competence and to be willing to work at it. Through vehicles such as Technical Excellence Committees and voluntary after-hours courses, technical staff are expected to display initiative, leadership, and self-help. For its part, RCA provides facilities, expertise, encouragement as well as tangible services such as libraries and the *RCA Engineer* magazine. This partnership forms a winning combination.

The Technical Excellence Center is visible evidence of RCA's commitment to excellence in science and engineering. It is a corporate representation of the successful partnership. As the accompanying box demonstrates, the Technical Excellence Center has developed the pervasive media and methods to bring engineers together. And the interest and support from the engineering community is profound.

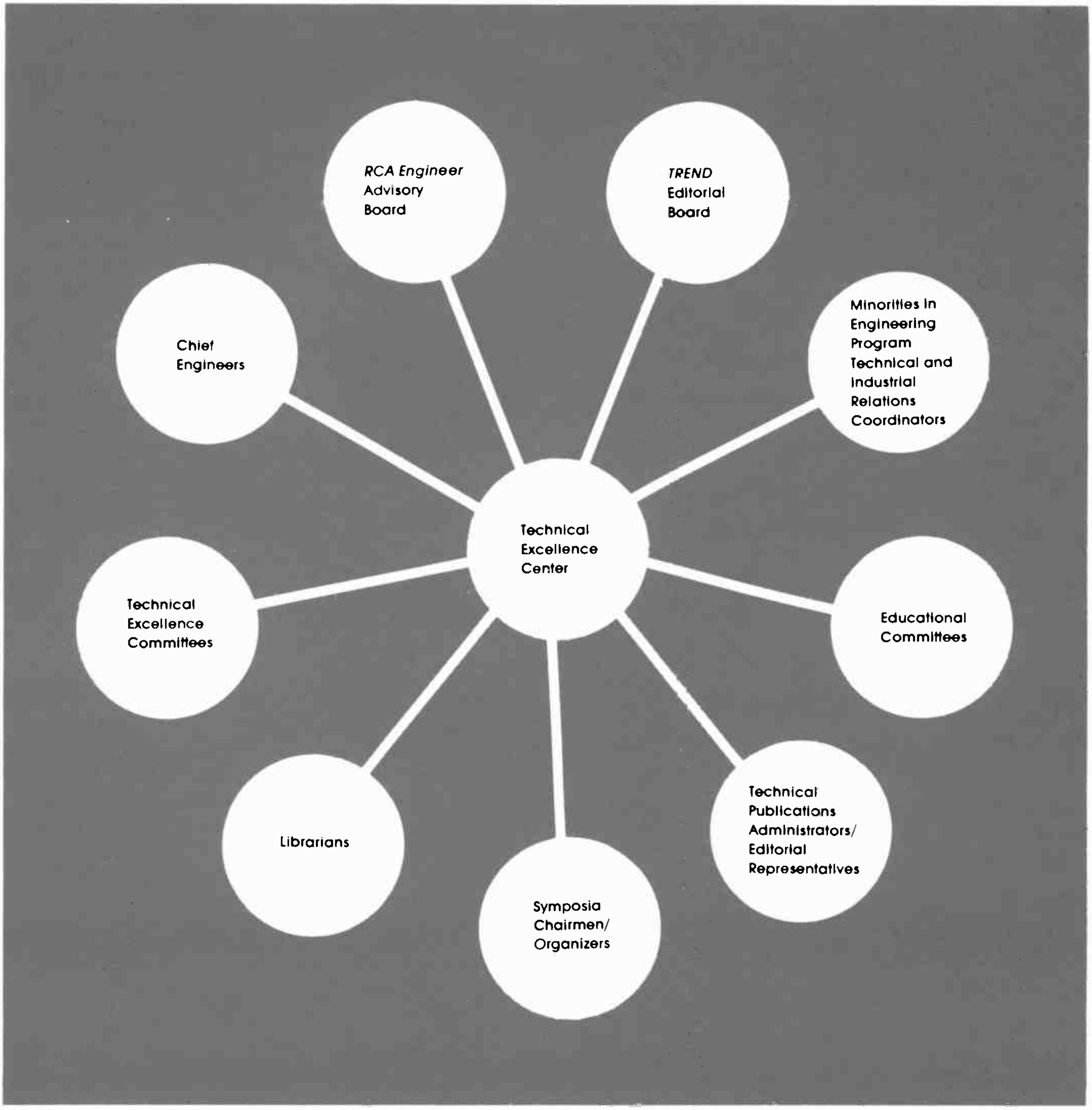


Fig. 1. *The Technical Excellence Center works with local networks.*

The Technical Excellence Center and the engineering population

Annual Corporate Engineering Education course enrollment: 3,000

RCA Engineer distribution: 10,000

TREND distribution: 14,000

RCA technical libraries: 24

Technical Excellence Committees: 20 (covering 85% of engineering work force)

Technical Abstracts Database references to RCA documents: 20,000 (1969 to date)

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Technical Excellence Center contacts

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General Management	226-3011	(609) 734-3011
Facility Administration	226-3023	(609) 734-3023
Technical Education	226-2971	(609) 734-2971
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A.M. Morrell

The RCA COTY-29 tube system

The RCA COTY-29 tube system was announced to the industry in June 1982. The new tubes will be starting into mass production this year. They should be the most popular new tubes in sets next year.

The RCA COTY-29 development is a new generation of color picture tubes having many improvements over the present in-line self-converging tubes. It is a system wherein all factors—the yoke, the tube, and the receiver interface—have been optimized for system cost and performance. Its name, COTY-29, stands for **C**ombined **O**ptimum **T**ube and **Y**oke with a 29-mm diameter neck. This system covers all tube sizes from 13V through 25V as well as 90° and 110° deflection angles.

The features of the COTY-29 system are:

- An improved electron gun using an extended diameter lens (XL) for reduced aberration and improved focus that is substantially independent of beam spacing.
- Maintenance of the 29-mm neck diameter for optimum focus.
- Improved convergence achieved by reduced beam spacing in the new XL gun without sacrificing focus performance.
- A miniaturized yoke for lower cost and lower deflection-power requirements.
- High reliability by continued use of the 29-mm neck diameter together with standard bases and sockets.

Tube evolution

To put the COTY-29 development in proper perspective, it would be useful to review some of the major steps in the self-convergence in-line color picture tube development since its early-1970s introduction.[1] Table I shows the major steps in this evolution.

In 1972, the first in-line tubes with self-converging 90° yokes and line screens were marketed.[2] These tubes featured a unitized in-line gun using a bipotential main lens with a focus voltage of 20 percent of the anode voltage. The deflection yoke had toroidal windings for both horizontal and vertical deflection. This type of yoke was chosen since the toroidal windings could be precisely placed and, therefore, make a very consistent product. A gun with beam-to-beam spacing of 5.1 mm was chosen to assure good convergence and to provide an adequate lens diameter for the 20-percent bipotential lens.

In 1975, the 110° version of this tube was introduced into the European market.[3] The gun was similar to its 90° predecessor except for the use of slot optics to minimize deflection defocusing. The yoke retained a toroidal-toroidal winding but an additional quad winding was included to aid in convergence.

The next step was the switch from the toroidal-toroidal type yoke to one using a **S**addle horizontal coil and a **T**oroidal vertical coil (ST yoke). This change was made primarily so that the horizontal coil inductance could be increased to provide a better match to the transistor drive circuitry. At this time the beam-to-beam spacing on most tubes was increased from 5.1 mm to about 6.6 mm. This was done to increase the available space given to each of the three guns. The extra space allowed a larger lens diameter for improved focus. To take advantage of the larger lens, the focus voltage was increased to 28 percent of the anode voltage.[4] Two years later the ST yoke and wider-spaced gun design was incorporated into 110° tubes primarily for use in the European market.

In 1977, there was another development in guns aimed at further focus improvement to allow the in-line system to be more competitive in large-size tubes with 90° and 100° deflection angles. Multi-element focus designs with increased focus-voltage requirements were developed in this time period. Several different arrangements were introduced.[5,6]

After the improved gun designs were established, changes in 90° and 100° yoke designs were introduced. Prior to this time, most of the ST yokes were corrected for north/south pincushion distortion, but the east/west pincushion distortion was corrected

Abstract: *This paper describes a new color television picture tube system which has been developed by RCA at Lancaster in conjunction with Consumer Electronics and the Labs.*

Called COTY-29 (which stands for "Combined Optimum Tube and Yoke in a 29-millimeter neck"), the system features an improved gun with a new XL focus lens and a cost-reduced, minimized yoke. Reliability and performance are improved while manufacturing costs have been reduced.

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Table I. *Major steps in the evolution of in-line picture tubes prior to the COTY-29.*

Year of introduction	*Deflection angle*	*Yoke type*	*Beam-to-beam spacing (mm)*	*Neck diameter (mm)*	*Gun type*
1972	90°	TT	5.1	29	20% Bipotential
1975	110°	TT plus quad.	5.1	29	20% Bipotential
1977	90°	ST	6.6	29	28% Bipotential
1977	100°	ST	6.6	29	40%/28% Tripotential
1979	110°	ST	6.6	29	28% Bipotential
1980	90°/100°	ST pin-free	6.6	29	Various
1980	90°	ST pin-free	4.8	22.5	Various

by means of circuitry. The new generation of ST yokes were designed and constructed to be pin free, thereby eliminating the cost of circuit correction. Although this provided an attractive option from the circuit standpoint, it complicated the design of both the yoke and the picture tube. To obtain east/west pin correction, the distribution of field gradients in the yoke were altered in a complex manner by means of biased windings and/or the addition of flux-shaping metal pieces. In addition to increasing yoke costs, these yokes also caused greater beam distortion due to their higher field gradients. Several different types of pin-corrected yokes were introduced; these were noninterchangeable because of the different register and coma error (difference in size of the raster of the center beam compared to the outer beams) characteristics produced on the tube.

In 1980, another tube-and-yoke design was introduced in Japan for smaller tube sizes—the neck diameter was reduced from 29 mm to 22.5 mm.[7] This change was incorporated to reduce yoke cost and deflection power. It also reduced gun size and required a reduction in beam-to-beam spacing from 6.6 to 4.8 mm. The smaller gun diameter challenged the gun designer to obtain good focus characteristics.

COTY-29 development

Against this background of design evolution, the COTY-29 system concept was developed. The designers' goal was to properly consider cost and performance of the tube, the yoke, and the circuitry. A further goal was to have a system that could apply to all tube sizes and to both 90° and 110° deflection angles. It was established that 90° deflection is optimum for small tube sizes up through 19V. With 19V as the cross-over type, 110° was selected as best for the 19V through 25V sizes.

The basic elements of the new system are a new XL gun for improved focus and a miniaturized yoke to reduce yoke cost and deflection-power requirements. The XL allows a reduction in the beam-to-beam spacing with little effect on focus performance.

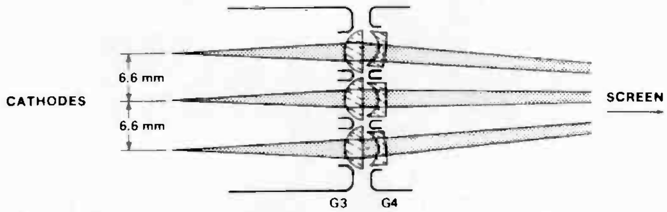

Fig. 1. *The optical analogy of the main lens in the present gun.*

This beam-spacing reduction gives better convergence and, together with a new optimum contour of the funnel, permits the miniaturization of the yoke.

The XL gun

The principle of the XL gun is best illustrated by reference to its predecessor. Previous in-line gun designs created problems because of limited available space for a low-aberration gun. Since the diameter of each of the in-line guns is limited to slightly less than one-third of the inside neck diameter, various systems have been designed to obtain the best focus within this basic limitation. Figure 1 shows the diameter limitation of most present gun designs by means of a light-optics analogy.

The XL uses a larger common lens for the major element of the main focusing lens. This is achieved as shown in the light-optics analogy of Fig. 2. An oval ridge on grid number 3 and also on grid number 4 forms a large lens encompassing all three beams. Because of its greater size, the aberrations of this lens are small by comparison to those of a conventional lens.

Figure 2 also shows that there are small lenses formed by the individual guns, but their action is small in comparison to the large common lens. This feature makes it possible to change the spacing between beams, without significantly affecting focus characteristics. The focus quality of this lens is limited primarily by the neck diameter, not the beam spacing. By taking advantage of this basic characteristic, designers have reduced the beam-to-beam spacing of the COTY-29 system from 6.6 to 5.1 mm.

This reduction in beam-to-beam spacing was selected because it improved the convergence. Most convergence errors are roughly proportional to beam spacing. The reduction in beam spacing by 23 percent will, therefore, result in approximately the same

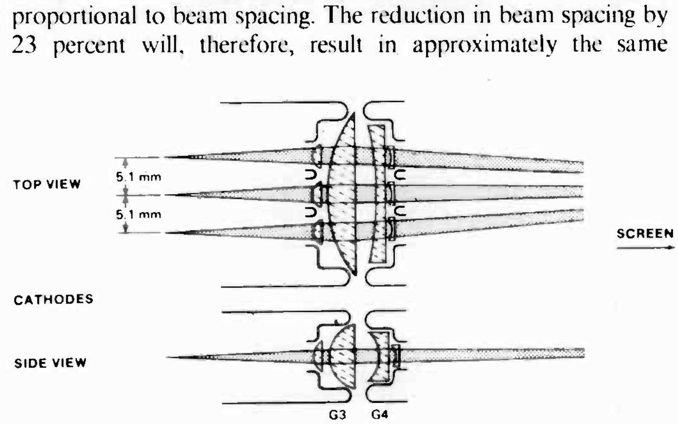

Fig. 2. *The optical analogy of the main lens in the COTY-29 XL gun.*

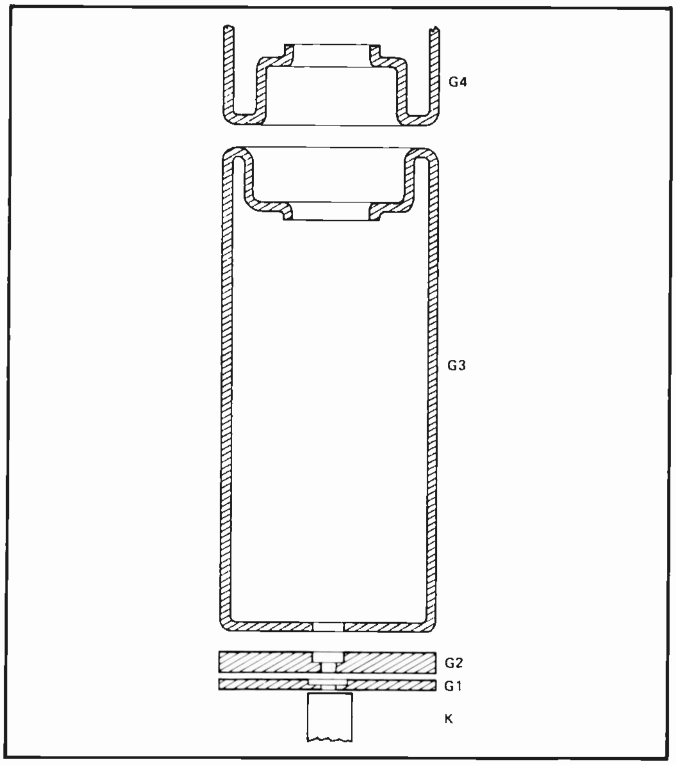

Fig. 3. *The XL HiPI gun.*

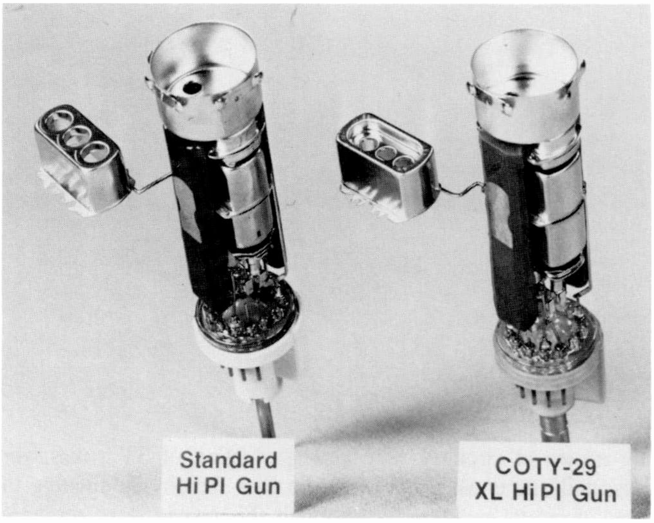

Fig. 4. *The XL HiPI gun (right) and the standard gun.*

degree of improvement in convergence. In addition, the coma error is reduced greatly by the smaller spacing. Experimental data shows that the correction for coma, by means of field formers on top of the gun, is reduced by a factor of two. This reduction is useful in providing a greater allowable tolerance for tube-and-yoke variations.

The reduction in beam-to-beam spacing, although it improves convergence, results in slightly reduced screen tolerances. The effect of the earth's magnetic field on screen register is inversely proportional to beam spacing. Internal magnetic shields, commonly used in present-day tubes, minimize this problem. Previous use of this spacing has shown that, from a practical point of view, this decrease in screen tolerance is quite small.

For 90° tubes, the XL feature is used in a high-focus-voltage bipotential precision in-line (HiPI) type gun. Figure 3 shows this construction. The focus voltage is approximately 26 percent. Figure 4 is a photograph of the XL HiPI gun compared to its predecessor. An extra grid number 3 has been attached to each gun in the photograph to show the difference in construction.

For 110° COTY-29 tubes, the XL feature is used in a double bipotential gun. Figure 5 shows this DB construction with the XL formed between grid number 5 and grid number 6. In this case, the focus voltage is approximately 31 percent of the anode voltage. The reason the DB design was chosen for 110° deflection types was to obtain the smallest beam diameter in the deflection yoke. Since all self-converging yokes cause deflection defocusing, the smaller beam size of the DB gun reduces this

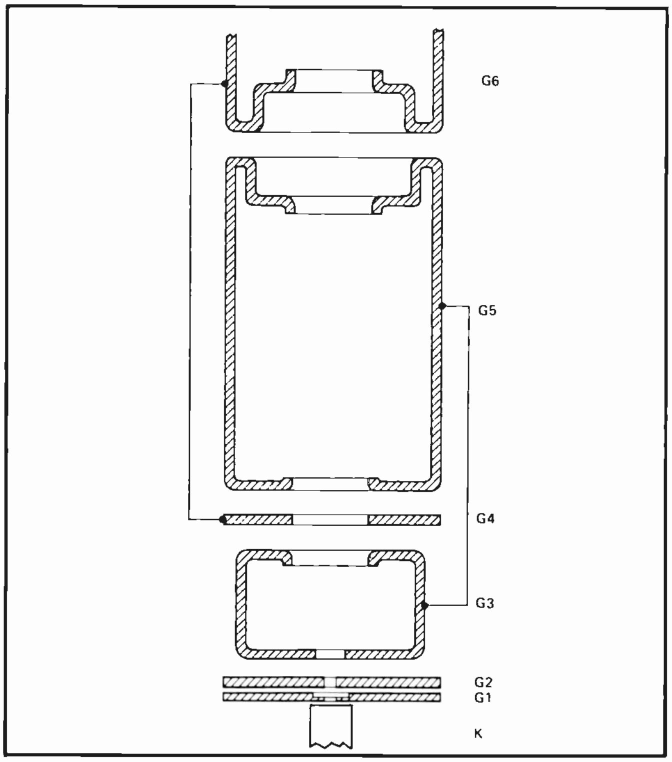

Fig. 5. *The XL DB gun.*

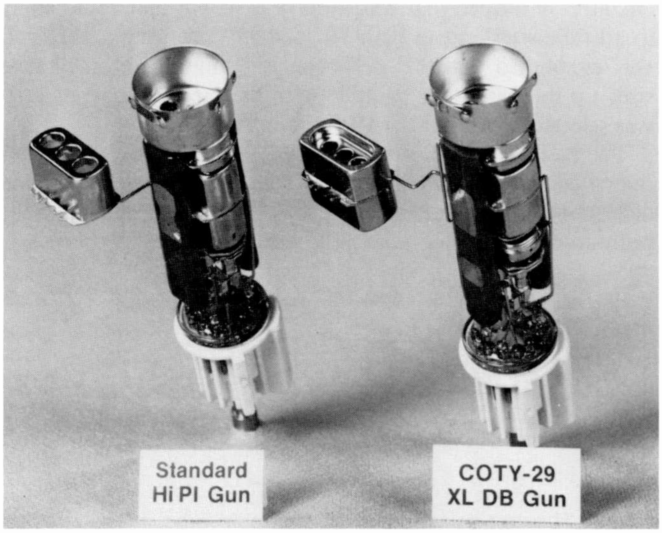

Fig. 6. *The XL DB gun (right) and the standard gun.*

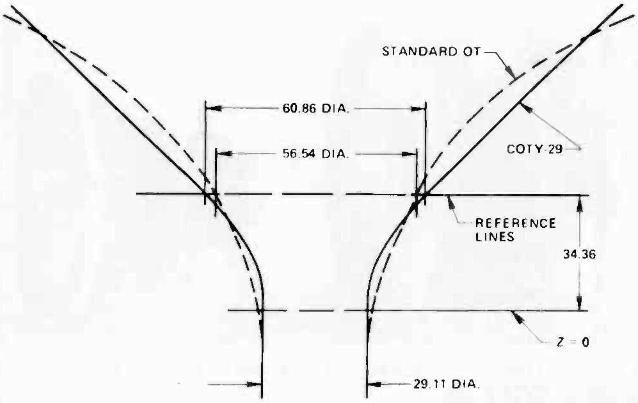

Fig. 7. *The 90° COTY-29 funnel in comparison to the present open-throat funnel in the yoke region.*

effect with the 110° deflection angle. Figure 6 is a photograph of the XL DB gun compared to a standard HiPI gun. In this photograph, an extra grid number 5 is shown in contrast to the conventional gun.

Both the XL HiPI and the XL DB guns employ slot optics in the beam-forming region. The reason for slot optics is to produce a different beam focal length for horizontal deflection than for vertical deflection. This differential focal length partially compensates for the differential effect of the self-converging yoke's pincushion-shaped horizontal deflection field and its barrel-shaped vertical deflection field. This concept was employed in the form of elliptical apertures in grid number 1 and grid number 2 in the early 110° in-line gun.[7] Since that time, various improved combinations of nonround apertures have been employed in these grids.[8]

A vertical slot on the grid number 2 side of grid number 1, combined with a round aperture on the cathode side, was selected for both of the XL gun designs. The parameters of this beam-forming region of the gun have been optimized to provide best focus over the entire screen. The use of slot optics in the lower portion of the gun in combination with the XL, and the adjustments that can be made between the two, provide better options for maximizing performance than were available in previous gun designs.

The XL, by its inherent larger size, reduces aberrations. To maintain the maximum advantage of this concept, the maintenance of the overall gun diameter was very desirable. Therefore, the neck diameter was kept at 29 mm. By maintaining this size, the use of standard stems, base configurations, and sockets was achieved. These proven features are valuable in the terms of reliability and freedom from high-voltage instability problems.

The focus performance of COTY-29 guns that have the XL is clearly superior to conventional designs. Data shows that highlight spot size is substantially reduced, and in addition, this new gun design gives even further reduction in flare. Comparisons with guns having main lenses with smaller diameters due to reduced neck size are even more significant. As mentioned previously, a unique feature of the XL gun is the gun designer's option of varying the parameters of the XL in conjunction with variations in the slot optics of the beam-forming region. With these two independent variables, the focus at the screen center and at the edge can be adjusted for best overall focus. Compensation for the defocusing action of the yoke is, therefore, significantly improved. The focus quality of the XL gun can be shown in comparison to a conventional gun by reducing the anode voltage of the XL gun. Comparable focus can be obtained with the XL gun operating at significantly lower voltage than that of the conventional design.

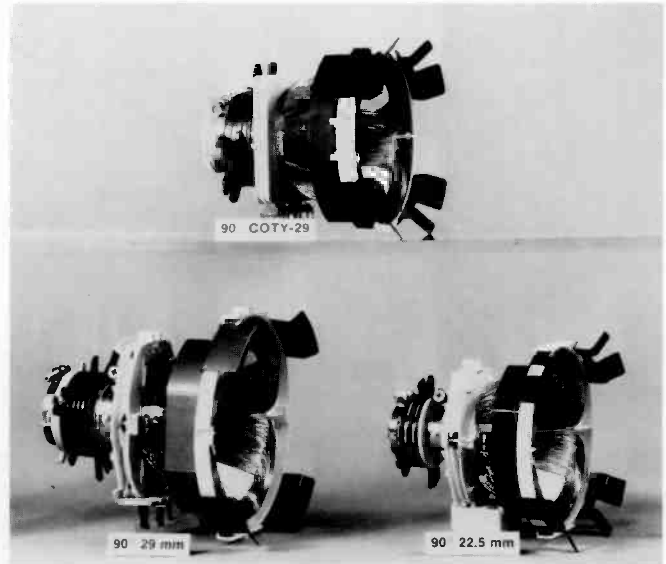

Fig. 8. *Three different 90° yokes, COTY-29, the standard 29-mm neck, and the 22.5-mm neck type.*

The COTY-29 yoke

As previously mentioned, the reduced beam-to-beam spacing and the optimization of the funnel contour in the yoke area have permitted the reduction in the size of the deflection yoke. In Fig. 7, the new funnel contour for the 90° tube is compared to that of the older open-throat design. This contour and the matching interior contour of the funnel were developed by computer computation and experimental data to closely match the beam path.

In Fig. 8, the 90° COTY-29 yoke is compared to a typical pin-free 29-mm yoke and to a yoke designed for a tube with a 22.5-mm diameter neck. The front cross-arm design is maintained to give east/west pincushion correction.

The reduction in size of the yoke permits lower material content; therefore, a lower cost. The deflection power requirement is also reduced in this design and is comparable to that of yokes designed for the tube with a 22.5-mm diameter neck.

The 110° COTY-29 yoke is also reduced in size because of smaller beam-to-beam spacing and a new funnel contour. Figure 9 shows this contour in comparison to the older open-throat design. It can be seen that it presents a slightly sharper curvature that is in accordance with the smaller yoke. Figure 10 shows the new yoke compared with its predecessor as used commercially on European tube types.

It has been concluded that the cost and performance disadvantages of a completely pin-free 110° design are a greater drawback than the cost of circuit correction. Therefore, east/west pin correction was not incorporated in the 110° yoke.

With both the 90° and 110° yokes, the reduced size has allowed the tube neck length to be reduced. This results in a 10-mm reduction in overall tube length compared to prior types.

Table II summarizes the power requirements of the COTY-29 yokes compared to their predecessors, when the tubes are operated at the same anode voltage.

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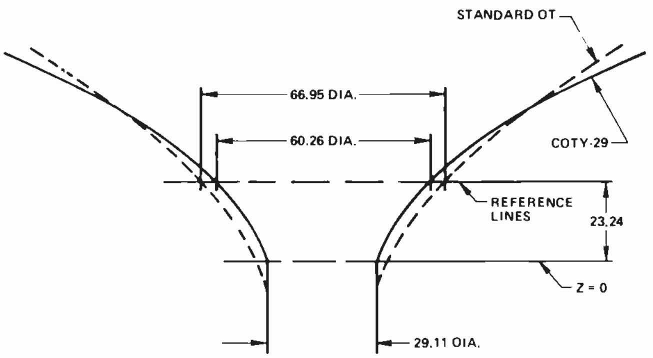

Fig. 9. *The 110° COTY-29 funnel in comparison to the present open-throat funnel in the yoke region.*

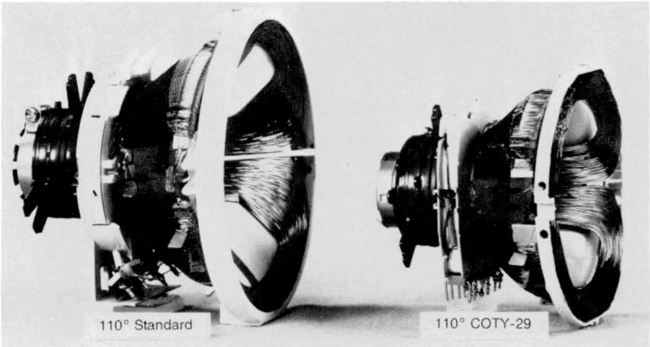

Fig. 10. *The 110° yokes—a standard European one (left), and the COTY-29.*

Table II. *Deflection power requirements at 25 kV.*

Yoke type	*Deflection angle*	*Horizontal stored energy $1/2\ I_p^2 L$ (mJ)*	*Vertical power $I_p^2 R$ (W)*
COTY-29, pin-free	90°	1.8	2.0
Conventional, pin-free	90°	2.2	2.8
Conventional, pin-free	100°	3.5	4.4
COTY-29	110°	3.8	3.4
Conventional	110°	4.1	3.4

Summary

The goals of the COTY-29 design were overall cost and performance improvements. It is believed that these goals have been met by the design of a cost-effective tube that maintains those features proven for manufacturability and reliability. The yoke has been designed with lower material cost and hence, inherent lower cost; the yoke also has reduced deflection-power requirements. The circuitry enjoys the advantage of lower deflection power and, if desired, lower anode voltage. The performance gain is better focus and convergence. It is felt, therefore, that a substantial technical gain has been achieved in the COTY-29 system.

Acknowledgments

The author would like to acknowledge the extensive engineering work done within all departments of the Video Component and Display Division in Lancaster, Pennsylvania. In addition, substantial contributions were made by the RCA Laboratories in Princeton, New Jersey, in both gun and yoke designs that were essential to the project. The Consumer Electronics Division in Indianapolis, Indiana was responsible for yoke development and provided guidance on systems costs.

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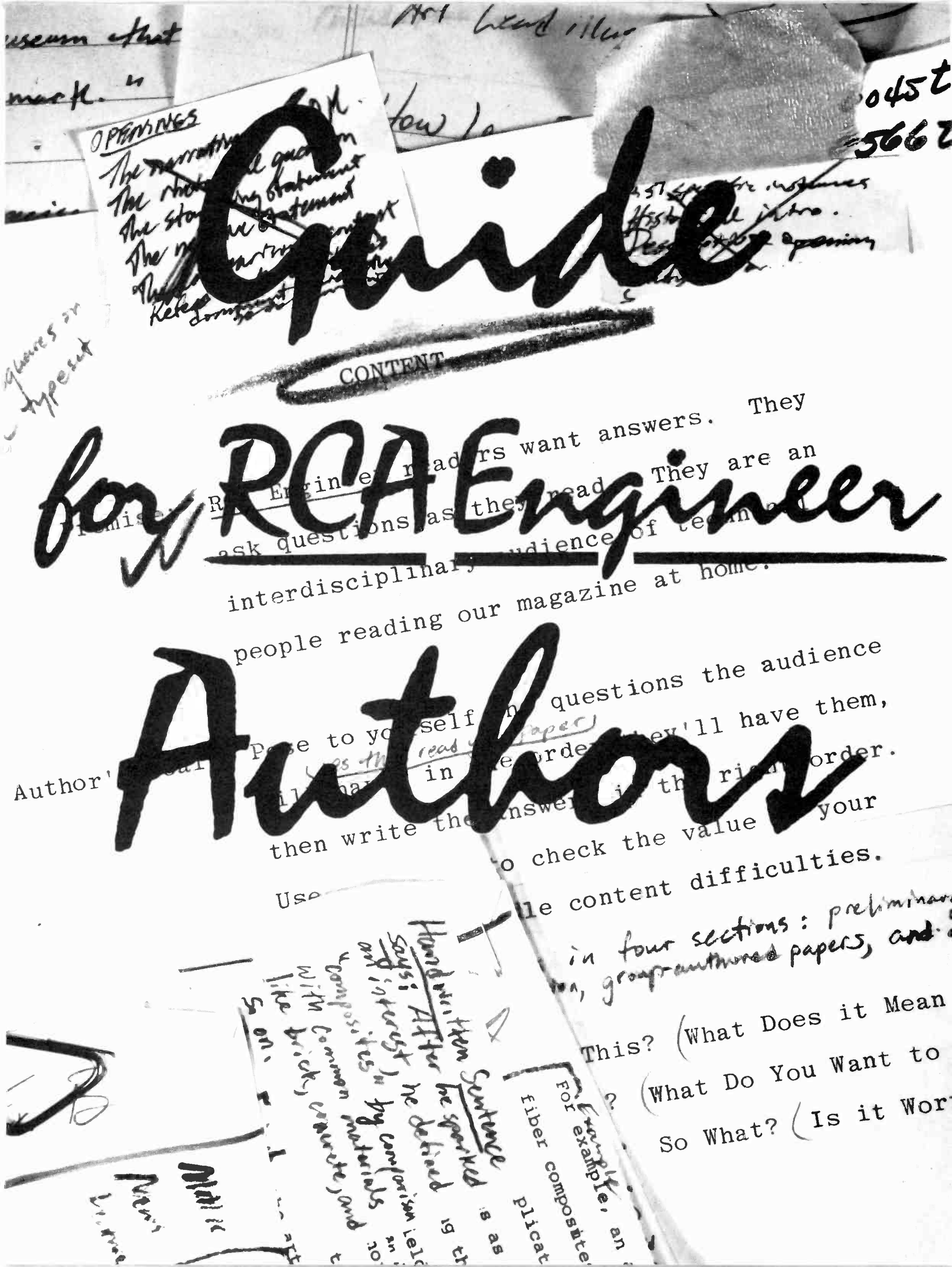
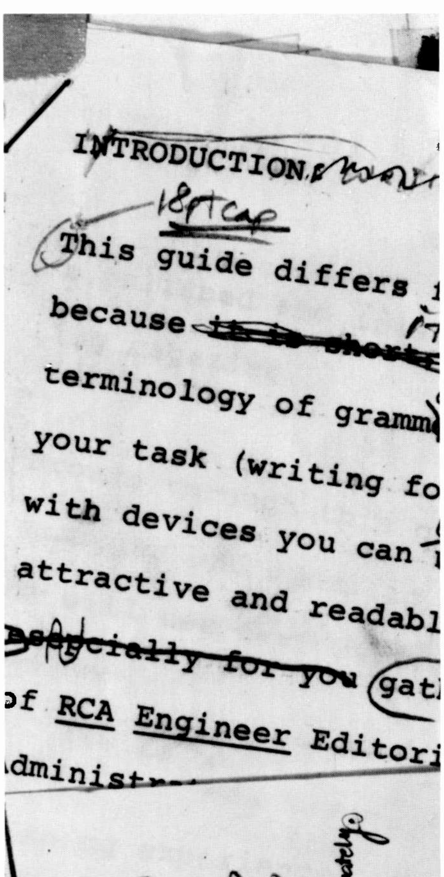
Guide for RCA Engineer Authors



Introduction



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This guide gathers into one package the effort of *RCA Engineer* Editorial Representatives, Editorial Advisory Board members, and Technical Publications Administrators having years of RCA engineering-and-publishing experience. We tell you who reads the *Engineer* and what kind of writing appeals to our readers. Using engineering writing samples, essays on side issues, and illustrations, we show you ways to give your writing purpose and direction, and ways to clearly transmit your information.

Browse through this guide for ideas, generous examples, and specific methods applicable to your task. We will use three chapters to show you the following:

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- *Article Style*
  How to use stylistic devices, sentence-by-sentence, that will hold your reader's interest, streamline your writing, and make your reader want to read on. How to deal with only those special grammatical problems most important to the engineer who writes.

Sections in this guide begin with a point for discussion on a specific writing topic—a *Premise*. Then, we summarize *Your Goal*, as author. Finally, we set up practical *Methods*—in bulleted telegraphic items—that you can use to achieve *Your Goal*. Many guides will tell you, for example, to "Use Good Topic Sentences," but few will tell you methods to achieve your goals.

You know your subject and are willing to write for us—basic courtesy demands that we clearly tell you what we want *before* you make the writing effort. In addition, once we do edit, we want to refer you to these guidelines that we use in editing, so you'll understand our methods.

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Guide for RCA Engineer Authors

by Michael R. Sweeny, Associate Editor

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Imagine what you could achieve; then check if you still lack motivation.

Nothing to Write About! Is your work really that dull and are you not accomplishing anything? What's "old hat" to you may be interesting to others.

Company Discourages Writing! To the contrary, RCA needs to maintain its reputation as a world leader in research and engineering. Therefore, RCA Policy Instruction 10211 states:

> "RCA Corporation encourages the writing of papers by qualified personnel for publication and oral presentation. Such papers help to establish the author in his profession and contribute to the good will of the public toward RCA."

A company that discourages publishing risks losing its best performers. RCA is not such a company.

My Management Does Not Appreciate My Publishing! To be sure, good judgment is required regarding classified work or the possibility of supplying information to competitors that might result in business loss. You will find your management ready to help you to determine the limits within which your work can be disclosed.

I Am Not The Sole Or Major Contributor! Multiple authorship may solve your dilemma. If your coworkers don't want to write, you can acknowledge their contribution in your paper.

I Cannot Write! Do not despair. It's time to overcome this limitation. Engineering publications people are willing to help.

What, You Can Think of Other Excuses? According to research statistics, the above covers more than 90% of the reasons given by nonauthors.

—*Hans Jenny*
Manager, Engineering Information

A glossary should contain at least 10 words. You may define words not in your text, but related to your topic. This gives the glossary editorial power. "Go the distance" with the words, acronyms, and unit symbols you pick. That is, define terms by using easily understood words, give the context for the concept, and then explain how the term is used. In the text, simply spell out an acronym the first time you use it. In the glossary, however, give a definition of the spelled-out acronym—define situations and uses. Perhaps the best time to write the glossary is during your preparations for writing the article.

■ **Introduction:** In addition to the abstract, every article should have an introduction (generally two paragraphs). See the guidelines (page 19) in "*RCA Engineer* Article Content." Keep contract identification and other routine material out of the introduction. Spark interest.

■ **Photograph of the author(s):** We ask for a group photograph of coauthors. Whether you are part of a group or on your own, think about where you will be, what props you will have, and what you will be doing in the shot. Choose surroundings that tie into the article topic. Arrange early for the photo session through your Ed Rep or TPA and then suggest your ideas to the photographer. Be sure you are satisfied with the result—check a photocopy of the print.

■ **References:** Your reference section, citing a variety of recent publications by other authors, conveys professionalism and advances the usefulness of your paper. List sources for the data and statements found in your paper. Do not include Engineering Memoranda, Technical Reports, and other company-private documents in your reference list, because people outside RCA may use the references to uncover proprietary information. Also, in a bibliography, list additional sources of information on the topic. Be selective, and favor recent sources. When you use them, try to put reference marks (numerals) within the text at the *end* of the appropriate sentences, not within sentences. Avoid confusing your reader with a reference mark beside a numeral. Do not drown your text with reference marks.

You do not need written permission to refer to others' work or to quote a few lines. But do get written permission if you quote several paragraphs, or if you copy illustrations. Get that permission from the copyright holder, usually not the author, but the organization or publisher. Talk to your Technical Publications Administrator if you are in doubt.

The following items belong in the reference or bibliography citation:

- **Author's name.** Use first and middle initials.
- **Title of the work.** Underline book titles; enclose paper or presentation titles in quotation marks.
- **Publisher's name.** In referencing a book, give the publisher's location and copyright date.
- **Journal name.** Underline the journal's name, include the volume, issue, and page number, and give the date of publication.

AUTOMATION FOR AUTHORS

Engineers in ever-increasing numbers are using their terminals to accomplish their writing tasks. And the compelling reason for this, we are told, is convenience. Authors who have used word processors (or word processing programs on computers) find that they can write faster and thus spend more time on the critically important rewriting, because it is so easy to add, delete or move words on the screen.

At the *RCA Engineer*, we received over one third of the articles published in the last several issues as machine-readable, word processing files. The time saved by not rekeyboarding entire manuscripts freed the staff to give more attention to other aspects of the production process—which has given us more-interesting articles.

Most of the WP files came to us as Wang floppy disks and (double-spaced) printouts of the files. In the *RCA Engineer* office we have a Wang telecommunicating workstation wired to an AM Varityper typesetter. This arrangement lets us amend the Wang files either before or after transmitting them to the typesetter. A telecommunications board in the typesetter converts the word processor's code set to the modified-ASCII code set used for photocomposition. Only editorial changes, corrections, type specifications, math, and tabular information are entered at the typesetter keyboard. Also at the typesetter we have a Racal-Vadic 212LC modem, permitting us to receive files over the telephone from computers and word processors equipped with asynchronous 212A-compatible modems. Users of the corporate computer system have sent copies of their files to the *RCA Engineer* ID on CMS. ➤

- **Conference presentation.** Give the title, location, and date.
- **Contract reports.** Give the customer's name and location, the contract or identification number, and the date.
- **Annotated bibliography.** You may wish to add a sentence or two explaining the contents or usefulness of a literature reference.

■ **Sidebars:** Sidebars are usually 300-word essays, sometimes with one figure, and always with a headline. Sidebars act as secondary "stories" that support your main text with information that is particularly useful or interesting to readers. These "modules," boxed away from the main text, increase readability and add perspectives. When you first plan your article, you will undoubtedly come across closely related material that belongs in a sidebar (for example, Lessons Learned). Before you write, talk to the *RCA Engineer* Editor or your Editorial Representative about sidebar ideas. Many readers, attracted by an interesting and short sidebar, go on to read the main article afterwards.

Example
For example, two authors were comparing custom manufacturing engineering and quantity manufacturing engineering equipment, processes and successes at RCA. The responsibilities of the two manufacturing engineers in these different functions made a pair of sidebars. These topics did not belong in the text, but created an interesting sidelight. In addition, the views of a quality control expert filled a third sidebar.

■ **Subheads:** Break up your text with subheads. A good rule of thumb: Use at least one subhead every six paragraphs. Keep the subheads to approximately three words, if possible, to save space within the text. Subheads can be "first-level," "second-level," and "third-level" to accommodate thought hierarchies.

■ **Text:** Talk to your Editorial Representative or the *RCA Engineer* Editor about the exact number of words (on double-spaced typewritten pages) that you will need to write. Generally, 3,000 words (12 double-spaced typewritten pages, if there are 250 words on a typewritten page) is our favorite length. This will occupy approximately four printed pages in our magazine, when the article is illustrated. Our upper limit is 4,500 words, which occupies six printed, illustrated pages in the magazine. If your article has between 16 and 20 typewritten pages, cut away some sections before sending it to us.

Present your text as double-spaced copy, and follow the guidelines given in "*RCA Engineer* Article Content." The *RCA Engineer* now has powerful capabilities for receiving telecommunicated copy and word-processing disks (see sidebar on "Automation for Authors"). Investigate these possibilities before you write.

Remaining considerations include the following:

- Don't use an acronym if you are going to use it only once or twice in the paper. Spell out all acronyms the first time they appear in the text. Overcome the "alphabet soup" that plagues some engineering writing.
- If you must use lists within your article, confine yourself to two or three lists and explain the items. Never put a list near the beginning of your article.

In preparing your articles, first try out word processing and then consider using these valuable telecommunications links to transmit your article to us.

Follow these guidelines when you decide to send us a file. Keep it simple. Eliminate underscoring and page breaks. Use a line length of between 60 and 80 characters. Avoid end-of-line hyphenations, other than those you want in the published article. In addition, avoid indenting material (at least, in the version of the file sent to us). Tabular material and mathematical equations will be reset in our office, so don't worry about how they are coded in the file. *Do* send us a *double-spaced* printout of the article along with the Wang disk or telecommunicated file. Carefully mark unusual characters, mathematics or underscores on this printout.

As of January 1983, we have received files from authors at the following locations:

Astro-Electronics, Princeton (Wang OIS 140)

Automated Systems, Burlington (Wang OIS 140)

Corporate Computer Services (CMS files from the IBM mainframe)

Missile & Surface Radar (Wang files from various input devices in MSR's text management system)

RCA Laboratories, Princeton (DEC VAX 11/780 and Lab/Net, their local area network)

Solid State Division, Somerville (Wang OIS 140 and CMS files)

Outside RCA (Televideo computer, TS-802)

—*Tom King*
Editor, *RCA Engineer*

- You may have to use mathematical expressions. Use only the final form, essential to the text. Make certain that your mathematical copy is clear, correct, and consistent—just the way you want to see it typeset.
- For the most part, engineering authors capitalize a bit too much. Most words can go into lower case. But capitalize the first letter of trademarked names, give the trademark, and give the company name in parenthesis after the name. Please give a generic designation after the first use of the tradename. For instance, refer to Hercules Company's Magnamite AS® **high-strength graphite fiber** (my emphasis), and refer to Coca-Cola® **soft drink** (my emphasis).

■ **Title:** Write less than eight words. Put the most important noun up front. Add an action word to the title.

The Schedule

The second main method for successfully negotiating the nuts-and-bolts of the publishing effort is to understand your part in the stages of the publishing process, so that you can fulfill obligations after you have an article idea.

Contact Your Ed Rep

Your contact with the *RCA Engineer* begins with a call or visit to your local Editorial Representative. Names, locations, and phone numbers are listed on the inside back cover of the *RCA Engineer.* Your Ed Rep is a knowledgeable and experienced publications person, engineer, or manager, who will guide you through the entire publications process. Ask the Ed Rep about future issue themes so that you can plan an article related to the theme (for example: Modeling, Simulation and Analysis; Microwave Technology; Electro-Optics; Manufacturing Engineering; and so on).

The Ed Rep, or the Technical Publications Administrator, at your location will help you to refine your idea for an article. These people can tell you which proprietary subject to avoid, and can help you "slant" your article to fit a specific issue of the *RCA Engineer.* These people meet regularly with the staff of the *Engineer* and with other Ed Reps and TPAs, so they can easily tell you more about our publication, too.

Call the Editor

Next, you will want to talk with the *RCA Engineer* Editor, at which time you will receive further information on how to put together your article to fit the rest of the issue, and on deadlines that you will need to observe.

The Editor may involve you in a "give-and-take" interview on your topic, to learn more about the technology, and to hear your "natural" descriptions of the topic. He may then identify points and descriptions that you could emphasize in your article for our multidisciplinary audience.

Once we receive your final package (generally at least three months before the issue is published and mailed, but check with your Editor or Ed Rep) our production work begins. Our issues are published once every two months, and we schedule them to be mailed midway betwen the months cited on the cover. For example, the Jan./Feb. issue comes out during the first week of February; the March/April issue is mailed during the first week in April, and so on.

INTERESTING ART

To develop more interesting or creative art, the author might first enlist the aid of an Editorial Representative or illustrator, explain his situation, and then ask for concepts or ideas to express a particular view in the article. Real-life applications could also be integrated into an otherwise dry input/output situation. Photographs, especially of equipment, can often be made more dramatic by the angle at which the photo is shot. Callouts or highlights by a reversed-out circle or arrow often emphasize important components. Screens can also be used to place emphasis on significant data in a chart or table.

In photographs, authors seem to look best in the natural, working environment. Avoid portraits at a desk or passport photos. The author(s) might be photographed concentrating on work at a piece of equipment.

At the Advanced Technology Laboratories, the author makes initial contact with the Editorial Representative and, in turn, the Ed Rep sets up a photo session in the author's working environment with our photo operations unit. Make the contact early. Consider possibilities for photographs to illustrate your article. Go beyond the author photo. We suggest that the Ed Rep and author scout for a good location and then take the photographer to this location.

The key to artwork, or any other production process, is planning. Your well-planned article will be a well-written and well-received article.

—*Ed Master*
Advanced Technology Laboratories

Publication Stages: Your Role

The following stages will affect you during the month preceding the cover dates (for the Jan./Feb. issue, this means in December; for the March/April issue, this means in February). We will mail marked galley proofs and rough layouts to your Ed Rep. The Ed Rep will then give you the galley proofs of your edited article, showing typeset columns of type. The rough layout of the article will show the way figures, tables, and text will look on the printed page. Read the galleys carefully for errors, and mark them with proofreader's marks if you want (look for proofreader's marks in the dictionary under "P"). The galley will hold queries from the copyeditor, and other callouts to alert you to sentence alterations. Check with your Technical Publications Administrator for approval status and changes. Usually, we want marked galleys returned within five working days.

Check the rough layout for correct and ideal placement of the figures and tables. Note that the layout critically depends on a *complete* article manuscript. Based on the layout, we may ask you to write an additional 300-word sidebar, provide an additional illustration, or cut an illustration or a block of copy. Be certain all artwork is correct.

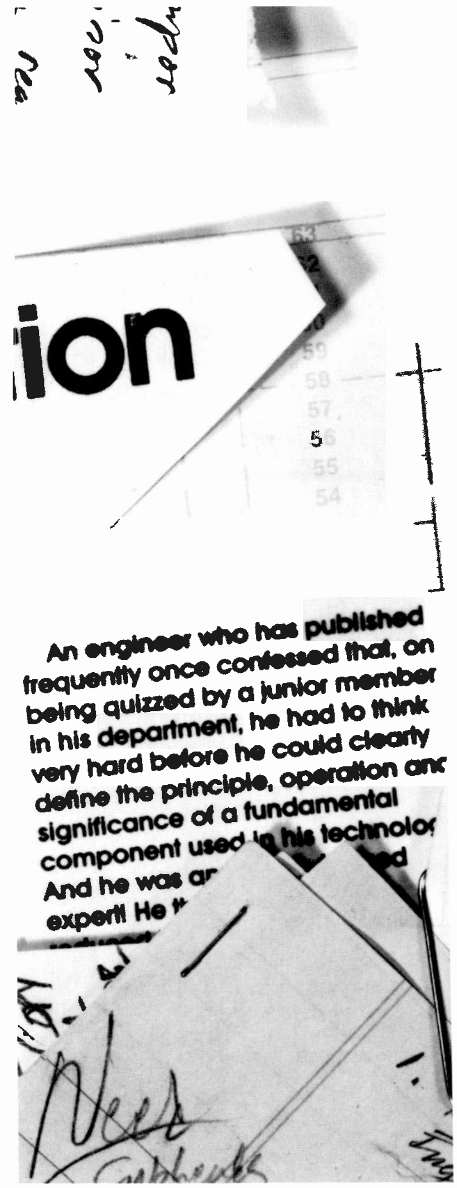
Finally, after you've marked and returned galleys and rough layouts, you will see a "page proof." This is a copy of the image of the page that the printer will photograph. Check it carefully to be sure all your corrections to the galleys are intact. Make only absolutely necessary changes at this stage—corrections cost money, take time, and sometimes result in additional errors.

After Publication

After publication, we send the authors 90 offprints of the article. Through the *RCA Engineer* Secretary, you can order additional reprints for a fee, after publication. Also, after publication, we can return your final artwork, if you request it. Often, trade magazines will want to republish your article after it appears in the *RCA Engineer*—call your Editor or Editorial Representative for details.

Conclusion

This section summarizes our editorial needs for a timely and well-produced article. In particular, articles look and read better when they include a sidebar giving a related perspective on your topic and fairly long, interest-provoking captions for the figures. In all cases, find your Ed Rep and TPA first, and maintain close communication with them throughout the process—they are vital to the successful presentation of your article.



RCA Engineer

Article Content

To help you overcome writer's block, this chapter gives various methods for presenting the content of your article to the reader of the *RCA Engineer*. Throughout the chapter, we emphasize methods for understanding the reader's point of view. Discuss your article in detail with the Editorial Representative at your location.

You can use the methods outlined in this chapter to begin your article, present your material more effectively, and understand requests from your Editorial Representative or *RCA Engineer* Editor for more, or less, or just plain altered materials. Choose freely from the various methods to suit your purpose, but spend some time using the techniques in "Section One. Your Reader's Three Preliminary Questions".

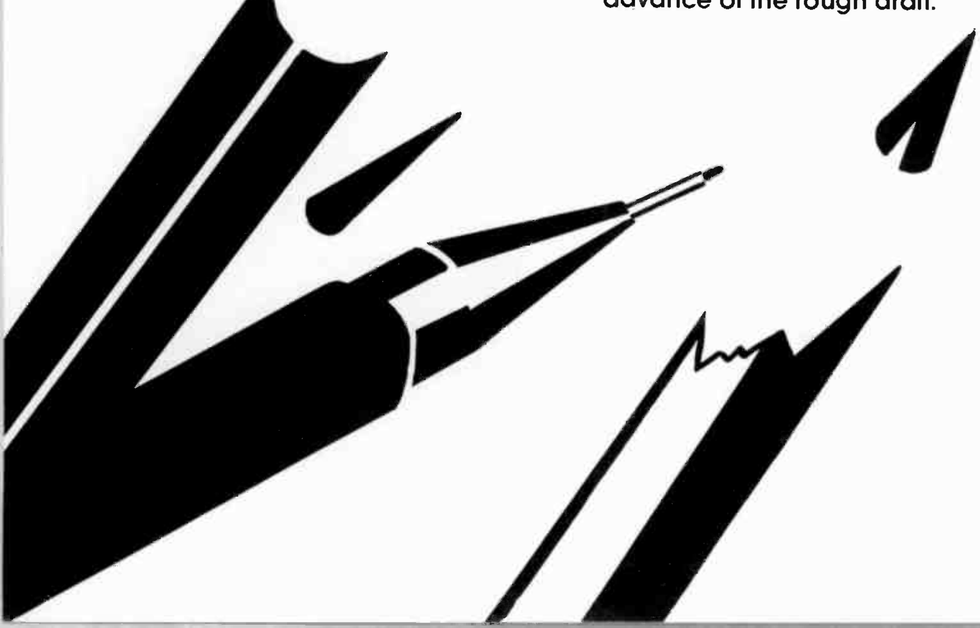
For each *Goal*, several suggested methods are often given here. Do not feel compelled to follow every suggestion—use them instead as idea-generating tools.

Each section and subsection begins with a *Premise* that we can use to help you to define *Your Goal*, as author. Then, we delve into *Methods* you can use to achieve *Your Goal*. As space permits, we give examples to illustrate the *Methods*. Found underneath a *Premise* and *Goal*, the *Methods* are bulleted items that need not be followed in sequence.

Section One covers our recommended preparations for writing (in addition to the really hard task of fact-gathering and research that you've undertaken). Begin to tailor your material to the audience. Section One will help you to focus your outline and to prepare material for the introduction to your article. At this meditative stage, you may be scribbling some ideas down or writing small sections of the article in advance of the rough draft.

Section Two helps you to start putting the article together—beginning, middle, and end. Our suggestions here more specifically show you how to use the material you have gathered in Section One. Use this section as you write your outline and rough draft.

Section Three gives additional procedures you should keep in mind as you write a coauthored paper. Last, we cover artwork guidelines in Section Four. Artwork deserves even more attention than manuscript copy. You can actually use artwork to help you organize your article. We urge you to look, early in the writing process, for the artwork you will use.



Premise *RCA Engineer* readers want answers. They ask questions as they read. They are a multidisciplinary audience of technical people. They read our magazine at home, but you must attract their attention and keep them reading.

Your Goal Pose to yourself the questions likely to occur to the people in the audience as they read your paper, in the order in which these questions will occur, then write the answers in the right order. Use the questions to check the validity of your outline and to handle content difficulties. As an author, you cannot immediately see your audience's reactions or know their questions but you can anticipate them.

Methods We cover the methods in four sections:

Section One. Your Reader's Three Preliminary Questions
Section Two. Structure and Organization of the Article
Section Three. Group-Authored Papers
Section Four. Artwork *Is* Content

Section One. Your Reader's Three Preliminary Questions

Reader's Question #1. Why Should I Read This?

Premise A great paper may not be right for the *RCA Engineer.* The best papers for the *Engineer* are those tailored to our readers' needs.

Your Goal Establish rapport with your readers. In your introduction and at strategic points throughout your paper, grab attention and gain credibility. Find reasons why your reader, who may be an engineer in another specialty, should read your article. Jot these "angles" down for use in your rough draft. Choose from the various methods below.

Methods ■ Connect your technology with other RCA technologies.

Example

Elicit Audience Interest

An *RCA Engineer* author wrote an article primarily about the advantages of fiber composites in satellites. But in his introductory paragraphs, he told his readers about other uses for fiber composites at RCA, citing composites' universal advantages as he referred to these uses. He ended his introduction by noting that his readers would probably see an application in their field for these ubiquitous and increasingly popular materials. Having sparked an interest, he defined composites by comparison with common materials like brick, concrete, and so on. Thus, the author successfully placed in a universal setting the narrower satellite-technology advantages he was most qualified to describe—the article became a primer on composites in general, but the author nevertheless stuck to his main topic, he developed it in detail.

■ Fit your contribution into the wide landscape of RCA's business interests and those of the industry.

WRITE FOR READERS

What's the reader looking for? The engineer is seeking to learn something he does not yet know. His major interests usually are:

1. In his own or a closely related discipline. Too many engineers seek to read only papers related to their own specialty—attracting them takes effort (see below) but can substantially enlarge readership span.
2. In fields other than his own, with which he is somewhat unfamiliar, but wants to keep up with on a broad basis.
3. In state-of-art reviews, tutorials, competitive evaluations, and applications information.

The *RCA Engineer* addresses mainly points 2 and 3.

What's the author offering?
The author usually presents specifics he has done within the framework of a larger view—interdisciplinary or industry-wide. Unless he clearly states what this comprises and also provides a thumbnail of the big picture, he has overlooked a major key to the success of his paper. The reader will not know where the paper fits in or what the value of its contribution is to him—and he will tend to move on rather than solve the puzzle. The author should use all the "accessories" available to advertise his paper and to convince the reader to read it. These "accessories" cover such items as: title, lead sentence, abstract, illustrations, layout, summary, and references. All of these should clearly convey the message of what exactly the author is offering.

And if the reader is really interested . . .
Often, if the paper has really interested the reader, he does not want to drop the matter. He ➤

■ Begin your article with a comparison/contrast, or a negative statement followed quickly by a positive assertion. This style establishes rapport because it appeals to a reader's knowledgeability and promises an article that will further extend his understanding.

Example

"The RCA 'CED' VideoDisc can be considered only a distant cousin of the audio record. The technical and performance demands were far greater than those required for the highest-quality audio record. New ground had to be broken in science, process technology, and manufacturing."

This colorful, concrete reference to *what a VideoDisc isn't* leads to effective statistics that show what a VideoDisc *is*—"one audio disc groove will accommodate 38 VideoDisc grooves—the VideoDisc holds about 10,000 grooves to the inch. One side of a 12-inch disc holds about 12 miles of groove length."

Make It Interesting

■ Visualize present or future news-feature aspects of your subject—how could it, or a system to which it belongs, make the evening news someday? Establish riveting immediacy. Engineering progress may seem undramatic and incremental to you. But try to find a wider perspective for your contributions. Because you are on the leading edge of technology, you may not have an aerial view of your work, but your reconnaissance efforts will lead to reader recognition.

Example

Monolithic Microwave IC (MMIC) research is immediately cast in an interesting frame of reference if the reader knows that:

"With recent FCC approval of standards for Direct Broadcast Satellite service, a whole new industry is in the offing. Gallium arsenide MMICs could be less expensive to manufacture on a high-volume basis than the hybrid circuits that are now more cost effective. Moreover, the smaller MMICs could combine receiving functions on a single chip that could be placed inside every rooftop satellite dish. But first some serious research must be done."

The industry prospects, presented with the punch of a news feature lead, open the way for a highly technical article on MMIC research results.

■ Position your engineering problems or your topic within a larger framework, a common engineering experience, and then focus on specifics. Tie your new ideas to an old idea that your readers understand.

Example

One group of authors began an article this way:

"Has this ever happened to you? You've worked all week to finish a phase in the development of a microcomputer-based system. On Monday, after a weekend of celebration, you begin the next step and find that the functions that worked so well on Friday are now totally inoperative. . . . Developing any computer-based system can be frustrating indeed."

Even the engineer with no specific computer experience could empathize with the feelings expressed here.

wants to pursue it further. How can he do this, other than contact the author (which is one good way)? The list of references plays an important role—it shows where the paper fits and where other aspects of the subject are covered. Particularly useful are RCA references that not only provide leads to other work done, but also provide access to the experts who did the work.

Where are the references?

Some of the fun of writing a paper lies in what you can learn doing it. Using today's tools of computerized reference searching, for example, you can quickly pinpoint worldwide (DIALOG, ORBIT, and so on) databases as well as RCA (TAD database) documentation—and, in doing so, improve your own overview. Too many papers come without literature references, indicating that the author's horizon is somewhat limited. A good reference list greatly increases the value of a paper to the reader. It also increases the probability that your paper, in turn, will be cited by succeeding papers on the subject and, thus, become a valued reference source itself.

The approval cycle

As you contemplate writing a paper, think about its possible impact, not only on your career, but also on your company. Will it support RCA's reputation as a leader in high technology? Good! Will it tip the hat to competitors and help them beat you? Not so good!

RCA strongly supports publication "to establish the author in his profession and contribute to the good will of the public toward RCA." However, the company's interest must be maintained.

Papers you write for publication covering your work are the property of RCA. As such, RCA is liable for any problems that may develop. This is the reason why patent and law activities must ➤

Assess the Level of Detail

■ Discover the level of detail you will need. Call another engineer working in another technology or another division. Outline your subject and ask him to phrase three questions offhand that he would want answered in your paper. Next, ask a colleague in your technology for three questions he would like to see answered. Keep these different top-of-the-list questions as indicators of the level of detail that will satisfy both the expert and the technical layman. Concentrate detail only in those areas for which even the expert needs further explanations, for there, most likely, is your new and important information. Devote the rest of your article to guiding the nonexpert through this information.

■ Introduce your article with a set of useful aspects of your technology. How could another engineer use your technique? Conversely, refer to a common technology, and tell how you decided to use it in an innovative way. Imagine the kinds of questions you would like an interviewer from an engineering trade magazine to ask you. Then go about answering them.

■ Establish context and give technical detail by use of the realistic narrative opening or the scene-setting introduction. The realistic narrative opening casts your introductory material into a story form. Engineering work has its drama—people's needs and desires, creative abilities, and intellect are tied to the contest to solve problems. Events and places sometimes merit descriptions that have camera-like accuracy. But be sure the setting ties in with the technical aspects of your paper.

■ Work from the part to the whole during a system description. For example, isolate a raw ingredient used in the VideoDisc and begin to trace its travels throughout the manufacturing system until the product is delivered to the consumer. As another possibility, take a general or composite example—even though it does not represent all cases—and show, step-by-step, how theory and practice can merge. Show how technologies work.

■ Gather your facts systematically. Computerized search services available at RCA libraries can help you find interesting information applicable to your technology. The service is comprehensive and easy to use.

Conclusion

The reader may give you only a few minutes. Prove that your article can mean something to him. This approach will immeasurably improve your credibility. Your repertoire of article openings should include the narrative; the comparison/contrast; and the negative statement followed quickly by a positive assertion.

WARNING: Do not go on and on with your opening! Get to the main point of your paper within *two paragraphs.* Throughout your paper you can use some of the techniques developed in this section to stimulate audience interest.

Reader's Question #2. What's the Big Idea?

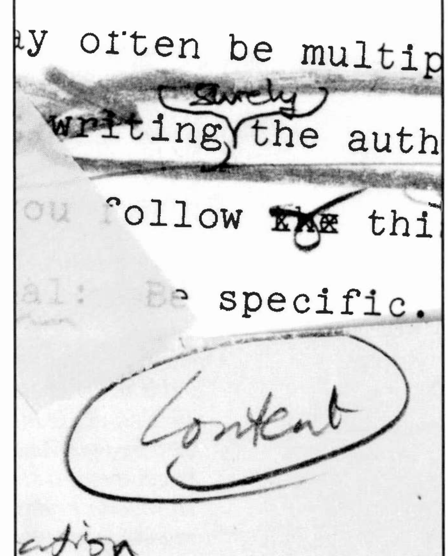
Premise

Complex, wide-ranging topics will virtually "organize themselves" if the author has one overriding message. You lead the reader of an article containing several equal messages—even if well-organized—past separate, loaded, circus boxcars. Frustrating. Put the whole complex show under one Big Topic—an overriding idea.

approve each paper. Proprietary interests, not only of your division, but any other concerned corporate activities, must be maintained. You need not worry about the mechanism for these approvals. Your TPA will see that they are obtained in a timely fashion, once you have initiated the approval cycle.

However, here is how you can save yourself some possible frustration: After developing an image of what your paper will cover, get your supervisor's approval and ask him to check with those who might have concerns and objections (engineering, sales, law, and possibly people in other RCA divisions or activities). Better to air such concerns in a timely manner than have a finished manuscript disapproved.

—*Hans Jenny*
Manager, Engineering Information



Your Goal Reduce your message to one concise statement and organize your points to support this statement.

Method ■ Identify your main topic. Complete one of the phrases: *"I want to tell you that . . . "* or *"I want you to remember that . . . "* or *"I want you to believe that . . . "* Once you have completed the phrase, cut off the italicized words, make a sentence from what's left, and put the sentence at the end of the introduction to your paper. Always refer to this main sentence as you write. Be sure the topic sentence of each paragraph in the middle of your article relates to this main sentence.

Example
I want to tell you that "Recent advances in very large scale integration have brought about major gains in the size and performance of metal-oxide semiconductor memories."

Example
I want to tell you that "Before embarking on a new project, or writing an article, you would do well to carry out a literature search—Nobel Prizes are not handed out for reinventing the wheel." The following questions can then be answered to support your main statement: Why? How? What? Who? When?

Conclusion Put your essential message, once you've found and refined it, at the end of your introduction, where it has the strongest impact. Use this message to control and define your writing effort.

Reader's Question #3. That's the Big Idea? So What?

Premise Be honest with yourself. The reader wants an article that has an essential message, or big idea, that will truly yield a reward worth the reading time he invests. You can complete the phrase *"I want to tell you that . . . "* with an uninteresting message that is over-generalized or over-specific. You can also write a spiritless outline. But few people will plow through an information sheet unless they have to get specific information. *RCA Engineer* readers, investing their leisure time, need more than just facts.

Your Goal Strive to convey understanding. Couch your facts in statements of their uses, and use facts not to bludgeon or impress, but to enhance understanding. Engineering issues create excitement. The good subject demands more than a well-organized information sheet.

Example
You may have written that satellites are quickly achieving commercial success, through technical advancements in all areas of engineering expertise, and you may have looked at future universal uses for technologies developed just for satellites. But you decided instead that *"I want to tell you that* C-band satellites are being developed by RCA, and they incorporate a number of technical innovations."

Well, this could make a well-organized information sheet, but few people will plow through the paper, unless they have to get specific information. Unfortunately many technical papers reduce to a bland statement like this—a report of detail, a technical update, and little more to excite your reader. Use the following methods to create interest and enhance understanding.

COMPUTER SEARCHING

Today's information explosion makes it increasingly difficult to have access to and manually search the technical literature on even a single subject. But what would have taken you hours or days to do manually, you can now do electronically, in minutes. Computer searching will obviously save you time in researching your paper. With the many sources of information available today, it would be impossible to cover them all manually—important information might be missed. Computer searching allows you to do a more thorough search of your subject. It also allows a greater degree of specificity in developing subtopics or sidebar topics.

On-line computerized literature searching is available through the libraries at most RCA locations. The first step in starting a computerized search is to go to your library and talk to the librarian. The librarian will elicit from you the appropriate information to formulate a search strategy. This includes the choice of appropriate keywords, the proper databases to be searched, and the time period to be covered.

All of the important abstracting and indexing publications are now available, together with hundreds of other databases.

In addition, the *RCA Technical Abstracts Database* (TAD) is also available for on-line searching. The results of your search will give you a listing of documents on your subject that will include all of the pertinent bibliographic information and an abstract. Once you decide on documents that will be helpful to you, your librarian will get copies of them for you.

—*Doris Hutchison*
Technical Information Systems

Methods

■ Acknowledge and dispose of an opposing point of view. Cut to the heart of an engineering issue and create the excitement of a fair and rational dogfight by technical aces. Jot down the issues and the developing points of view for later use.

Choose an Effective Topic

■ Make your best, most rational thesis a mild affront to somebody, somewhere—it will not reiterate old ideas, and it will require supporting arguments and facts. Do not avoid the issues if you can prove your point. Otherwise your article will lack energy. But maintain a clear-headed approach—arguments aren't fights. A purely descriptive exposition of the facts is useful, particularly in the "How to" books currently crowding the market. But, ultimately, your goal is to communicate complex technical information and understanding, not opinions and speculations. When you pick an "argument," you immediately simplify the task of defining, partitioning, and narrowing your subject without shirking technical detail. Bring into the foreground the debate over the best engineering for a specific application. Jot these "angles" down for reference while writing the paper.

Example

Revise that tepid statement about C-band satellites. Write instead: *"I want to tell you that,* Although K-band technology being developed here and elsewhere shows great promise for satellite communications in the future, our C-band satellites, because of the engineering refinements we have introduced, will be more profitable in the long run." Now that is a statement that needs support!

And consider this different, but no less interesting statement: *"I want to tell you that* C-band satellites with a number of add-on technical innovations are being developed at RCA, because we must work effectively within the present manufacturing and technology constraints." The artful tension in this statement, necessary for the exchange of hard information, frames the article with a subtly argumentative edge. You are the only person who can provide this edge. You know the issues and the competing technologies.

Support Your Topic

■ Give the reader information that is useful, not just informative, entertaining, or theoretical. Give brief examples and give sources of additional information.

■ Show accurate, original work. Or show us how you built your innovations on others' engineering advances.

■ Share with the reader some reasons for your engineering decisions. Establish the context of your reported results and effects by giving the situation before you did your work, and the causes that led to the reported effects. Or define several engineering options, then write a decision-analysis section that gives the reasons for picking one method over another. What lessons were learned?

Example

"I want you to remember that Fourth-generation computer languages are replacing FORTRAN," can be changed to *"I want you to remember that* Fourth-generation computer languages, which require minimal operator training and which allowed Product Assurance to spend only $500 for a comprehensive database that normally costs $10,000 in FORTRAN or COBOL, can help you to . . . ." This statement is eminently arguable, evokes curiosity, and had better be supported. If the author disposes of the potential arguments, answers the reader's questions, and supports his state-

ENGINEER'S NOTEBOOK

We've published many well-read and useful two-page *RCA Engineer* articles! You may wish to sharpen your communications skills and give special insights on your technology with a concise article for "The Engineer's Notebook," a special section devoted to applictions and advances that don't warrant a full-scale article in the *Engineer.* "The Engineer's Notebook"—where you can report the facts, but not all the facts you have—is easy to spot and easy to read. Use approximately 250 to 1000 words and one to three illustrations with descriptive captions to tell your story. Often, authors compile "Engineer's Notebook" items from available materials. Consider the section a technology bulletin board. We particularly favor items that relate to an issue theme—see *RCA Engineer* Table of Contents for announcements of upcoming themes. Call your Editorial Representative (see the inside back cover of the *Engineer*) before writing.

—MRS

ments with abundant data and technical description, he will succeed beyond expectations in his quest for readability.

■ Avoid "puff pieces," one-sided articles that could be commercials for a product or system. Enthusiasm, style, determination, and pride in craftsmanship—yes. Deception, lack of substance, failure to tell the whole story and answer the reader's questions—no. Recognize the types of articles *RCA Engineer* readers want to read (see sidebar, page 12).

Conclusion A simplistic message may lead to a well-organized but unimportant article. Be daring. Be sure your essential message will interest our readers.

Section Two. Structure and Organization of the Article

Premise Writing aimed at busy readers slips away in time almost as do speech and music—these forms don't stand in space the way paintings or engineering prototypes do. Aristotle recognized long ago that three-part organization stabilizes fleeting forms of communication. For us, it means that articles need a beginning, a middle, and an end.

Your Goal Organize your preliminary information and begin to write the article. Use tactics for the beginning of your article, derived from your answers to the reader's questions (discussed in Section One and in this section), and continue with tactics for the middle and the end of your article (outlined in this section). Like a good chess game, your article should have beginning, middle, and end tactics. Discuss article length, article direction, and art requirements with the *RCA Engineer* Editors. Ask also about our requirements for sidebars (300-word essays, with titles, used as separate modules within articles to support information in the text), long captions (25 to 50 words), and sometimes glossaries. Aim for a 3,000-word article: 12 double-spaced typewritten pages. Occasionally we may indicate a need for a shorter or longer article. Seven-hundred words, plus art, equals a page in the *RCA Engineer* (2½ double-spaced typewritten pages is approximately 700 words). How much art do you need? Two or three illustrations per 700-900 words is a good start. Get the *RCA Engineer* Editor or your Editorial Representative to answer your questions about article length and editorial direction, emphasis and level of detail, art requirements, and author photo/biography needs. Also, refer to the Checklist (page 6).

Methods **Tactics for the Introduction to the Article**
Your article will begin with a title, a lead sentence underneath the title, and an abstract. Then choose from several elements to construct your introduction. Draw on the material gathered in Section One, and use some of the suggestions here. All of these vitally important elements must accompany the final article package you submit to the *RCA Engineer* three months in advance of the publication date.

FORMS OF ORGANIZATION FOR THE MIDDLE OF THE PAPER

Most articles for the *Engineer* fall into three categories: applications articles giving specific aspects or descriptions of equipment or processes; articles that show solutions to problems; and review or "survey" articles on the state of the art, which show device, system or applications-development trends. After you have decided on a category for your paper, you can choose from various methods to organize the contents.

Logical ways to organize the material in the middle of your paper include the following: Ascending; causal; chronological; comparison/contrast and familiar-to-unfamiliar; decision analysis and interpretation; problem-solution; spatial; and topical orders. Although you need not use one order exclusively in your article, you can more readily achieve cohesive and parallel treatments of your various subtopics if you *decide on a dominant order or form of organization* before wading into the middle section of your technical paper. Swamped by information, you'll want to grasp some basic ways of mapping the material.

Ascending order simply means: Position your points in increasing order of importance to support your main message. Because reader interest normally slackens during the middle section of a paper, your subtopics put in *increasing* order of importance or interest will combat the natural tendencies of your readers.

Causal order means that you organize your topic by looking at causes and effects. Scientists and engineers since Aristotle have used this powerful approach. You can work from an effect or set of effects back to a cause or set of causes. And vice-versa. Some-➤

The First Words Your Reader Sees

■ **Title:** Write about five to eight words, and your title will boldly and attractively introduce your article. Think of the most important noun associated with your topic and put this word up front within your title. One action word (verb) in the title adds "snap." The title should stand alone as a description of the article—don't rely on the text.

Examples
"Teleconferencing is a telecommunications alternative to travel"

"What electron beams can do for LSI"

"CRITIC highlights errors in IC-mask artwork"

"VideoDisc material compounding demands the right chemistry"

■ **Lead sentence** underneath the title: The lead sentence could be one sentence, or it could run up to three sentences long. That's OK. Its purpose is to spark interest in the article; do not attempt a summary (that's given in your abstract), but do present a pertinent detail or two. Note the relationship between the titles and lead sentences in these examples below.

Examples
Title: *"Advances in CMOS static memory development"*

Accompanying lead sentence: *"RCA locks horns with the competition by improving circuit densities and access times in bulk CMOS and CMOS/SOS static memories."*

Title: *"The 1981 RCA space constellation"*

Accompanying lead sentence: *"RCA will put up to eight satellites into orbit during the next 12 months. Twenty-two years of experience help to make it look almost easy."*

Title: *"Custom and quantity manufacturing: An engineering comparison"*

Accompanying lead sentence: *"While one flawless satellite is being put together, a half-million quality VideoDisc players could leave the assembly line. Differences and similarities in these two styles of production tell us a lot about manufacturing engineering."*

Title: *"Computer programming and systems analysis in the rapidly changing VideoDisc environment"*

Accompanying lead sentence: *"Want to spend $500 to set up a computer software system that would normally cost $10,000? Try FOCUS."*

■ **Abstract:** As short, complete article summaries, our abstracts should be 75 to 125 words long. They stand alone as complete and separate entities. Most readers prefer informative abstracts, but we will accept a good topical abstract. The *topical abstract* tells what the article is about, but omits the findings and conclusions. Writers often follow the subheads of their articles to write topical abstracts. *Informative abstracts,* in contrast, are longer. These abstracts tell what the article covers, and show the article findings as well. Begin by restating the main idea, and then link the other ideas in your paper to it, in order of importance. Use few abbreviations. Indicate scope, objectives, method, and findings.

times you can take a set of existing conditions and show how these conditions will cause certain effects in the future. Another way to go—powerfully and visually describe future effects or consequences, and then link these effects to present causes. Causal order mixes well with other forms of organization—chronological, topical, problem-solution, and so on.

Chronological order gives a history of events in the sequence in which they occurred. This order makes it difficult for you to use other logical orders, so be careful. If you use this order, the best method is to begin your middle section in the "present," then "flashback" to the past, and then bring your reader back up to the "present" and into the "future." For example, the middle section of an article on the development of the VideoDisc system would begin with a summary featuring the present system on the market, followed first by a "flashback" to the beginning of the development and then a preview of things to come.

Comparison-contrast forms and **Familiar-to-unfamiliar** forms. These organizations hold similar characteristics and often convey your message most efficiently. The writers of National Public Radio's "All Things Considered" program often use these forms to explain technical topics for an intelligent, interdisciplinary audience. Thus, you can explain an unfamiliar concept or technology by clearly referring first to commonplace concepts or technologies. For example, the explanation of nonconventional hyperthermia cancer treatment gains strength when the treatment is compared to conventional treatments. Or computerized electronic shopping for Christmas presents from the home is compared to shopping by the familiar method. With ➤

Introductory Paragraphs— What to Do . . .

■ **Introduction:** Use an inverted triangle for your article introduction (one or two paragraphs), which moves from broad generalizations to the last sentence of your introduction containing your essential message (your answer to "Reader's Question #2. What's the Big Idea?"). Remember, use no more than two paragraphs to introduce your subject. A lead that's too-soft will frustrate your reader, who wants you to get to the point quickly.

Get Attention

■ Grab attention, establish a common ground. Open with material that answers "Reader's Question #1. Why Should I Read This?" Don't assume audience interest—you are not writing a technical manual or report. You must persuade our audience that your topic, though outside their specialties, deserves their interest. Use analogies, comparisons, metaphors, or definitions of the impact of a technical detail. In addition, you can choose from the following elements that work well here:

—Unusual, related facts and stories

—Startling assertions or statistics

Example

"Chemists at 'SelectaVision' VideoDisc Operations in Indianapolis must assure that the materials that go into your VideoDisc are absolutely pure. Looking for the critical part per million of impurity in the PVC, however, is like searching for a 1-gram needle in a ton of hay. To achieve that sensitivity, RCA scientists used state-of-the-art chemical analyzers that helped them to identify, throughout the VideoDisc manufacturing development effort, chemical problems never before encountered."

—News information

—Anecdotes, scenarios, or analogies that set the scene for your topic

—A reference to the marketplace, industry, or overall RCA business

In all cases, maintain credibility and stick to the facts or to authoritative sources. Raise doubts, or the specter of sensationalism, and you will lose your audience.

Establish Scope

■ Briefly, describe the scope of your work—where did it start and stop? What kind of progress did you make (theoretical, experimental, mockup or prototype, completed engineering project)? How does the work fit in with what went before? Your idea or someone else's idea? Primary and secondary objectives?

■ Indicate the organization of your paper in your introduction, if you wish. You can do this by rephrasing your article subheads and by weaving the result into a deft sentence or two.

State the Message

■ Put your essential message (see Section One) at the end of your two-paragraph introduction. It has greatest impact there.

Methods

Tactics for the Middle of the Article

Use some or all of the methods below to write the outline and the text for the middle of the article. Never eliminate or dilute substantive technical materials.

familiar and unfamiliar forms presented in parallel throughout your paper, you hang your new information on a powerful and familiar skeleton. CMOS vs. NMOS, gallium arsenide vs. silicon, linear vs. digital—comparisons with competing technologies abound in technical writing.

Decision analysis and interpretation works well in engineering writing for the *Engineer*. Readers favor business/technical overviews because they show how the company's engineering work fits into the "big picture" (see page 12). Most engineering decisions must balance technical, cost, and customer/market considerations. You can build your technical article on these tradeoffs by examining the choices made among various ways of engineering a product. Why is one way chosen over another? Your technical points work well within this framework, which encompasses advantages and disadvantages. It is similar in form to problem-solution order, but much more detailed. John Dewey, the American philosopher, in essence gave the following five steps: (1) formulate and clarify the question or problem; (2) analyze it and get only the root causes (not symptoms) and basic facts; (3) know the criteria for possible good solutions; (4) test the possible solutions; and (5) clearly show the preferred solution. Your writing can describe these steps, in whole or in part, on the path to a successfully engineered product or system.

Problem-solution organization is often an engineering success story told in retrospect. You can inform *RCA Engineer* readers of a technical problem that you or your group faced, and then present the solution that you successfully implemented. In general-interest *Engineer* articles, you may even look at a techni-➤

Choose a Form of Organization

■ Choose from the several forms of organization available for your paper, including problem-solution, chronology, cause and effect, description of how something looks or works, comparison-contrast, decision analysis (why we did it this way), lessons learned, and so on. Once you decide on the framework, make all of your main points within this structure (see sidebar on Organization, page 17).

Outline from Questions, or . . .

■ Jot down a set of questions, which you *may* want to answer, on index cards. Use brainstorming techniques (see sidebar on Brainstorming), and give questions equal weight at first. Get as many points down on paper as you can, and finely divide the topic.

■ Decide on the right questions for your paper by using the following steps:

1. Discard questions that are uninteresting or that have uninteresting answers.
2. For each question, imagine your questioner. When would your answer bore him? How detailed must your answer be? Alter, throw out, or add questions. Use details wisely. If a general statement has only trivial examples, then question the general statement because it may be trivial, too. Once you have details, don't just name or catalog objects or characteristics. Find descriptive examples and analogies that put life into them.
3. Use the index cards to order your questions according to a natural flow, from least interesting and simplest to most interesting and most complicated, and according to the answers to the reader's three questions in Section One. You may gradually construct a traditional outline. Tag questions that you could handle—outside the natural flow of the article—in a reference; a glossary entry; an explanatory sidebar; or artwork with a 25- to 50-word caption. Stick to the main point you isolated during your preparations.

Example

A group of authors, writing a survey article on microprocessor system development in various hardware environments, came up with some good, organized questions that they used to write their paper. Though these authors explicitly used the questions cited below as subheads, we recommend that you use questions only to prepare and organize. Use only the answers, not the questions, in your final draft.

- ☐ *"What are some good analysis and design tools to help me simplify the task of microprocessor system development?"*
- ☐ *"Suppose I can't afford the best development tools money can buy—what then?"*
- ☐ *"How do I decide what to implement in hardware and what in software?"*
- ☐ *"How do I obtain wonderful tools and the expertise needed to use them?"*
- ☐ *"What questions must we resolve in analyzing and designing a microcomputer-based system?"*
  - — *"When must the system be finished?"*
  - — *"At what cost?"*

cal problem on a broad scale and then offer a corrective technical program that you feel would result in a solution. Problem-solution patterns are excellent models for engineering writers because they cut straight to the heart of the engineering experience. You can take up several related parts of one problem and, in turn, present the solutions.

Spatial order is based on parts of a whole, standing in space. How does something look or function? Spatial order works, through definitions and descriptions within a systematic plan, to answer this question. The definition gives the meaning of something by reference to a *purpose* or *function*. The description helps the reader *visualize* something—an equipment or process or system. The advantage of concise descriptions is that they are definitive by their nature—so you can do two things at once in a carefully chosen and well-illustrated description.

Our readers like device descriptions that have these elements: the definition, the significance, the underlying principle, the generalized view, the analysis of important parts, and (again) the device's operation or function in summary. Readers like descriptions of a process to follow the same pattern, but you should substitute the analysis of important steps for the analysis of parts and show some spatial images. In a process description, a summary that shows operation or function would be redundant. Try to work definitions into your descriptions. Because systems are increasingly important to high-technology companies, we recommend process description of some sort.

Topical order means that you define the organization yourself, according to your own approaches to the topic. Confine ►

— *"Who is available to work on the project?"*

— *"What aids will help with the design task?"*

— *"Is it really that simple?"*

— *"What if I must implement in a bare-bones environment?"*

— *"Can I really debug without sophisticated tools?"*

— *"How about debugging the software?"*

The questions, used to build the article structure, continued in this vein.

Outline from Artwork, or . . .

■ Envisage the content. In addition to the "question method" for organizing the material and for establishing a natural flow, you may want to organize your article around scenarios and important artwork. Organize your story completely with only visual scenes, photographs, and artwork. After you've established an order and decided what you will present and what you will omit, write the text to conform to this visualized order. Artwork and text will fuse into a coherent magazine article. In addition, your artist may be able to develop excellent illustrations or photographs from the visual ideas that you generate.

Use examples, metaphors, comparisons and analogies, and scenarios so that the reader can grasp the material (*Comprehendere* literally means "to grasp" in Latin). Jot down a list of images associated with your topic and use some of these when you write. You cannot avoid purely abstract words and principles, but you can try to give a guided tour of engineering experience, too. Metaphor means "to transfer" (in the mind), and metaphor can effectively communicate abstract concepts.

Outline from Speech, or . . .

■ Make a tape recording of your ideas and phrases, then refer to them as you begin to organize the paper

Organize around Engineering Specifications

■ Write specifications (numbers, ranges, dimensions, and equations) that you may be using in your paper. Then assess them. Again, imagine questions your reader will have about these numbers and measurements. Organize your writing effort around certain critical specifications.

1. State the qualitative significance or values of these specs—how do they compare with others achieved? Do they influence the performance of the system—how and how much? Attach qualitative statements to the specs (good? bad? mediocre? the limits of what can be done in a given situation? how do they compare with what others in the industry have achieved? useful? compared to what? what effect? more important than what? impact on system?). In other words, give us quantities, but not in a vacuum. Tell us what the numbers mean.

   Example
   By acknowledging an opposition (simply a different point of view), you gain credibility with your audience. At the same time, you place your technology or topic in perspective. When you cite a spec, for example, of a solid-state power amplifier, and also cite that of the traveling-wave tube to be replaced, you're giving the spec meaning and strength. Do not assume that you are responsible for reporting only on your device, system or whatever. Put your technology or application in con-

yourself to no more than three approaches. For example, survey state-of-the-art microwave components by establishing two approaches at the outset—component design considerations, and potential product applications for the developed components. Or classify your topic by components with military potential, or consumer electronics potential, and so on.

For you and your readers, the different forms of organization are like different bridges across a hidden lake that you've explored for years. The views are fairly complete and quickly surveyed. You may have to use a combination of bridges. But you'll never show the lake by just wading in—you and your guests would drown.

—*MRS*

text. This pro-con approach can work for various organization schemes and will create the transitions you will need throughout your paper.

2. Reduce drastically the specifications and equations you will allow in your paper. Which specifications or equations are most important to the main point? Which will be the most useful or understandable to an engineer outside your specialty?
3. Avoid redundancy. Specs in tables should not need detailed mention in the text. Which specifications belong in a table with an explanatory caption, and which belong in the text with qualitative comments?

Use Transitions

■ Use transitions. They are the most effective tactic you can use in the middle of your paper. As you begin to write, first acknowledge and dispose of the "opposition." The following example shows two ways you can anticipate objections by using pros and cons to create successful transitions throughout your article:

PRO	***CON***
(The advantages of your technology far outweigh the advantages of the alternatives.)	*(You dispose of the opposition quickly after first acknowledging their point of view.)*

THESIS: "This is so."

"Of course, this is so, too."

But that is impractical . . ."

"And . . ."

"Moreover, . . ."

". . ., and so forth."

"Therefore, . . ."

PRO	***CON***
(Your technology has strong competition. Run explanatory statements about the technology in parallel with the statements about competing methods.)	*(Here you have several strong points that you must acknowledge about the competing systems—make "mini-comparisons" throughout the article.)*

THESIS: "This is so."

"To be sure . . ."

"But . . ."

"Yet, one might realize . . ."

". . ., however, . . ."

ARTICLE REVIEW

As an engineer or supervisor with an interest in writing, you surely will be asked to review papers written by others. And if you are an author, you will undoubtedly review your own writing. Follow these guidelines.

When reviewing a document, look first for the *author's purpose in writing*. The reader should not have to discover or interpret the writer's intentions. The purpose of the paper should be clearly and simply stated within the first two paragraphs. Basically, the first two paragraphs should provide the answers to the questions, who? what? where? when? and why?

However, the purpose of the paper is not the only thing the reviewer must watch for. If the author does state the purpose, the reviewer must also determine if the body of the text supports the author's intentions. Is there a general pattern of organization? Is the flow of thought clear so that the conclusions are rational? Do the text and conclusions lead to valid recommendations?

The reviewer must read the paper with the following questions in mind. The answers will provide the writer with the necessary information to improve the paper.

- □ Why is this being written? What is being proved or presented?
- □ Is the purpose of the paper presented in the first two paragraphs?
- □ This paper is being written to (technician, engineer, manager, executive officer); Is it at too low (high) a level?
- □ Have all the relevant facts and ideas been included?
- □ Do the main points stand out?➤

"But then . . ."

"But after all . . ."

"Nevertheless, ..."

"Indeed, . . ."

"Besides, . . ."

"Therefore, . . ."

"Some think . . ."

"Still, one must admit . . ."

" . . . is all true."

■ Create transitions. Transition words like *But, however, nevertheless, therefore, indeed, of course, also, moreover, in fact, on the other hand, later, at last, finally* work well, but may leave your reader hanging. Topic sentences work better at the beginning of each paragraph, especially if you hook the thought into the preceding paragraph: "Researchers at RCA have other ideas" might be a topic sentence complete with transition. Tell the reader where you were, where you are, and where you are going. Give variety to your transitions, your signposts—tell us what connections exist between ideas, and why you are giving information. Here is an old standby: In the new topic sentence, repeat crucial words from the last sentence of the preceding paragraph, and then introduce a new idea. Or simply restate, in different words and in condensed form, the phrases or ideas from the preceding paragraph, then go on to a new idea.

Check Article Flow

■ Limit the subject of each paragraph with a topic sentence. A convenient tactic, after you've written a rough draft, is to scan topic sentences in the middle of your paper and decide if the result makes sense as a summary. If the result is disjointed, check for paragraphs that may have slipped in unnoticed—the topic sentences should relate to your main sentence, your big idea.

■ Place short (1- to 5-word) subheads throughout your article to help your reader to follow your transitions. Subheads work best every six or seven paragraphs, when the text content shifts direction. Strive to delete numbers and acronyms in your subheads, and add an action word to create more informative subheads.

■ Readers favor articles with paragraphs that are four or five sentences long (about one-third of a typewritten page).

Methods

Tactics for the Conclusion of the Article

Every paper should have an ending. Here are ways to create harmony in this third part of the article.

■ Avoid repeating the introduction, or the abstract summarizing the paper. Instead, restate, in different words, your main point and the principal information. Use *then, finally, thus, so,* followed by this strong restatement of your thesis.

■ Work from the specific point back to a generalization (reversing your approach to your introduction) to give your article a feeling of finality.

■ Give conclusions, or recommendations, but only those that follow from the paper. The reader does not have to read between the lines—if you want him to reach a certain conclusion, tell him.

- ▫ Are minor points related to the main points?
- ▫ Does the text flow logically from one point to the next?
- ▫ Are the relationships clear?
- ▫ Are there any unexplained acronyms in the text?
- ▫ Are there any indefinite or vague statements?
- ▫ Are analogies appropriate and reliable?
- ▫ Are there enough descriptions and illustrations for clarity?
- ▫ Are there any repetitions? Should they be left in for emphasis?
- ▫ Should any narration be converted into cause and effect or into analysis?
- ▫ Are definitions functional?
- ▫ Does the text prepare the reader for the conclusions that are stated?
- ▫ Are the conclusions supported by the data?
- ▫ Are the conclusions clear and logical?
- ▫ Are recommendations clear and supported by the conclusions?
- ▫ Can any of the text be supported or replaced by a table, chart or figure?

It is now up to the writer to take your comments and make the necessary corrections and additions. Then the paper is ready for grammar corrections and style improvements.

—Joel Haness
Technical Publications
Missile and Surface Radar

Conclusion Once you gain a sense of your reader and of the three parts of your paper, you can move easily into the writing task. Use this section to guide you.

Section Three. Group-authored Papers

Premise Group-authorship at its best results in interdisciplinary treatments; but at its worst it produces long-winded, patchy, directionless papers.

Your Goal Try to get a coauthor, or at least an advisor willing to read your paper before submission. Present a unified paper that meets our guidelines.

Methods ■ Decide on possible coauthors in other areas or divisions when you decide on a topic. Approach them.

■ Talk with your coauthors about mutually acceptable directions for the paper.

■ Sit down with the group at the outset and use this guide to agree on the answers to the reader's three questions in Section One concerning the purpose and the audience, the tactics for organizing the beginning, middle, and end of your article, the organization and length, the ideas for artwork, the style and . . . *the deadlines* (see your Ed Rep).

■ Firm up the outline and avoid overlap during the writing. Clearly define and distribute revision tasks, and assure that everyone sees the progress of the entire manuscript—for example, be sure the best organizer, the best content reader, the best grammarian, and so on, reads the whole article.

■ Keep an independent devil's advocate close by for critical readings. Whether you are an individual author, or part of a group, seek out one or two people outside your area and ask them to read the manuscript. Then, ask them the following:

- What have I done and what does it mean? Where have I failed to answer your questions?
- Did I explain or do what I said I was going to do?

Conclusion Group authors benefit from each other's expertise, and split the workload. If you are alone with a narrow topic, you can automatically double your scope (and your credibility) by getting a coauthor. Simply approach your topic the way you would an engineering project—plan in advance.

BRAINSTORMING

Brainstorming, either alone or with others, will lead to some effective and useful concepts and images for your article. You can then judiciously select the best concepts from a plethora of ideas. Follow these rules when brainstorming alone or with others:

1. Keep everything positive. Criticize ideas only after the session is over.
2. Encourage any idea. Even the wild ones may lead to a superb idea later.
3. More is better. Favor quantity over quality during brainstorming.
4. Improve on your own ideas, or on the ideas of others, and join two or more (ideas) into still another idea.

You can spark ideas by asking questions concerning your subject or topic. For example:

1. New ways to use it?
2. What can it be adapted to or from?
3. Can we modify it?
4. Magnify it?
5. Minify it?
6. Substitute something for it?
7. Rearrange it?
8. Reverse it? Opposites?
9. Combine it?

Your next step, evaluation of the ideas, depends on your engineering skills and should be no problem for you.

—*MRS*

Section Four. Artwork *Is* Content!

Premise Artwork for the *RCA Engineer* must have high information content. Art attracts attention first, and indicates article scope and quality at a glance. It uses up to half the space in an average article, and, therefore, art *is* content.

Your Goal Treat art selection and execution with the same care you give to the text and content.

Methods ■ Find a general-interest lead illustration that cuts to the heart of your article, summing it up and introducing it all at once. This illustration will go on the first page of the article, near the title. The figure will place your technology in context.

Find the Lead Illustration

Example
A group of authors were to describe the transformation of chemical reagents into finished pellets for VideoDisc molding operations. The natural lead illustration in this case was a "before-and-after" pair of photographs showing the reagents (loose powder, beakers, bottles) on the one side and the finished product (the pellets) on the other. Photographs usually make the most effective lead illustrations because of their immediacy and realism. Artists' illustrations follow closely on the audience-interest scale. Avoid submitting a block diagram as the lead illustration.

Make Art Tell a Story

■ Choose and edit figures carefully. Some authors do their outline in visual images, (the art) and then write the text to accompany the art. The art should tell the story.

- Too many figures will confuse and diffuse your topic. Submit about two or three figures for every 700-900 words.
- Include photos and show action. In general, avoid Polaroid photos. We need black-and-white glossy photographs, and we prefer 8 × 10-inch prints. In general, use grey or dark backgrounds to make your subject stand out.
- If possible, avoid submitting computer printouts. Show important points or samples. If you must use a printout, submit the original output sheet, and put labels on a photocopy of the output so that we can understand the parts of the program.
- Combine block diagrams with photos of the section of circuitry being described. Also, we can use shading to highlight areas in the diagram that demand special emphasis, if you use a copy to tell us where we should highlight.
- Describe your artwork with a 25- to 50-word caption, not just a label. If you have good reasons for choosing to publish the art, an informative caption should explain the art or embellish the ideas shown. Find something to say that's left unsaid in the text. Or summarize what the figure shows. Or choose an important detail and feature it in the caption. The caption is your best opportunity to draw your reader's attention to the text.
  Much of the "unusual" material you generated in Section One should work in your captions. Think of statements you would make in a presentation if the art was all you had to convey the topic. Avoid phrases like: "Photograph of . . .," "Block diagram of . . .," "Schematic of . . .".
- Think of interesting symbolic or visual imagery for your graphs.

ARTWORK GUIDELINES

In line drawings, carefully attend to the relative thicknesses of lines, the clarity of symbols, and the size of the lettering. Keep in mind that the illustrations will be reduced to small size for publication. Pages in the *Engineer* are usually made up with three columns of type per page. Column widths are as follows:

Column width	*Inches*
single	2¼
double	4 11/16
1½	3⅜

Illustrations should be drawn at twice the final reproduction size. Plan most figures to fit in a single column width, as long as the smallest significant detail in the illustration will still be legible in that size.

Miscellaneous
Mark each illustration with the author's name and figure number. Send original art with the approved manuscript or sooner. Indicate the column width that the art was made to fit. Always indicate the top edge of an illustration (especially, a photograph). Illustrations should be mailed flat, well protected by heavy cardboard. Never send a folded illustration. A crease can cause breaks in type and lines when reproduced.

Use black india drawing ink. Do not send lead pencil drawings. A nonreproducing light-blue pencil should be used for guide lines. Never send photocopies for use as "originals." They do not reproduce well. Avoid wasted white space when planning charts and graphs. Crop marks (if necessary) should be indicated on the white edge of the photo. If the photo has no border, mount the photo on a larger sheet of paper and indicate crop marks. Do not use tissue overlays to show crop marks. Never put paper clips or ➤

Balance Art and Text

■ Evenly blend figures and text. A glut of figures followed by text citations makes for jumpy reading. Try to balance it so that our staff can make figures and text references fall on the same page. In the body of your manuscript, when you refer to a figure, explain what the figure is, shows, or does.

■ Delete figures for the following reasons:

- The figure is explained, or could easily be explained, in the text.
- The point illustrated is irrelevant to your outline.
- If the data can be combined into an existing figure, then incorporate them in that figure.
- Unexplained details in the figure confuse rather than clarify. Delete anything in the figure that is not explained.
- Take text information that belongs in a table and put it into one.

Line drawings exist to *simplify* and *emphasize.* A complex line drawing conflicts with this goal. Again, do not submit one that contains many elements you cannot explain in the text or the caption. Drafters at your location use your drawings and instructions to prepare *RCA Engineer* artwork. Talk to your Ed Rep about preparation details and mechanics, and see the accompanying sidebars on our artwork needs.

Conclusion

Artwork, the primary and most immediate communicative device you have, deserves thoughtful consideration *before* you write your article draft. Artwork and editorial in a magazine fuses cohesively in a communication that is greater than the sum of its parts.

tapes on photos. Use thin cardboards in front and in back of the photo and put a clip (or merely rubber bands) over the cardboard. This will prevent marks on the photo. Don't write on the backs of photos—it shows through when printed.

—*Louise Carr*
Art Editor, *RCA Engineer*

ARTWORK

Every engineer knows that technical papers require supportive graphic illustrations and photographs. But art too often is an afterthought, dependent on graphics that currently exist or on the author(s) knowledge of graphic design. An engineer who relies solely on his empirical graphic instincts will generate weak graphics that distract the reader by disturbing the paper's logical flow.

The two most common mistakes an author makes are: (1) underestimating the importance of the selection of art and of the graphics design process; and (2) overcompensating, to counteract weak technical content, by increasing the quantity of art. The following graphics guidelines should be used by an author before writing a technical paper.

- Plan the number and type of illustrations when generating the outline and before starting to write.
- Use graphics *only* to enhance and support technical claims or results.
- Simplify each illustration (consult graphic illustrators, if available). Depict only the essential elements.
- Avoid computer printouts. They are hard to read. If you must use a printout, pick a small section (no more than 75 lines), and mark callouts on a copy of the original to explain the code. Then, send the original printout, unmarked.
- Each illustration must have a caption that describes the purpose and content of the graphic.

Photographs
Photographs add realism and "snap" to your technical article. Submit a set of 8 x 10 glossy prints (we prefer black-and-white, but will accept color prints with good contrast). See that prints are not marked, bent, or rolled in transit. Send them in a protected and stiffened package. Mark the figure number and author's name on a piece of white tape and then put the tape on the back of the photo, near one edge. Never cut, or trim the photo. Never mark the photo (back or front) because every indentation and mark shows on the printed page. Put all figure captions together on a separate page.

Lettering
Mechanical lettering is required (Leroy or Varitype are examples of acceptable quality). Lettering sizes must be large, and the amount of lettering should be kept to a minimum. The *RCA Engineer* reduces most illustrations to a single-column (2⅛ inches) or two-column (4½ inches) width; acceptable lettering size, after reduction, is 7 points (1/10 inch). Before sending the art, check completed line art for a consistent use of units and labels. Be sure everything is spelled correctly.

Photos with callouts
Use callouts on photos, but have them mechanically lettered on a clear (acetate) overlay—never on the photo itself. If facilities are not available for this, send in an overlay with the callouts hand-lettered in position. Do not paste callouts on the photo, unless an unmarked print is sent along as well. Or mark up a *copy* of the art to show position. Oscilloscope photos should be mounted on a board with any necessary lettering around the edges.

Line drawings
Use black ink on linen, vellum, or drafting paper. We cannot use pencil work. We *can* use "PMTs" (or "stats") if the image is clear and correct.

Sketches and artist's concepts
Large renderings (2 feet by 3 feet or more) originally prepared for a presentation are generally poor illustrations for a technical paper, especially when the original is in color. As a test, have a black-and-white photographic copy made at about 8-inch by 10-inch size; if the material looks good (that is, sharp black-and-white contrast without gray tones), then it will be usable. The same principle applies to any color photo or retouch work: It must have good tonal quality in black-and-white.

Negatives
Submit only positive prints,

Slides
Avoid submitting slides of line drawings as illustrations; they suffer in visual quality when copied and blown up. Send the original artwork used to make the slides. But if you have some "super" slide images for illustrating your article, tell us about them. Under special conditions, we *may* be able to use them.

Identification
Be sure the figure number and author's name appear in a corner or on the back of all illustrations, with the special care noted above for photos. Again, do not put captions on the illustration.

Viewgraphs
We cannot use the viewgraphs themselves, but you can consider the graphic ideas in the viewgraphs when you search for images for your paper. If these requirements create a problem, contact the editors for early help. Don't wait until the last minute to settle the matter of illustration format. Preparation of illustrations is expensive, time-consuming, and vitally important to the paper.

—*Dale Sherman*
Automated Systems

TABLE CONSTRUCTION

Basically, a table is a simple tool to list exact data for purposes of comparison and analysis. When the data are numerous and complex, table construction demands clarity.

The Basic Table

Figure 1 shows all the essential parts of a table.[1] The following points are important rules for constructing and reading a table.[1,2]

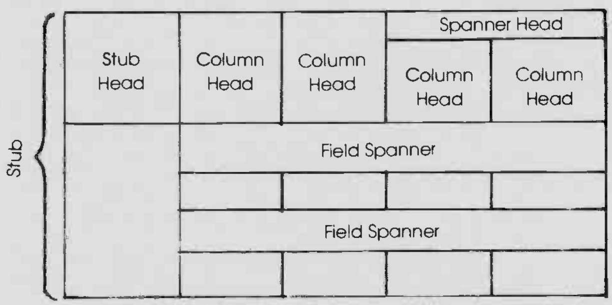


Fig. 1. The major parts of a table. (Courtesy of M.F. Buehler and Society for Technical Communication.)

- Information always reads *down* from the boxhead, all the way to the end of the table.
- Information should also read *down* from the stub head.
- But information controlled by the stub column reads *across*.

Do this:

Liquid	*BP (° C)*	*FP (° C)*
Water	100	0
Ethylene glycol	197	− 20

Don't do this:

Characteristics:	*BP (° C)*	*FP (° C)*
Water	100	0
Ethylene glycol	197	− 20

The Invisible Box

The easiest way to visualize the structure of a table is to think of it as a box—even if the box is not drawn (see Fig. 2).

The following guidelines help authors and word processor operators to set up the "boxless" table.

1. Note that the underscore for each column head extends from the beginning of the longest word in the head (in this case, the word *Column*) to the end of that word; lines above or below the longest word are usually centered in regard to it.
2. The line underscoring the spanner head extends from the beginning of the longest line in the first column head it spans to the end of the last column head it spans. The spanner head itself is centered over that bar.

Table 0. *Parts of a table.*

			Spanner Head	
Stub Head	*Column Head*	*Column Head*	*Column Head*	*Column Head*
	Field Spanner			
	Field Spanner			

Fig. 2. The "boxless" table.

3. Instead of underscoring a roman typeface, you can use italics if available. Conventionally, italics in a table direct you to read *down*. You might have italics in the boxhead, and italics (sometimes without underscore) in the field spanner.
4. In one respect, styling a table with a box differs significantly from styling one without a box: In the former, column heads should be centered vertically as well as horizontally within their own boxes[3]; in the latter, column heads should be aligned horizontally with the column heads under the spanner head (as in Fig. 2), or with the bottom column heads under the spanner head (see Fig. 3).

Table 0. *The Boxhead*

		Spanner Head			
Column Head 1	*Column Head 2*	*Column Head*		*Column Head*	
		Column Head	*Column Head*	*Column Head*	*Column Head*
bbb	ccc	ddd	eee	fff	ggg

Fig. 3. Column Heads 1 and 2 look awkward. Anyone can see that Column Head 1 is "wrong." Although Column Head 2 is not "wrong," it is too high above the data it is to control, making the table hard to read. The empty space above Column Heads 1 and 2, if they are aligned with the bottom column heads under the spanner head, may be a mild eyesore—but not disturbing enough to forego the advantages of that format.

Rules of Construction

The pointers given below will help you with problems encountered during table construction.

Independence from Text Material. A table, like a figure, should be able to stand alone. The caption and heads should tell the whole story in case the reader skips the surrounding text.

Avoiding Clutter. Never repeat a unit symbol in more than one place if you can help it. For instance,

Do this:

Boiling Point (° C)
100
197
290

Don't do this:

Boiling Point
100°C
197°C
290°C

If the table you are constructing also calls for the freezing point, and especially if it is complex and has other spanner heads, you might introduce a spanner head here, too. Then you can avoid repeating "°C" even once. In that case, you might

Do this:

Temperature Constants (° C)	
Boiling Pt.	*Freezing Pt.*

Rather than this:

Boiling Pt. (° C)	*Freezing Pt. (° C)*

Imaginatively shift material from the caption into the boxhead or vice versa to achieve maximum economy and clarity. For instance, if your caption reads "Temperature Constants," you can make that "Temperature Constants (°C)" and limit your column heads to "Boiling Pt." and "Freezing Pt." But if your caption reads "Physical Constants" and there are additional column heads or even spanner heads, with different unit symbols, you must stick to the last two correct versions above.

Footnotes. Many editors prefer lower-case super letters to indicate footnotes (see Fig. 4).

Table 0. *Temperature Constants (° C)*

Liquid	*Boiling Point*	*Freezing Point*
Water	100	0
Ethylene glycol	197	−20[a]
Glycerol	290	0[b]

[a] In 44% by vol. (antifreeze) solution.
[b] Gradually solidifies.

Fig. 4. The use of footnotes.

Footnotes may be used to indicate a shift in units when the unit used in the column head fits most, but not all, entries underneath. For example,

Item	*Cost* ($)[a]
A	105
B	37
C	95¢

[a] Unless otherwise indicated.

Consistency. You wouldn't want identical or comparable column heads to appear in different form in the same table or in consecutive tables within the same publication.

Another inconsistency occurs regularly in the handling of missing or inadequate or negligible data. Say, you have a column of temperatures, as follows:

Temperature (°C)
1025
--
837
-
916
569
None

First, note that there is a useful convention among some editors to leave empty spaces for missing data or to use the word "None." A dash is used for inadequate data or for negligible quantities. Second, make up your mind to use either a single or a double dash to denote identical situations.

As you may have noticed in all of the above examples, comparable figures are aligned under their appropriate digits. If some of the entries have decimal points, align on the decimal point, or wherever the decimal point would be, if there were one. In the case of numbers less than one (1), use a zero before the decimal point (0.95, not .95).

Common Pitfalls

The following common pitfalls in tabular material will surely stump your reader.

Lack of a Stub Head. Alas, many a table shows a stub column without a stub head. Authors often omit this head because the line heads listed in the stub column are so disparate that a common denominator for them is not easily found. This in itself points to a weakness in the table. The author should make the effort to come up with a common denominator or, if this proves impossible, consider revising the table.

Misuse of the Field Spanner. Do not use only one field spanner—it doesn't make sense. Two is the minimum. Frequently authors, or their typists, get the first field spanner mixed up with the boxhead. It won't happen to you if you think of the table as an "invisible" box. Remember that the field spanner spans *all* the column heads (see Figs. 1 and 2), but not the stub column.

Errors. When you have finished a table, look at it as a whole and check for obvious (or not so obvious) inconsistencies in the data. Say, Column 3 shows increasing values, and suddenly there is a drop. This might indicate an exception, a special case the author wants to bring out—or it could signal a mistake! Also, there may be a relationship between various columns in a table—for instance, Column 3 may be the product or sum or square root or other derived value of Columns 1 and 2. If so, this lets you check for errors. Last, there are certain errors of fact that only the author can diagnose.

—Eva Dukes
RCA Laboratories

References

1. M.F. Buehler, "Table Design—When the Writer/Editor Communicates Graphically," *Proc. 27th ITCC*, pp. G-69 to G-73 (1980).
2. M.F. Buehler, "Report Construction: Tables," *IEEE Trans. Professional Communication*, Vol. PC-20, No. 1, pp. 29-32 (June 1977).
3. C.K. Arnold, "The Construction of Tables," *IRE Trans. Engineering Writing and Speech*, Vol. EWS-5, No. 1, pp. 9-14 (August 1962).

RCA Engineer

Writing Style

Writing style critically affects article content and article readability. Everyone intuitively knows this, particularly when we take the reader's viewpoint. Certain sentences, analyzed by grammatical and linguistic rules, show a clean, more elegantly engineered design that everyone can recognize. Make your writing style conform to the standards for clarity we give in this chapter, because the technical content means little if it is seen "through a glass darkly."

This chapter isolates five major style problems and presents the solutions that you can use to dramatically improve your written expressions and make them lean and straightforward. Submit a paper that follows the suggestions in only two of these areas, and the paper will be significantly improved.

When you submit an article for publication in the *RCA Engineer*, we stamp it: "This article will be edited to conform to the *RCA Engineer* format." This section states our editing principles for your reference. If your sentences get changed by our editors, you can look up some of the reasons *here*.

Our writing-style chapter has an overall *Premise*, *Your Goal*, and five major *Methods* for achieving *Your Goal*. Then, within each of the five sections, we follow the same structure: *Premise*, *Your Goal*, and *Methods*. The emphasis, again, is on your reader's attitude toward what you write.

Premise You can achieve a fine engineering writing style without memorizing the specifics of grammar and parts of speech. Improvement in any of five practical areas cited below, under ***Methods,*** will lead to better writing.

Your Goal Write directly, with a forceful, economical, elegant and logical style that parallels engineering thinking. Too often, in an effort to be formal and to sound important, authors lose their directness in a sea of overqualifying statements. Accurate but simple is the goal. Get your thoughts on paper first, by using guidelines in the preceding sections. Then, use what follows to refine your writing.

Methods A sentence written to sound exactly the way you talk will seem silly. So will the sentence written to sound important. Don't write quite the way you talk, but check your sentences for flaws by reading them out loud after you've finished portions of your article.

Five Stylistic Areas

■ Learn to recognize and control some necessary, but rebellious, words and phrases. The following five areas present the best opportunities for improving your sentences. We devote a section to each of these areas.

Section One. Use the forms of *to be* sparingly in your sentences. Write active sentences that clearly show "Who (what) does what to whom (what)!"

Section Two. Cut down on "governing and relating words" like *of* and *which.*

Section Three. Control "modifying and qualifying words" like *very,* or *high-quality.* Modifiers, used carefully, more-closely define the meaning of the noun or modifier to which they belong. Avoid the syndrome where nouns modify nouns. Use hyphens rigorously. Avoid what we call dangling and squinting modifiers.

Section Four. Deal with "connecting words" (like *and*) that signal parallelism (or the lack of it).

Section Five. Make sure words like *it, this,* and *there* refer clearly to a noun.

Note that sidebars throughout this chapter are about *words.* Words reflect the concrete nature of your subject matter. When you *examine* you can choose various actions—be specific, use just the precise action word. How did you *examine*? Choose the simple and familiar over the complex and erudite. Readers understand visual images. Words should reflect the concrete nature of your subject matter. "What we need is a mixed diction," said Aristotle. For the engineer this means putting simple words side by side with necessary technical words. Mix the short sentence with the long sentence. Define acronyms, terms, abbreviations. Beware of wordiness. Average sentences in business writing are about 25+ words. Shorten these to 15 to 20 words. Use concrete words and images in place of abstract words and concepts.

Conclusion This chapter on writing style contains detailed examples. If you choose any area here and follow the guidelines, your writing will improve—no grammar and punctuation rules here! We have isolated only the areas that streamline the sentence. Even if you do not want to use this style guide, reading it will help you understand our editing practices. To some extent, this chapter details work your editor will undertake. But to a great degree, the style points covered here will help you convey your thoughts ungarbled to the reader.

STYLE REVIEW

The following is a checklist of the more significant faults of both grammar and style. They are the types of things both reviewers and writers should watch for and correct. The first eight items are grammatical.

- Punctuation. Look out for commas, either too many or too few. Punctuation is necessary to clarify written technical communications; if it does not clarify the text, it should not be used. Often a sentence that is hard to punctuate should be rewritten.
- Spelling. Nothing makes a paper look worse than misspelled words.
- Subject-verb agreement. Plural subjects take plural verbs, and (the corollary) a singular subject takes a singular verb.
- Verb tenses. Watch for consistency. Are several tenses used in the same paragraph?
- Faulty pronoun reference. Generally the pronoun should refer to the last noun used.
- Modifiers and sentence order. A phrase about a subject should be near the subject.
- Parallel construction. Coordinate ideas in the same sentence should be expressed in a similar form.
- Dangling participles and modifiers. Connect these phrases immediately and unmistakably with the words to which they refer.

The remaining items are primarily style-oriented guidelines.

- Each paragraph should have a topic sentence.
- Stress major ideas.
- The sentences within each paragraph should be in logical order. ➤

Section One. *To Be* or not *To Be*: Passive Versus Active Sentences

Premise Active sentences bring cause and effect into focus and show the agents that do the acting. These sentences are interesting, shorter, more direct and more understandable than passive sentences. If you write mostly active sentences with a few passive sentences for variety, you've taken the single most important step on the path to clear style.

Your Goal Make three out of four sentences active. These sentences make the subjects the doers; passive sentences show that the subject is acted upon (by whom? or by what?).You can use *we, I,* or *the author(s)* in describing your work.

Methods ■ Recognize that passive sentences contain some form of the "existence statement," *to be,* followed by an action word or verb, (for example, *is* ____, *are* ____, *was* ____, *were* ____, *has been* ____, *will be* ____, *may be* ____, and so on). Closely watch every *is* because it may signal a passive sentence. These forms of the existence statement waste space in your article. Simple existence statements bore readers. Go beyond showing existence. At every opportunity use an active, colorful verb instead. Draw a relationship, tell *how* and in what *state* something exists, by use of an accurate verb. Readers, naturally, appreciate your extra effort—often without being aware of it.

Activate Sentences ■ Make sentences active. Turn the subject of a passive sentence into an object—flip the sentence end-for-end—and if you don't have the subject (the active agent), find one! Active sentences have forward motion—the subject transfers action through the verb to the object.

Example 1

There had been major changes *in the presentation related to data accumulated as a consequence of exhaustive study of the results of the checking program routine.*

Find the active agent and change this passive sentence to an active one:

The author changed *his presentation after* he *exhaustively* studied *the results of the checking program routine.*

Or, if more accurate, write:

We changed *the presentation after* we studied *the results of the checking program routine.*

Example 2

As data about each signal is read in, *a sequential number* is assigned *to the signal, and both the signal and its sequential number* are printed out.

Note that active representation of the parts of a machine, system or program leads to active sentences and greater accuracy. Get inside that machine and take your reader on a "Fantastic Voyage" through the active working parts of a program or process. With this in mind, we can change the passive sentence above to an active sentence like this:

As the operator reads in data about each signal, the computer assigns a sequential number to the signal and prints out both the signal and the sequential number.

- ☐ A paragraph is usually too long if it exceeds seven sentences.
- ☐ Active sentences are better than passive ones; therefore, use action verbs.
- ☐ Avoid two long sentences in a row. Give the reader a break.
- ☐ Use necessary and correct connective words.
- ☐ Limit "It is (important, interesting) to note that . . ." construction.
- ☐ Don't start a sentence with a numeral.
- ☐ Long words may not be understood.
- ☐ Avoid deadhead expressions "in the case of . . . ," "needless to say . . . ".
- ☐ Delete superfluous words.
- ☐ Avoid elaborate words, cliches, colloquialisms and jargon.
- ☐ Don't use the wrong word.
- ☐ Don't use ambiguous or incomplete comparisons.
- ☐ Delete needless repetition.
- ☐ Avoid round-about and trite expressions; for example, shorten "In the case of" to "If" or "Is responsible for selecting" to "Selects".
- ☐ A long sequence of noun adjectives is generally unnecessary, and often difficult to understand. Avoid them, or correctly hyphenate them.

After this stage of the review process, the author should make the necessary corrections and the paper should be ready for final typing and final review. By using the checklist to evaluate the paper, you, the reviewer, have assisted an author with specific rather than general comments.

—*Joel Haness*
Technical Publications
Missile and Surface Radar

■ Cut *is . . . and* constructions from your sentences, because they rarely add information. Instead, butt phrases up against each other.

Example 1

The second part of the text is *directed to manufacturing engineering* and *begins with a general discussion of robotics.*

Eliminate the "is . . . and" ho-hum construction:

The second part of the text, devoted to manufacturing engineering, begins with a discussion of robotics.

Example 2

This example combines approaches to passive sentences.

The cable data network (CDN) connection scheme is shown *in Fig. 1,* and is applicable *to any topography. Each node* is connected *to two or three neighboring nodes by full duplex cable.*

Rephrase this passive sentence by changing *is shown* to *shown, is applicable* to *applies, is connected* to *connects,* and eliminate *is . . . and* constructions. Put the horse before the cart—put the subject before the verb:

The cable data network (CDN) connection scheme, shown in Fig. 1, applies to any topography. Full duplex cable connects each node to two or three neighboring nodes.

Example 3

It was decided *that, based on* the current lack of progress *on the project, it* would be inadvisable to effect an increase *in salary this year.*

Rephrase this sentence actively and positively:

Jack and I decided to freeze your salary this year because the project progressed *too slowly.*

Here's another example of passivity:

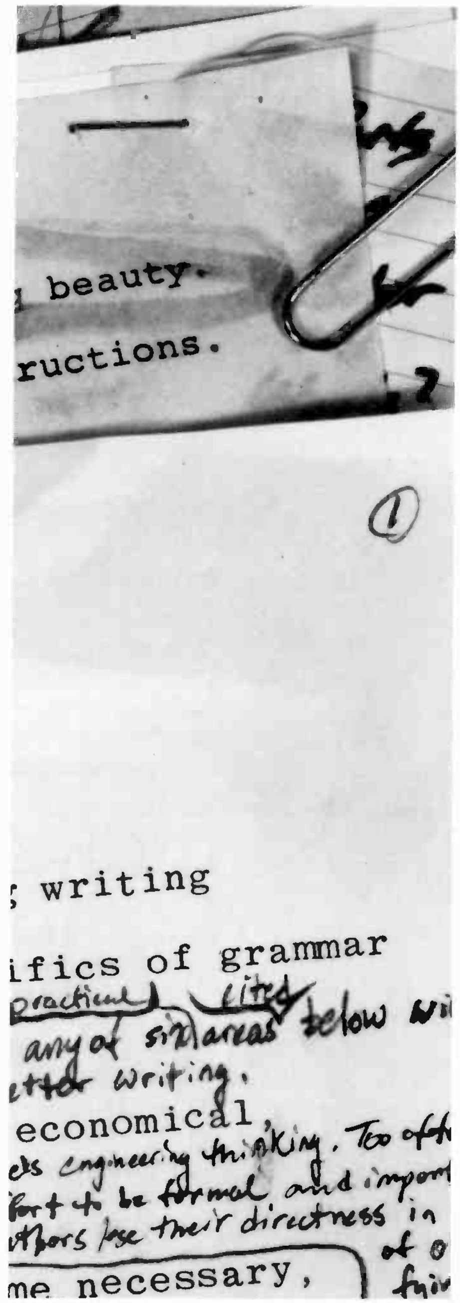
An RCA career in engineering should not be unexciting *because of a lack of opportunities to participate in interesting work.*

Change to:

The many opportunities to participate in interesting work make an RCA engineering career truly exciting.

Conclusion

Your attempts to write active sentences will transform your thoughts and send positive reverberations through everything you write. Identify and eliminate as many passive sentences as you can. Active sentences rely heavily on colorful action words and on clearly established relationships of cause and effect. They powerfully present your ideas and enhance your credibility and charisma. Aim to make three out of four of your sentences active.



Section Two. Beware the *Of* and *Which*

OF

Premise Connective words and phrases (for example, *of, for, at, in, from on, with, by, to, about, in place of, from under, with regard to, out of*) tend to bloat sentences and obscure meaning. These words—called prepositions, or prepositional phrases—connect two terms and show their relationship. Prepositions, though necessary, frequently overrun technical sentences.

Your Goal Recognize these words and remove or alter them so that your action words, simple nouns, and modifiers can come alive. For crisp, lean writing, reduce fat-inducing prepositions, connective words, and prepositional phrases to less than 25 percent of your text.

Methods ■ Delete prepositions if you can.

Example

In *order to provide a means* for *testing the equipment . . .*

Delete *in order* first. It's an unnecessary connective word.

To provide a means for testing the equipment . . .

Another solution here—simply make *testing* the action word.

To test the equipment . . .

Cut the Fat

■ Convert phrases obscured by these prepositions to phrases dominated by an action word. Find a noun you can change to an action word. Make that action word lead a new phrase with vitality.

Example

We cannot freeze our design standards for *too long a time without a loss* of *our ability to keep* up with *the state* of *the art.*

Isolate that "sausage effect" at the end of the sentence (caused by too many fatty prepositions), and use an action word to rephrase the thought positively. For example, *a loss of our ability to keep up* is another way of *falling behind.* Thus,

We cannot freeze our design standards for *too long without* falling behind *the state of the art.*

Now, distill this sentence further. Overshoot the goal—you can always reinstate words or thoughts, if necessary.

If we freeze design standards too long, we will fall behind.

Do not fear stating an important thought in a simple form. But if you should discover that your thought is, in reality, too simple, too unimportant, rethink your message. Perhaps you have something more important to say. For example, in the above sentence, what is "too long?" Can the author say something more substantive than this?

■ Convert two nouns joined by a preposition into a noun and a modifier. Keep one noun, make the other noun a modifier, and delete the preposition—"noun-preposition-noun" forms thereby become "modifier-noun" forms.

SIMPLY WORDS

Readers most often stumble over words, the building blocks of our thoughts—the bigger the word, the higher the hurdle. The "dead languages" cause the problems. Abstract, abstruse accretions of polysyllabic Latin- and Greek-based words (like *abstract, abstruse, accretion*) muck up your writing and sap reader interest. Short words, like short wavelengths, excite; they are specific. Use the colorful, one-syllable Anglo words that have been the guts of the English language since before the Romans invaded Britain. Look in your dictionary for word origins (*Guts,* marked OE = Old English; *Pluck,* marked ME = Middle English; *Courage,* marked F = French; *Intrepidity,* marked L = Latin). You only need your technical terms (many are Latin- and Greek-based) 15- to 20-percent of the time; simple English words usually bring an image to your mind and complement these necessary technical words. By mixing your diction—English words beside Latinate words, short sentences beside long ones—you infuse your writing style with strength, liveliness, and intelligence. Here are some examples of simple words substituted for complex words and windy phrases:

a number of → many; several
accentuate → stress
accomplish → do
along the lines of → like
at the present time → today; now
at the rate of → at
be cognizant of → know; be aware of
by means of → by
designed to fit → fits
due to the fact that → because
during this time → while
effectuate → carry out
exhibit a tendency → tend
for a period of → for
for the purpose of → for
initiate → begin; start
interrogate → ask; question
in close proximity to → near; close to
in order to → to
in terms of → in; for ➤

Example

It is a question of importance.

It	*is*	*a*	*question*	*of*	*importance.*
			↑	↑	↑
			noun	prep.	noun

Make that noun, *importance,* into an adjective, *important.*

It is an important *question.*

Eliminate Prepositions ■ Activate passive sentences, and you will incidentally also eliminate prepositions. Here's an example that shows how to combine the techniques and write a streamlined sentence.

Example 1

They are capable of high precision *and are used* in watch manufacture.

Identify the active agent—who or what is "they?" Then write an active sentence.

These highly precise machines *can help* workers manufacture watches.

The sentence is more accessible because the active agents (*machines, watches*) stand out.

Example 2

The extensive use of *computer-aided design programs* for *the design* of *large-scale integrated circuits has created the need* for *an inexpensive means* of *checking the correctness* of *those designs.*

Change this example to an active sentence and those prepositions naturally fade away.

Designers, now extensively using computer-aided design programs to lay out large-scale integrated circuits, need an inexpensive way to check their designs.

Conclusion Sentences suffering from too many prepositions (like *of*) need major surgery. To free clogged sentences and allow the thoughts to flow, make prepositions less than 25 percent of your text.

WHICH

Premise Most authors overuse or misuse the word *which.* This mistake often conceals the meaning of the sentence.

Your Goal Cut the *which*'s, or change them to *that*'s. Otherwise, insert a comma before the *which* and after the phrase that it belongs to.

Methods ■ One possibility—cutting *which* out entirely, and possibly cutting the phrase it precedes—often works best.

Example 1

Note that here the author didn't enclose his phrase in commas, and created a confusing sentence.

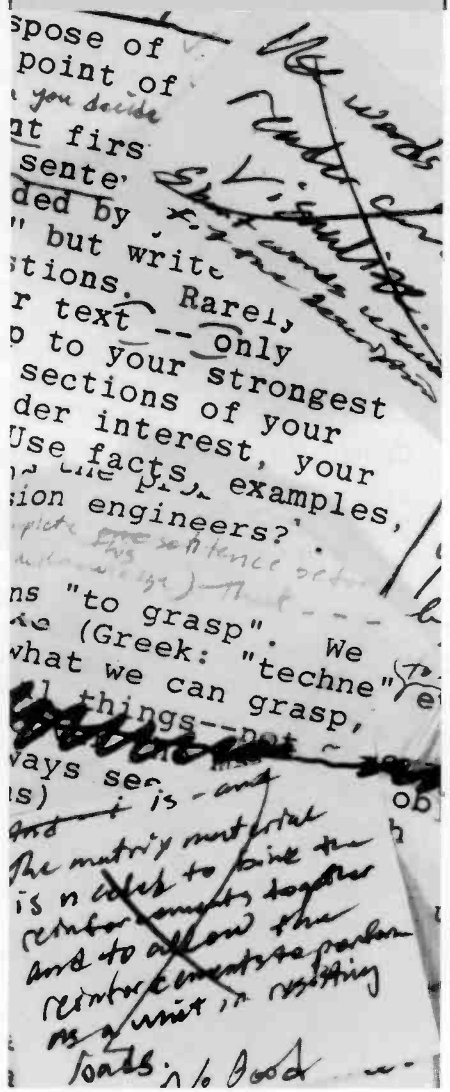
The electronic mail study which *we carried out attempted to understand, and to incorporate the features important to the mailer.*

By rephrasing this sentence we can make it a better sentence:

The electronic mail study was an attempt to understand and incorporate the features important to the mailer.

in the event that → if
in the following manner → this way
in the majority of instances → usually
in view of the fact that → because
involves the use of → employs; uses
is dependent upon → depends on
is equipped with → has
is provided with → has
it is necessary that → must
obtain → get
perform a test → test
pertaining to → about
prior to → before
reflected in the results → shown
subsequent to → after; for
with the aid of → with
with respect to → about

—*MRS*



Which? or That?

■ Substitute *that* for *which,* unless the phrase attached to *which* is virtually a parenthetical comment. Properly used, *which* almost always follows a comma. Whenever you use *which,* check your sentence by tentatively deleting *which* and the phrase, enclosed in commas, that follows *which.* After your deletion, can the remaining sentence stand alone and convey your meaning? If not, change *which* to *that,* and eliminate the commas surrounding the phrase, because your phrase is inextricably tied to the meaning of the sentence: it is necessary to the definition.

Example

Thus, the precise Electronic Mail Services which *we will find most useful and the letter structures* which *we will find most attractive are unknown.*

Now, test this sentence. Can we put commas in?

Thus, the precise Electronic Mail Services, which *we find most useful, and the letter structures,* which *we will find most attractive, are unknown.*

We have altered the meaning. *Which* has altered the meaning all along. Our phrases are absolutely necessary to the definition, not virtually parenthetical comments. Therefore, we must substitute *that* for *which* and cut the commas.

Thus, the precise Electronic Mail Services that we will find most useful, and the letter structures that we will find most attractive, are unknown.

Again, we could eliminate *which,* and also *that,* entirely.

Example

Thus, the precise Electronic Mail Services we will find most useful and the letter structures we will find most attractive, are uknown.

Conclusion

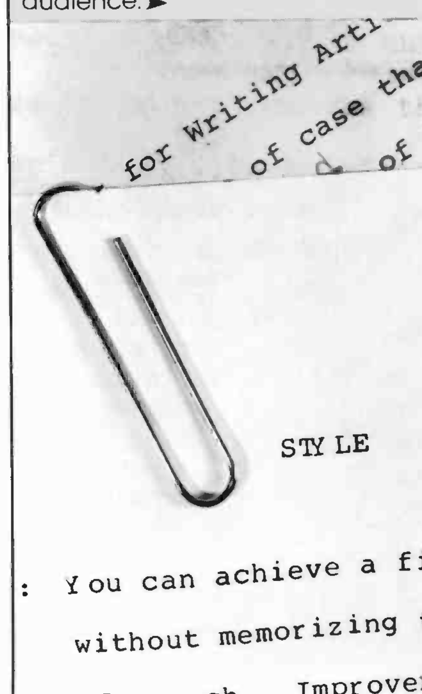
The ~~In this~~ sentence's ~~the~~ "connective tissue" ~~of the thoughts, which are~~ the prepositions and other ~~of the~~ connecting words, should ~~be put in the background, in the role of a supportive set of words behind the scenes.~~ unobtrusively support the "bone structure," the verbs and nouns. When you reduce connective words like *of* and *which* ~~rise~~ to ~~above~~ 25 ~~to 35~~ percent of the total, your ~~number of words in the sentence, you should begin to think about how to get yourself out of the~~ troubles ~~which you are in. In the event of this occurrence, the above types of words should be cut down on by the~~ subside. Use ~~of~~ the techniques ~~which are~~ outlined in this section.

The sentence's "connective tissue," the prepositions and other connecting words, should unobtrusively support the "bone structure," the verbs and nouns. When you reduce connective words like *of* and *which* to 25 percent of the total, your troubles subside. Use the techniques outlined in this section.

THE AUDIENCE

An expert in computer sciences would be wrong to assume that her or his report, distributed to all managers in the company, would be easily understood by administrative, marketing, and all technical personnel. But even though the audience that reads your report has educational and professional backgrounds different from your own, there are techniques you can use to clearly deliver your message to anyone who reads it.

First, identify your audience precisely. This investigation will enable you to know where to begin, what to include, what to leave out, how to organize your writing, and what stylistic level to use. There are four types of audiences: Executive, expert, technical, and lay. The extent to which you define terms, use analogies and graphic aids, and modify professional jargon will vary, depending on the audience. The *RCA Engineer* has a multidisciplinary technical audience. ➤



Section Three. Modifying and Qualifying Words

Premise Modifiers closely define and limit the meaning of the noun or modifier to which they belong. But vague modifiers, overused modifiers, too many modifiers, and dangling modifiers will stump your reader every time.

Your Goal Recognize and fix problem modifiers. Keep related words together. In particular, keep the noun that does the acting, and the action word (verb), together.

Methods ■ Avoid vague modifiers. Complete your meaning. Often we cannot state a precise quantity, but we can give limits or a range. For example, if we say something is *high quality,* we must define *quality.*

Be Precise

Example 1

Several volts were added to the load, producing a high-quality response.

What is *several*? How many? What is the *load*? What is the *response*? Why is it *high quality*? If the reader has no answers to these questions, he will lose interest.

Example

Inspections are performed regularly.

How often is *regularly*?

■ Don't overuse the same modifiers. Vague modifiers get used again and again because they have an all-purpose meaning.

Hyphenate

■ Beware of too many modifiers. Noun-upon-noun-upon-noun before a main noun is usually unnecessary. When necessary, hyphenate correctly to establish a logical grouping and hierarchy. Only you can hyphenate to create the exact meaning that you intend. *The Chicago Manual of Style, Words into Type* and the *GPO Handbook* hold all the information you need to hyphenate compound modifiers correctly. Use qualifiers judiciously. The temptation to be obsessively accurate and entirely literal can lead to convoluted, incomprehensible sentences.

Example

Extruded polyethylene insulated 22 gauge BF type wire has commended for use in the cable.

If you cannot cut down on the modifiers, then hyphenate within this sentence and establish some subordinating relationships.

A 22-gauge BF-type wire with extruded-polyethylene insulation has been recommended for use in the cable.

Change to Action Words

■ Change modifiers and nouns into action words, where possible. In English, many nouns have multiple meanings, and the meaning usually depends on the verb. Faced with a clot of nouns, use active verbs and your sentences will instantaneously flow more freely.

Stating your purpose for writing your article or report is also helpful. Additional practices that can facilitate successful communication between the writer and the reader focus on lean writing—writing succinctly. The following checklist summarizes principles for effective writing.

- □ Simplify words and phrases
- □ Avoid ridiculous metaphors and dangling modifiers
- □ Define technical terms and acronyms
- □ Avoid cliches, deadwood phrases, and redundancies
- □ Avoid ambiguity by using concise, concrete words instead of abstract words
- □ Write in the active voice
- □ Make sure text and graphic aids complement each other

—*Carle Spriggs*
Advanced Technology Laboratories
Publications Department

Example 1

The ultimate in long length high data rate performance is obtained with this type of fiber.

Besides the offensive passive construction of this sentence, we have grave problems with nouns modifying nouns. They pile up like bumper cars in expressway accidents. Make the sentence active, and tow some of the nouns away.

This type of fiber allows the ultimate in high-data-rate performance over great distances.

Stacked nouns jam your signals and confuse the reader.

Example 2

The figure shows an idealized sketch of a typical double heterojunction semiconductor laser energy band diagram and refractive index profile.

Note the buried nouns in this sentence. Underline them. Then try to establish hierarchies and groups of modifiers. In modification all are not equal! The buried nouns are *figure, sketch, diagram,* and *profile.* The skeleton sentence is: *The figure shows a diagram and profile.* We can now begin to hyphenate.

The figure shows a typical double-heterojunction semiconductor-laser energy-band diagram and refractive-index profile.

Danglers and Squinters

■ Fix dangling and squinting modifiers. Dangling modifiers make your sentence read with two different meanings—your own and the very silly second meaning that others will notice. Anyone unfamiliar with your subject may even mistake the "silly" second meaning for the real meaning. The term "dangling modifier," may evoke nightmarish school memories. You cannot see the havoc such modifiers can create for others, because you are too close to your material. First, recognize the problem: Dangling modifiers attach to one part of your sentence, but swing free from the rest; squinting modifiers occur when you place certain words incorrectly—they lead to two possible readings of the same sentence. Make all parts of the sentence refer to the right things, and eliminate unintended meanings. Next, try to use active voice.

Examples of Danglers

Example 1

Such mail is often subjected to delays at the Post Office and, therefore, may be delayed in processing and meeting outgoing dispatches.

Is the mail doing the processing and dispatching? Obviously, the second meaning here is silly. Try this:

Such mail is often subjected to delays at the Post Office and, therefore, mailroom employees may be delayed in processing it and meeting outgoing dispatches.

Be sure that this is the intended meaning. Then, try rephrasing the sentence in an active voice. You will achieve greater accuracy.

Circumstances at the Post Office often delay such mail and, therefore, company mailroom employees may fail to process it and meet outgoing dispatches.

Example 2

To make flawless wafers, a "clean room" helps.

Clean rooms seem to be as adept as highly skilled technicians here. Often action words (like "to make") precede a phrase swaying to an anarchic, dangling beat. Try this:

A "clean room" helps our technicians make flawless wafers.

FUNDAMENTALS

Hard writing makes easy reading; the burden to communicate clearly and effectively is on the writer. I have listed a few writing fundamentals below.

KISS (keep it short and sweet). The shorter a message, the greater its impact.

Appropriate diction. Use a dictionary and a thesaurus to pinpoint the word that will precisely express your thought. The facts, badly written, do not communicate themselves.

Simplicity. Keep it simple—explanations are hard to write. Simplicity is accomplished through crisp, uncluttered diction and a step-by-step approach.

Audience analysis. Be aware of the readers' (audiences') educational and professional backgrounds.

Planning and organization. Clear, logical thinking yields clear, logical writing.

—*Carle Spriggs*
Advanced Technology Laboratories
Publications Department

Example 3

The optical coupling can thus be up to twice that which can be achieved using a single layer of the recording material.

For a moment, we might think that single-layer material permits the better performance. That is not what the author meant.

The optical coupling can thus be up to twice that which can be achieved by the use of a single layer of the recording material.

This sentence does not dangle. But we really need to avoid *using, by the use of,* and so on. The concept of *using* is usually inherent in the verb. Try this:

The optical coupling can thus be up to twice that which can be achieved with a single layer of recording material.

Now introduce some additional elements (data) and rephrase in active voice for clarity:

Trilayer material couples twice as many optical signals as does single-layer recording material.

Example 4

Referring to Fig. 4 again, the actual tape can be inserted to obtain checkplot information.

Who or what is doing the "referring" here? This "actual tape" can read Fig. 4 in the *RCA Engineer*? Words ending in *-ing* often signal a phrase that is "slowly twisting in the wind"—a dangler. Try this:

Referring to Fig. 4 again, you will note that the actual tape can be inserted to obtain checkplot information.

Here, an explicit statement of the subject, *you,* clarifies the sentence.

As you can see, dangling modifiers result when the relationships between elements in the sentence are assumed rather than spelled out. The passive sentences contribute to the confusion.

Recognize Danglers

■ Expose dangling modifiers with a simple test—rearrange the sentence so that the modifier explicitly belongs with the word it modifies.

Example

Being reasonably satisfied with the circuit performance, *it was decided that the tester should be replaced.*

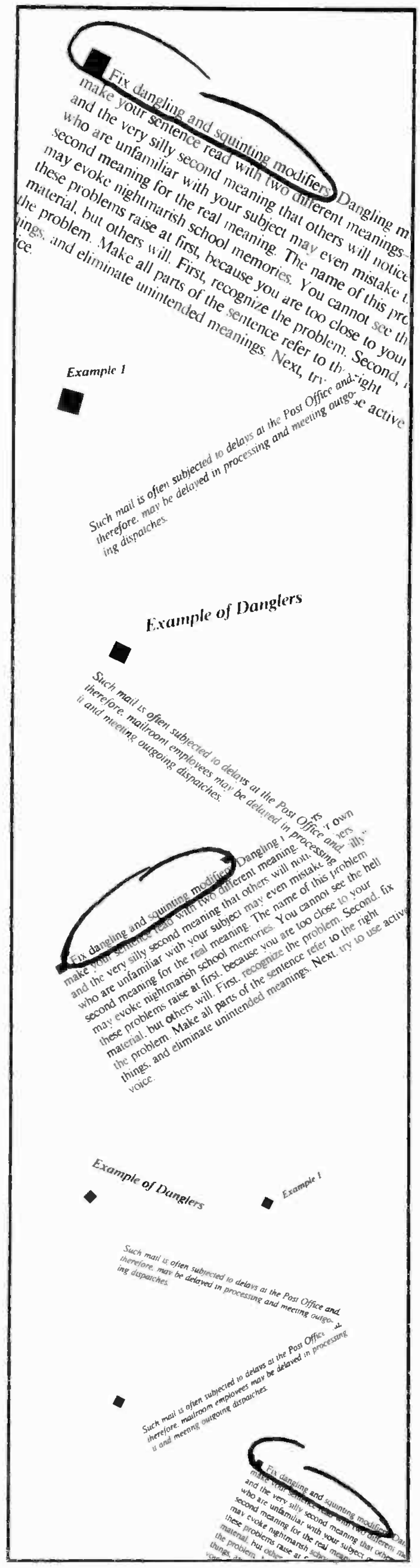
After rearrangement, note the absurdity of the dangling phrase:

It, being reasonably satisfied with the circuit performance, *was decided that the tester should be replaced.*

We have three solutions to the problem.

1. Keep the phrase, but find a subject for it. Who did the deciding? The Project Supervisor?
   Being reasonably sure of the circuit performance, the Project Supervisor decided we should replace the tester.
2. Make a clear clause, without an "--ing" word and with a verb.
   Because the circuit performed well, we decided that the tester should be replaced.
3. Perhaps you do not need to give reasons.
   We replaced the defective tester.

That's all. Period.



Squinting Modifiers

Examples of Squinters

Example 1

They informed us after ten days to notify them.

Did they wait ten days to inform us? Or did they tell us to notify them after ten days? Try this:

They told us to notify them in ten days.

Or, depending on your intent:

Ten days later, they told us to notify them.

Example 2

We have provided an interface on our indicators applicable to a series of accessory units.

Is the interface applicable or are the indicators applicable? Try this:

On our indicators we have provided an interface applicable to a series of accessory units.

Here, we have put elements that modify each other together. Or try this:

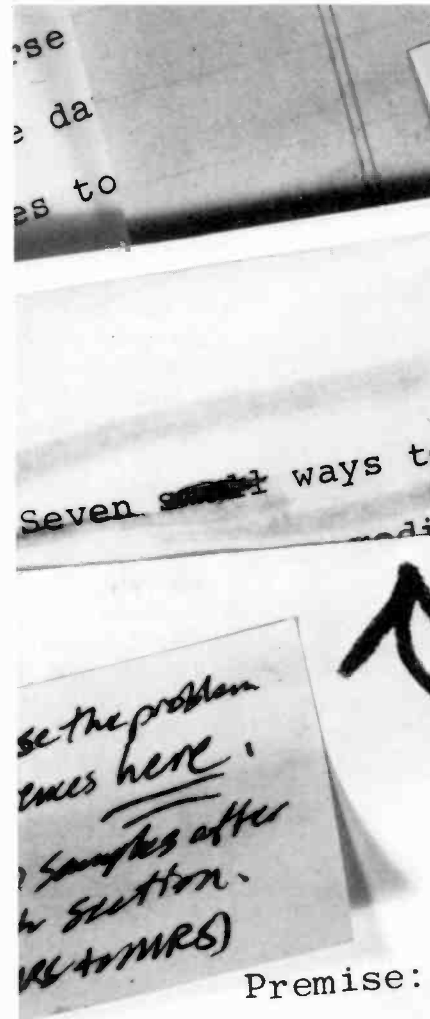
We have provided an interface on all our indicators, which are applicable to a series of accessory units.

Or this:

We have provided an interface on all of our indicators that are applicable to a series of accessory units.

Take your pick. Squinting modifiers, as you can see, point in two directions within the sentence. The sentence's exact meaning, therefore, becomes unclear. The best solution is to put the modifier next to the element to be modified. Keep related words together, and keep modifiers with the word they modify.

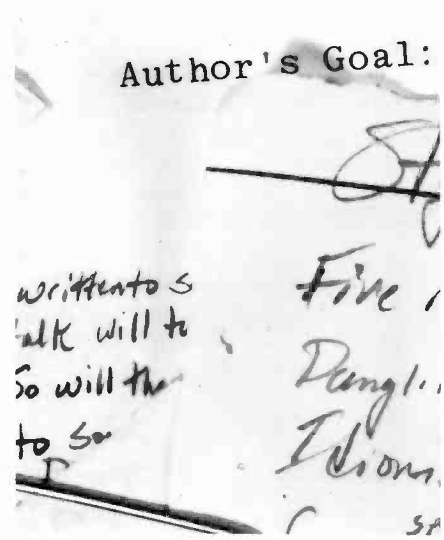
Conclusion Modifiers closely define and limit your main words—under ideal conditions. Use modifiers sparingly. Too many modifiers—and particularly the vague ones like *high-quality, regularly,* and *cost-effective*—overwhelm your action words and nouns, and sap your sentence's energy. Misplaced modifiers, such as "danglers" and "squinters," need to be tied firmly to a noun or phrase. In general, put related words and modifiers close to each other in the sentence.



Section Four. Connecting Words and Parallelism

Premise Thoughts, words, and expressions that parallel each other in their construction have a natural rhythm that leads to immediate comprehension. Parallelism as a writing device promotes clarity, because it casts differing characteristics into comparable molds.

Your Goal Build similar ideas on similar foundations. In other words, establish parallel relationships—symmetries among words, sentences and paragraphs. Parallel concepts allow you to organize your material more completely. Parallel expressions allow the reader to grasp your concepts more readily. And parallel word forms support your sentences more steadily. Connect your phrases together in parallel, construct series in which the elements have the same form, and your sentences, no matter how lengthy, will flow smoothly.



Parallelism exemplified.

"Vigorous writing is concise. A sentence should contain no unnecessary words, a paragraph no unnecessary sentences, for the same reason that a drawing should have no unnecessary lines, and a machine no unnecessary parts. This requires not that the writer make all his sentences short, or that he avoid all detail and treat his subject only in outline, but that every word tell."

—William Strunk, Jr.
The Elements of Style

Methods

■ Carefully control words and phrases connected by the word *and.* Be sure that parts of a series are parallel. Strunk constructed his writing style, as demonstrated in the example above, in parallel phrases.

Example

Orientation for new employees seems both worthwhile and a necessity.

This sentence is not parallel. Here, *worthwhile* is connected to *necessity;* the sentence sounds odd. If you look these words up in a dictionary, you'll see that *worthwhile* is an adjective (a descriptive word that further describes, or modifies, a noun). *Necessity* is a noun. Yoked together by *and,* these words have the grace and power of a pony in harness with a Clydesdale, pulling the reader in conflicting directions! Change *necessity* to *necessary,* an adjective, and you have joined two "ponies."

Orientation for new employees is both worthwhile *and* necessary.

Making the Sentence Parallel

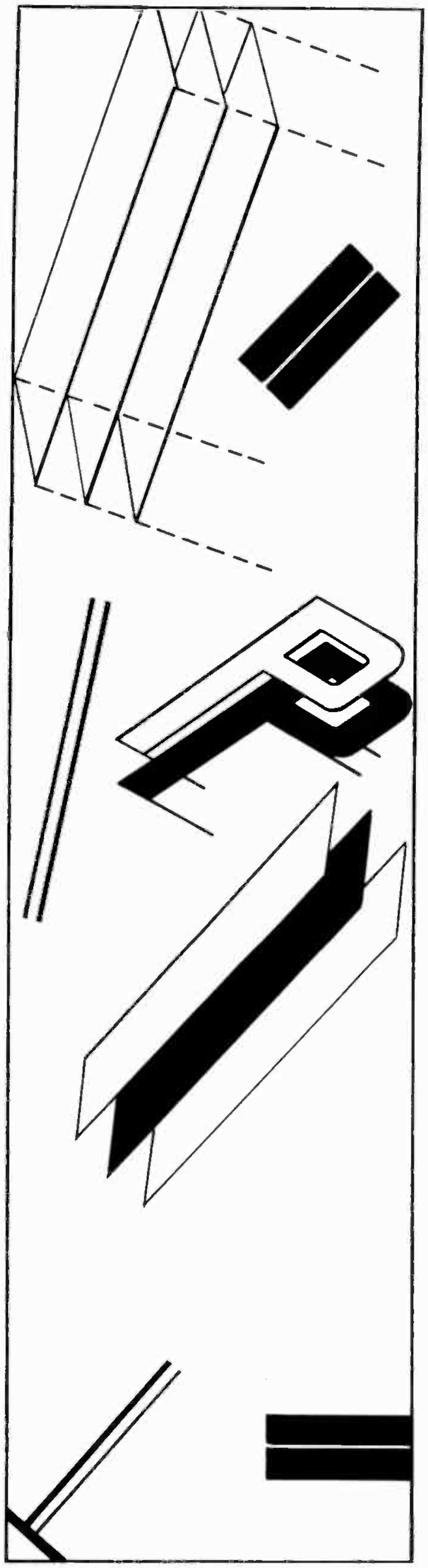
Example

Problems with parallelism invariably occur more subtly. Here's an example of a nonparallel sentence:

In addition, the permanence of optical disc recordings, their removability, ease of handling, storage and transporting as well as lower ultimate disc cost has influenced most computer and electronics companies to start system development.

Remember that words and phrases seek their own kind. Be sure to construct the important words in parallel. Also, when you have phrases in a series, try running the same introductory word before each phrase, to clearly separate the parts in the series. In the example above, the author too quickly subordinated the possessor (*optical disc recordings)* of the series of characteristics (*the permanence, their removability, ease of handling, storage and transporting as well as lower ultimate disc cost*). In addition, the characteristics given here show like an indistinguishable mongrel litter (are *storage* and *transporting* separate characteristics?) These characteristics need a stint in basic training. They need to be lined up, put into uniform, and groomed to show their individual character as they march in parallel. Isolate the solid core of each phrase, the noun: *Permanance, removability, ease, cost.* Now, the schizoid "Three Faces of *Ease*" (*handling, storage, and transporting*) deserve special treatment, otherwise, *ease* will require an asylum. Make *storage* into *storing.*

In addition, the permanence, *their* removability, ease *of handling, storing and* transporting *as well as lower ultimate disc* cost *of optical disc recording has influenced most computer and electronics companies to start system development.*



Next, find one article or word that can lead off each phrase, to show clearly that *ease* has integrated its three personalities and to show that the items are parallel. This repetition of an introductory word ensures clarity. In this case, we'll use *the.*

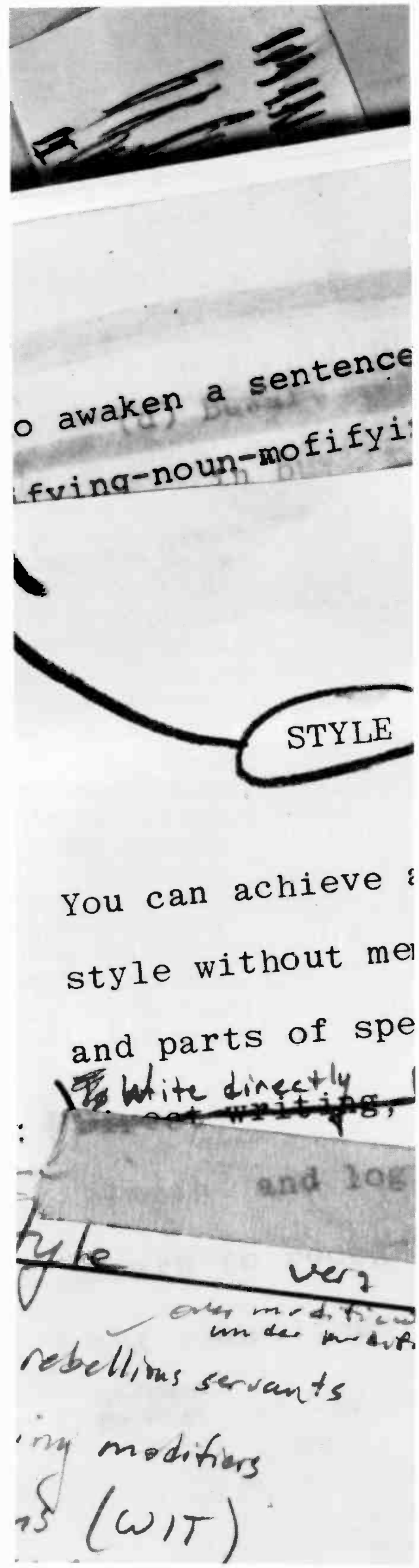
> *In addition,* the *permanence,* the *removability,* the *ease of handling, storing, and transporting, and* the *ultimately lower disc cost of optical disc recordings has influenced most computer and electronics companies . . .*

Finally, tie all the loose ends together by bringing the singular verb (*has influenced*) into agreement with this group of nouns—make the verb plural, *have influenced.*

> *In addition, the permanance, the removability, the ease of handling, storing, and transporting, as well as the ultimately lower disc cost of optical disc recordings,* have influenced *most computer and electronics companies to start system development.*

Now, you have parallelism.

Conclusion Parallel construction gives your reader clearly marked lanes to follow on the road to comprehension.



Section Five. Pronouns "Do It!" (Refer to a Noun)

Premise Suddenly nonspecific nouns proliferate. *Do it right the first time. We want to help you do it right. Go for it. Nobody can do it like (this major hamburger chain) can. Make it special, make it (our hamburger chain). (Our car) does it again.* The engineering writer is not exempt from this handwaving, and sometimes uses pronouns without antecedents. A great advertising man Claude Hopkins, in his *Scientific Advertising,* devoted a chapter to "Being specific." He wrote that the weight of an argument may often be multiplied by making it specific. Aristotle also held to this view centuries ago. In engineering writing, surely the authority behind your statements will increase if you follow this timeless advice.

Your Goal Be specific. When pronouns like *it, this, that, they, he, she* are your best writing choice (for brevity's sake), make certain that you clearly establish the connection to the exact word to which you are referring.

Methods ■ Watch particularly for constructions that begin with *This is,* or *There are,* or *It is.* Then, look at the sentence or phrase that precedes these kinds of phrases and be sure that only one noun is clearly referred to. If no clear referent exists, then repeat the noun or rephrase the noun and use it (that noun) instead.

Find Specific Antecedents

Example

What does *its* refer to in this example?

> *The conductive resistance of the circuit board was calculated to be 16.14 °C/W based on* its *multilayer construction.*

Improve this sentence by clearly referring to *the circuit board* and not to the *conductive resistance* or the *16.14 °C/W.*

Based on the multilayer construction of the circuit board, *the board's conductive resistance was calculated to be 16.14 °C/W.*

Example

In the 1960s, transition to solid-state circuitry was started and it *was almost a decade before* it *was fully completed. During this time in which television was the dominant video consumer product,* it *was considered by many to be a mature business.*

After finding specific antecedents to the vague pronouns, and after a bit of rearrangement to bring words together,

In the 1960s, consumer product manufacturers started the transition to solid-state circuitry, and almost a decade passed before this process was complete. During this time, television was the dominant video consumer product, and many considered it to be a mature business.

Note the ill-defined pronoun, "it," in the last line—is the "mature business" television or solid state? These questions will be asked by your readers.

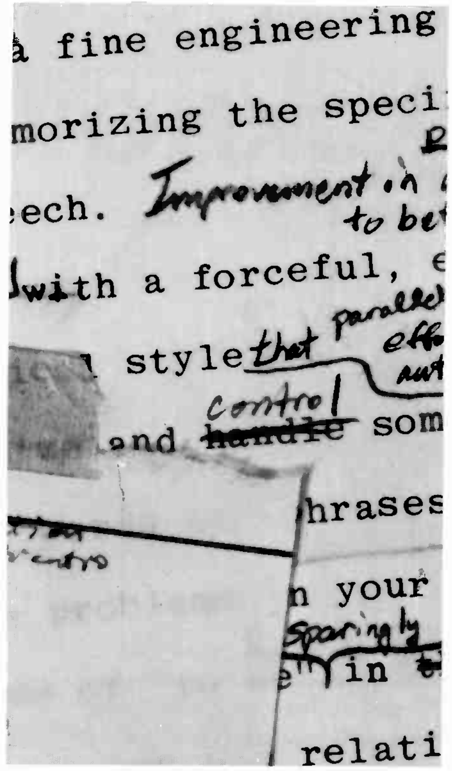
Example

It is important to note that . . .

Always delete this wordy windup.

Conclusion

Although you may think that relationships between your concrete nouns and your pronouns (*it, he, she,* etc.) are clear, they often fail the test. When in doubt, repeat the concrete noun.



Conclusion and Acknowledgments

We trust that this guide clearly reviews principles for our experienced authors, and also gives comprehensive and encouraging editorial direction for our new authors. Instead of rigid rules, we have listed techniques, suggestions and guidelines for approaching your unique writing task for the *RCA Engineer*.

Your primary writing goal is to get the material—the engineering achievements that make your project or topic worth writing about—on paper. Use any technique you can to break that initial barrier. Use a tape recorder, set up a brainstorming or interviewing session with coworkers, visualize problems and solutions over the course of an engineering project and then write them down, or write a totally unrefined, uninhibited narrative of events. Don't worry, at first, about the way you express yourself. Using this guide, you can concentrate on expression after you've made a start on content.

The *RCA Engineer* calls for free writing protocols for a diverse, multidisciplinary audience. You're probably familiar with engineering writing that places extreme constraints on you, because of your specific audience (maybe one person), your closely defined goal (for example, a report on a vendor's product), or the brevity of your writing effort (two paragraphs written on a form). In contrast, the *RCA Engineer* offers you unparalleled opportunities.

You have freedom to use your unique technical experiences and contributions, your writing ability, and the resources of Editorial Representatives, Technical Publications Administrators, and *RCA Engineer* Editors to write broad-based articles that present your technology in the context of your general industrial and technical knowledge, your familiarity with the hot technologies, and your in-depth understanding of the state-of-the-art.

Moreover, a diverse *RCA Engineer* audience that includes company management reads the survey articles, tutorials, histories, applications articles, and articles on engineering systems. This magazine, an exciting forum for the exchange of technical ideas, creates a sense of community among engineers currently working in the three major (and increasingly related) areas identified by RCA's management as core businesses—communications, electronics, and entertainment. There are other advantages. Trade publications reprint *RCA Engineer* articles. Many authors increase their prestige and that of RCA when this happens. Publications offer a lifetime return on your investment of time and energy.

Your decision today to contribute an article to an upcoming issue will start the process. We normally devote each magazine to a technology theme—your Editorial Representative, who is listed on the inside back cover of the *RCA Engineer*, can preview upcoming technology themes for you. Once you get the go-ahead from the *RCA Engineer* Editor, refer to the first chapter of this guide to remind yourself of the parts of the article and the schedule requirements. The first chapter summarizes our needs.

The second chapter (on Article Content) contains a series of idea starters. Use Section One of this chapter to understand how you can make your topic interesting for the *RCA Engineer* audience, and how to gather information for the various parts of your article. Use Section Two of this chapter when you actually begin to write. It tells you what we need in the beginning, the middle, and the end of your article. A sidebar in this section of the guide helps you to choose a predominant form of organization. We encourage group-written articles because they tend to be multidisciplinary; that's what Section Three covers. Section Four of the chapter tells you our artwork requirements.

The last chapter isolates five major writing-style problems and shows, via examples, ways to improve your expressions. We ask that you focus on at least one or two of these style points when you revise your rough draft. For example, try to use active sentences—make sure that each sentence clearly identifies the agent doing the action(s). These tips on writing style apply to virtually any writing effort. Because the writing-style methods lead to more-straightforward sentences, they'll lend power to your statements and make writing an easier task for you.

To be successful in engineering work at a large company, you rapidly learn that you must write—engineers commonly write more than those in other professions. Moreover, you must master a variety of written communications, including engineering memos, technical reports, and refereed technical presentations and articles in your field. Each form has its rules. Sometimes it may seem that writing tasks consume the valuable time you need for doing the engineering work—especially when different people have different ideas on how you should write up essentially the same material. We don't want to add to your burden.

Instead, we hope that this guide, together with regular contact with your *RCA Engineer* Editors and Ed Reps, will ultimately save you time, and increase the impact of your message to the RCA community. We look forward to seeing new faces and fresh articles in upcoming issues of the *RCA Engineer.*

Acknowledgments

I am most grateful to Eva Dukes, our Editorial Representative at RCA Laboratories, for contributions to this guide. At critical manuscript and galley stages she made the document her own, and sent voluminous constructive criticism, expert editorial work, and level-headed encouragement. Authors and potential authors, she is an RCA editorial resource who will make you look good.

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Betty Gutchigian of the *RCA Engineer* staff made many difficult phototypesetting refinements that you see, but may not recognize.

In addition, I am grateful to the following engineers, a cross-section of the engineering population, who spent valuable time reviewing this guide: Joe Solomon (Astro-Electronics); Enrique Melendez (Automated Systems); Jim D'Arcy (SelectaVision VideoDisc Operations); and Bob Duschl (Technology Transfer Laboratories in Lancaster).

Of course I am grateful to all the bylined individuals in this guide who contributed sidebars. Finally, I'd like to thank all of the Editorial Representatives and Technical Publications Administrators who contributed to the discussion of this guide at several Editorial Planning Board meetings during the past year.

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Going beyond philosophy, this book gets down to business—fast. "The *Rhetoric* of Aristotle is a practical psychology, and the most helpful book extant for writers of prose and for speakers of every sort," says Cooper in his introduction.

Baker, Sheridan. *The Practical Stylist*. New York: Thomas Y. Crowell Company, 1973.
This basic book, primarily for college students, exemplifies and teaches a straightforward writing style. The author tells his story firmly, with humor and grace, but you won't get help on technical writing here.

Bartlett, John. *Familiar Quotations: A Collection of Passages, Phrases, and Proverbs Traced to Their Sources in Ancient and Modern Literature*. Edited by Emily Morison Beck. 14th rev. ed. Boston: Little, Brown and Company, 1968.
Why not use an appropriate quotation to liven up a section of your article? Here's the ultimate source.

Bernstein, Theodore M. *The Careful Writer: A Modern Guide to English Usage*. New York: Atheneum, 1965.
Here's an alphabetical list of usages, good and bad, with reasons for using, accepting, or rejecting them. Bernstein was Assistant Managing Editor of *The New York Times* before he got rich and famous.

Blicq, Ron S. *Technically—Write! Communication for the Technical Man*. Englewood Cliffs, New Jersey: Prentice-Hall, 1972.
The author covers technical writing and speaking. This book will help you report to your boss via memoranda and research reports.

Crowley, Ellen T., and Thomas, Robert C., editors. *Acronyms and Initialisms Dictionary*. 3rd rev. ed. Detroit, Michigan: Gale Research Company, 1970.
This is a guide to alphabetic designations, contractions, acronyms, initialisms, and similar condensed appellations. If your manuscript begins to look like alphabet soup, use this book to cure the problem.

Cunningham, Donald H., and Estrin, Herman A., editors. *The Teaching of Technical Writing*. Urbana, Illinois: National Council of Teachers of English, 1975.
A potpourri of articles—from teachers and professionals on technical writing—ranges from the quantitative to the qualitative, the practical to the theoretical.

Damerst, William A. *Clear Technical Reports*. New York: Harcourt Brace Jovanovich, Inc., 1972.
In the effort to teach technical writing, this superbly comprehensive and short book starts from scratch and takes students through exercises to improve their skills. Look, in particular, at Chapter Eleven on "Articles."

Ewing, David W. *Writing for Results in Business, Government and the Professions*. New York: John Wiley & Sons, 1974.
Fine material for the business writer, concisely presented with lots of examples. The book applies more to letters and memoranda than to technical articles, but the principles are useful to the technical writer. This is a fun book.

The Editorial Staff of the University of Chicago Press. *The Chicago Manual of Style*. 13th rev. ed. Chicago: The University of Chicago Press, 1982.
One of the most comprehensive and detailed guides to manuscript preparation—if you have specific questions, a good index in the back of this book will lead you to the answers.

Flesch, Rudolf. *The Art of Readable Writing*. New York: Harper and Row, 1949.
This author advocates people-oriented articles. He teaches a highly personalized style of writing that many staffers on consumer and trade magazines favor—that is, descriptions of problems, situations, or actions in terms of specific people or groups. This classic book will really help you to write actively to your audience.

Fowler, H. W. *A Dictionary of Modern English Usage*. London: Oxford University Press, 1926. 2nd ed. rev. by Sir Ernest Gowers, 1965.
A somewhat staid classic, directed to universities, but often a good source of information.

Harkins, Craig, and Plung, Daniel L., editors. *A Guide for Writing Better Technical Papers*. New York: IEEE Press, 1982.
Put out by the Institute of Electrical and Electronics Engineers Professional Communications Group, this collection of articles covers all aspects of technical writing. The collection is useful because it is geared to industry, not to academia.

Hathwell, David, and Metzner, A. W. Kenneth, *Style Manual for guidance in the preparation of papers for journals published by the American Institute of Physics and its member societies*. 3rd rev. ed. New York: American Institute of Physics, 1978.
This authoritative guide for technical authors and editors focuses on manuscript preparations and may be useful if you need to handle technical terms or mathematical equations. A good section on artwork may also help you.

Honig, R. E., and Chu, W. "On-line computerized literature search at RCA." *RCA Engineer*. Vol. 26, No. 5, pp.34-39, (Mar/Apr 1981).
This article can show you how easy a computerized literature search can be. Ask your librarian for more information on this powerful research tool.

Jay, Frank, editor in chief. *IEEE Standard Dictionary of Electrical and Electronics Terms*, 2nd rev. ed. New York: The Institute of Electrical and Electronics Engineers, Inc., 1977.

King, Lester S., M.D. *Why Not Say It Clearly: A Guide to Scientific Writing*. Boston: Little, Brown and Company, 1978.
The former Senior Editor on the prestigious *Journal of the American Medical Association* shows clear ways for you to achieve a good writing style, sentence by sentence. The author explores, in particular, the ambiguities that result when scientific writing suffers from stylistic problems.

Mathematics in Type. Richmond, Virginia: William Byrd Press, 1954.

Though somewhat antiquated because of the current predominance of phototype over metal type, use the information here (if you have to include mathematical equations in your text) to help us to understand exactly what you want to appear on the printed page.

Michaelson, H. B. *How to Write and Publish Engineering Papers and Reports*. Philadelphia, Pennsylvania: ISI Press, 1982.

The author has worked on IBM publications for many years, so he has a genuine industry perspective. His refreshingly practical efforts to help engineering writers overcome the many obstacles they face demonstrates his goodwill and expertise.

Morris, William, editor. *The American Heritage Dictionary of the English Language*. American Heritage Publishing and Houghton Mifflin, 1969.

Usage notes within the entries help. Other examples, on grammar and meaning, and on language analysis by computers, may interest some authors.

Morris, William and Mary. *Harper Dictionary of Contemporary Usage*. New York: Harper and Row, 1975.

Language evolves; words and expressions once thought outrageous become standard. In this book, English usage is raised (or lowered, say some "aristocratic" linguists) to a "democratic" process. Trial by experts shows votes cast for or against various usages. The book makes fascinating reading if you want to know the arguments for or against particular usages. Otherwise, don't bother.

Osborn, Alan, F., *Applied Imagination*, Rev. ed., New York: Scribners, 1957.

Skillin, Marjorie E., Gay, Robert M., and other authorities. *Words Into Type*. 3rd rev. ed. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1974.

One of the most comprehensive and detailed guides to manuscript preparation—if you have specific questions, a good index in the back of this book will lead you to the answers.

Strunk, William, Jr., and White, E. B. *The Elements of Style*. 2nd rev. ed. New York: Macmillan, 1972.

Short and sweet. Highly respected.

RCA Technical Communication Programs, a master reference manual on RCA's corporate-wide technical communications programs. Prepared by editors with Engineering Professional Programs.

This binder includes the following booklets: "TPA Guide," "Publication Requirements," "How to Write—Style Guide," "Technical Reports," "Reference Anthology," and "Research and Engineering Publications."

Technical Documentation Department, Bell Laboratories. *Editorial Style Guide*. 3rd rev. ed. Whippany, New Jersey: Bell Laboratories, 1979.

For the technical writer in an electrical engineering discipline, this nearly 200-page manual sets editorial standards in great detail. Lots of material and examples apply to Bell Laboratories only.

Tichy, H. J. *Effective Writing for Engineers, Managers, and Scientists*. New York: John Wiley & Sons, Inc., 1967.

This book is recommended by Eva Dukes, Technical Publications, RCA Laboratories.

United States Government Printing Office. *Style Manual*. Rev. ed. Washington, D.C., 1973.

If you work on a government-related technology, you may want to use this book.

Wallechinsky, David, Wallace, Irving, Wallace, Amy. *The Book of Lists*. New York: Bantam Books, 1978.

Books like this one provide "off-the-wall" facts and statistics that you may find useful if you want to dress up your paper.

The Way Things Work: An Illustrated Encyclopedia of Technology, Volumes One and Two. New York: Simon and Schuster, 1967.

You will find descriptions of virtually every important technology in these books, presented especially for the intelligent layman. You, too, may want to use portions of these descriptions to set the scene for your particular technology. Many other dictionaries and encyclopedias of science and technology could prove useful in sparking ideas for multidisciplinary approaches to your topic and to your artwork, too.

Webster's New Collegiate Dictionary. Springfield, Massachusetts: G. & C. Merriam, 1977.

This is the dictionary to keep by your desk.

Webster's Third New International Dictionary of the English Language. Unabridged. Springfield, Massachusetts: G. & C. Merriam, 1976.

In the opinion of the highly respected editors of the University of Chicago Press, this is the best American dictionary on the market. The dictionary does not suggest "good" and "bad" usages, unlike the American Heritage Dictionary—rather, it describes usage, without value judgments.

Wilson, John F., and Arnold, Carroll C. *Public Speaking as a Liberal Art*. Boston: Allyn and Bacon, Inc., 1974.

It's for public speakers, but it's practical for writers also, because it shows you how to organize and develop an effective presentation. This book covers communications in general—these principles are immutable and transferable.

Woodford, F. Peter, editor. *Scientific Writing for Graduate Students, A Manual on the Teaching of Scientific Writing*. Council of Biology Editors, 1981.

Here's a hands-on approach to writing an article or a thesis. The context is biology, but the principles are universal.

The Corporate Engineering Education activity holds videtapes and videotape-based courses on various technical subjects that you may want to view in preparation for writing on your topic. The following videotape and course, available from CEE, directly apply to your writing effort:

Garfield, Eugene. *Information Retrieval*. Philadelphia, Pennsylvania: Institute for Scientific Information, March 1981. Tape #188.

Course W1: Effective Writing. New York: Time-Life Video.

THE KEY TO YOUR ARTICLE

In your article's introductory paragraphs, begin "wide" and narrow down to your main point, then give details in the middle section of your article. End your article with a restatement of your main point, followed by generalizations or conclusions you wish to draw, and a final sentence that lets the reader know the article is over.

Title

Introductory Paragraphs

Broad Generalization

Main Point

Middle Paragraphs

First, acknowledge and dispose of the opposition's point of view. When you decide on the paragraph order, present paragraphs with your weakest point first and write a topic sentence for each paragraph. Follow the natural flow demanded by your sequence of the "reader questions" but write sentences that answer the questions. Rarely use a question directly in your text—only for rhetorical effect. Lead up to your strongest point as you proceed through the sections of your paper. To counteract flagging reader interest, your strongest points should go last. Use facts, examples, concrete images, simple words and phrases, and vivid language dominated by action words and nouns—if you see too many modifiers surrounding a noun, then change some to action words. "Comprehend," in its original Latin form, literally means "to grasp." Use words that the reader feels he could touch; always use action words: human nature loves movement.

Concluding Paragraphs

Restate the main point in words different than you have used in the introduction.

Generalization

Final Sentence

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Factory data versus factory information

Factory data are often hard to use for process improvement. You get better information if you use deliberate experiments and formal problem-solving methods.

What's the difference between factory data and factory information? Let's walk through a factory, look at some of the processes and machinery, and talk to some of the people.

Our thoughts will be shown in italics.

As we walk out of the offices onto the factory floor, we are immediately greeted by the sounds and sights of modern industrial production. Everyone we see is quite busy. Several assembly lines are visible both nearby and in the distance.

Our guide takes us over to a row of grinding machines, each putting the finishing touches on a cylindrical piston that will be used in a compressor assembly. There are eight machines, each with an operator. "Ladies and gentlemen, I'd like you to meet Tony. Tony is the day-shift foreman for the machining and grinding operations." Hands are shaken all around. "Tony, these folks are interested in how you keep track of production and quality here . . . what data you take."

Tony says, "You want to see data? You've come to the right place. Step this way." Walking over to his stand-up desk, he pulls out a drawer on one of his two filing cabinets and extracts a sheaf of filled-out forms. "This is a day's work." he says. "There are twelve forms, each different. This one is a production summary. It logs how many of each part were made on a machine. We also have a log for each machine. This log details breakdowns and changeovers, and also gives us use figures for periodic maintenance. That's not in the file, it's in a notebook hanging from each machine."

Sounds good so far, but why twelve forms? Seems like a lot.

"This form is an operator summary. We can tell a lot about productivity from this. We compare the performance of each operator with that of the others and with the work standards, so we know when to give awards and when some remedial advice or training is needed."

A wonderful idea. I wonder how hard a person has to work to get an award.

"Excuse me . . . How much harder than average does an operator have to work in order to qualify for an award?"

Tony replies, "Well, there's really no set amount. This log isn't used as much as it should be. The foremen look at it mostly when they feel someone is slacking off and needs talking to. They look back maybe two or three weeks and try to get an idea if what they think they're seeing is borne out by the data, and maybe they'll talk to the operator anyway. It's pretty tough flipping back through the forms, too. Sometimes the data aren't written down right, and you can't tell as much as you should be able to. Most of us don't spend much time really looking at this one."

Hmm . . . that doesn't seem fair. Everyone has good and bad days, and the machine-breakdown data are not kept in this same file. Someone could have a couple of off days combined with a couple of machine breakdowns, and he or she might get into a lot of trouble. I think I would have a hard time figuring out what's really happening just by trying to analyze all these data sheets. I wonder if a computer could figure it out.

"Now this report shows the results of our in-process checks. The operators do a quick test of each piston with a gauge to make sure that it is roughly the right size. After the measurement, they make a check mark on the sheet to indicate whether the part passed or failed. The failed ones are put in this bin to be reworked."

I see from this sheet that some hours show no marks at all. That can't be right.

"Why aren't there any marks for 11:00 A.M. today?"

"I don't know. The machine might have been broken, or

Abstract: *Factory data are the numbers gathered during production to measure or count the product, to determine whether items meet certain criteria. Factory information, in contrast, is knowledge that can lead to action. This information comes from asking well-designed questions whose answers are fed back to control, improve, or stabilize a manufacturing process. In this paper, the authors discuss ways to convert data into information. Factory data issues, and the application of formal problem-solving methods to them, are described during a fictitious walk through a manufacturing plant. The use of computers for this purpose is also discussed.*

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Reprint RE-28-4-6

Five steps from data to information

1. Ask the question.

You should decide what it is that you want to know. Machine wear? Operator performance? Consumer acceptance of the finished product? These and many others are all legitimate quantities to be measured at some step in the manufacturing process. You must think about, and clearly define in advance, the questions you are *really* asking.

2. Define the measures.

You should decide what you are going to measure. Every data capture requires some kind of measurement: a voltage, a count, a time—something. The measurement data are *unlikely* to be the actual answer to (1), above. Instead, the data are probably a *predictor* of what you want to know. For example, screen brightness of a television set might be a good predictor of consumer satisfaction, but this assumption needs support or experimental verification before you can be certain.

3. Design an experiment.

You should run well-designed, deliberate tests. Tests, experiments, and studies designed to highlight particular cause-and-effect relationships (to answer a specific question) tend to be harder to carry out, but yield a much higher information content than the use of existing data.

4. Get good data!

You should use structured and disciplined techniques for data gathering. When you run a designed experiment, you can collect measurements of physical quantities where only counts were available before. Historical data, especially data on some variable other than the one of immediate interest, are less likely to be the answer to the actual question.

5. Be systematic.

You should use formal problem-solving methods. They may seem oversimplified, and they can be tedious to use, but they are useful because they reduce the likelihood that something important was missed. More problems get resolved when many people work systematically than can be solved by a few designated problem-solvers who depend on brilliance and luck.

maybe the operator got too busy. It gets pretty hectic here sometimes, and her orders are that production comes before record-keeping. The sheets also rarely say why the data are missing, and it's often hard to reconstruct what happened. It's usually okay, though, because we only need approximate numbers here anyway. When we count the pistons in the rework bin, we know exactly how many were rejected.

"This report shows a sample of the output of each machine by exact size. They're all supposed to produce pistons of the same diameter, of course, but there's machine wear, and the blanks are sometimes different hardnesses, so things aren't always right. The quality people sample the output of each machine and let me know when we start to make parts that are out of spec. If we do start to make bad parts, we take the machine off line, and maintenance tears it down and repairs it. The report has the sizes of all parts that are made out of spec, along with the date and time, so that we can track down parts that got away."

But no records of what the parts are while they're good? Time for another question . . .

"Are the machines down often?"

"You know, this is a tricky process. The engineers call for a very close tolerance, and it seems that one or another machine is always having difficulty meeting it. Repair downtime is one of our biggest problems. Sometimes I look at the data that the QC department takes, hoping I can spot a trend before they do, but their stuff isn't exactly what I need to see either, since they only log failures. I'm not sure anyone is taking exactly the data I need."

So . . . there's even more data than the twelve forms kept here, yet some of it isn't where it might be useful. Some of what is here isn't exactly what's needed. It's not even really *clear what is needed.*

What is happening here? In this example, lots of data have been gathered and stored, and the gatherers and potential users of the data are clear and articulate about what they have done. What is much less clear is why certain data are gathered or what in fact the use is. The questions have not been clearly formulated, and the data gathering is not disciplined. Sometimes hours or days are missing or the data are entered incorrectly on the record, and it's therefore difficult to know what the data mean.

When you gather data about your process, your staff, your productivity, your incoming materials, or your outgoing product, these are just numbers. The usefulness of these data requires a lot of planning and insight, and proper analysis and application of the numbers gathered.

It's almost always better to gather new data than to try to make sense out of what has already been collected. Often, factory data are gathered for accounting purposes, or to track and control factors that used to be problems but are now solved. Much of the time, the data are not the best to show what you are really trying to measure. For example, if you compromise your data quality and use historical records, you compromise the information content of your conclusions.

It's also better, for example, to gather numerical data such as voltages or lengths (called attributes) than to gather counts of items such as test failures or product rejects. The numerical measurement data can tell you much more about how a process is doing when it is working right than you can get from counts or failure data. When you know *why* you gathered the data, have been disciplined about analyzing them, and can use them to find and solve specific factory problems, then you can begin to call them information.

The purpose of having factory information is to control a factory or a process. This is done by using the information to iden-

A computer can help, but . . .

Computers are very useful machines, but they don't turn data into information, even though it's very tempting to try to use them for that. In one example here, our factory tourist notices that two different pieces of data are needed in one place to reach a conclusion about machine breakdowns and operator production. It is surmised that a computer could help, and so it *could*. It's hard, though. Harder than it looks. You don't just go out and buy a computer and expect the job to be done.

Computers that can help with this kind of activity can easily be bought. In fact, you don't need very large computers to turn data into information. Unfortunately, the computing needed is less than half of the total work that has to be done.

For a computer to help with this "factory measurement," it would need to be installed and fed data in such a way that both components—breakdowns and productivity—would be represented by measurements stored in the computer. It would also need a program that had access to both types of data. The data would have to be in comparable form (daily, weekly, per-piece or per-hour, and so on) or the program would have to know the different forms and be able to convert. In addition, the program would have to be able to be asked to collect the two components, put them on a common basis, and calculate the desired statistic. Arranging the factory so that the right data are collected by the computer and translated into meaningful, comparable numbers is work for people, not computers, and constitutes a large piece of the total picture.

A very general facility to collect data and massage them into a form where meaningful comparisons may be made is necessary if many different kinds of questions are likely to come up. One way to do this is to attempt to predict all questions that will arise, and to calculate and present answers in the form of reports. Reports such as this are, by their nature, full of less-than-relevant answers simply because they are intended to answer everything. It's as if you asked a question about dinosaurs and were handed a whole encyclopedia as an answer.

It's also difficult to decide in advance what should be included in such a report, and this is the heart of the matter. It's hard to find computer system designers who know a lot about factories, and also hard to find factory people who know a lot about computers. The design of a system that is truly useful must be a cooperative effort. This takes a lot of work, usually by people who are already overloaded because they know a lot about computers, or know a lot about factories, and are much in demand for these skills alone.

Another alternative, one which is very attractive but even harder to carry out, is exception reporting. In this technique, the computer looks at all of the data, and attempts to figure out what's happening in the factory that's normal and what constitutes an exception that needs to be called to the attention of an engineer. To write a program that will do this requires first that the full apparatus for the general report, discussed above, be in place and understood. In addition, the same valuable and busy people who decided on the list of reports needed now have to decide which deviations constitute a significant event, and also have to specify which *combinations* of deviations, each by itself not necessarily significant, requires attention by a person. It is really a lot to ask, even of the most talented design team, to specify all of this while the system is being built. It has to be determined by experience with the computer and the factory process over a long time. This evolution requires continuing development of the system, even after it has been "finished."

The very act of installing a computer does make things better because the system imposes a discipline and neatness on everyone's data gathering and recording. Such a system, though, may be little more than a way of storing twelve forms a day (from the example in the text) on a magnetic disc instead of in a file cabinet. If that's all it does, it's not an *information* system.

More important is that the answers are at best only as good as the questions asked or programmed. Making calculations based on existing data can provide good information, but it's invariably better to design and carry out experiments to generate answers to specific and carefully targeted questions. These will produce the most pertinent, accurate, and supportable information. A computer can be a lot of help gathering, organizing, and analyzing the results of such a specific study, but it cannot design one or carry it out.

The computer just can't do it alone.

tify the causes of errors or variability so that they can be eliminated from the process. One very good way to obtain high-quality information for this purpose is to use a structured and disciplined approach to asking questions and finding answers. Examples of this approach are given in the next section. Other ways, such as the use of existing data, can give good results but are less likely to succeed. Figure 1, by B.H. Gunter,[1] shows this relationship graphically.

This discussion has been summarized in the box on this page.

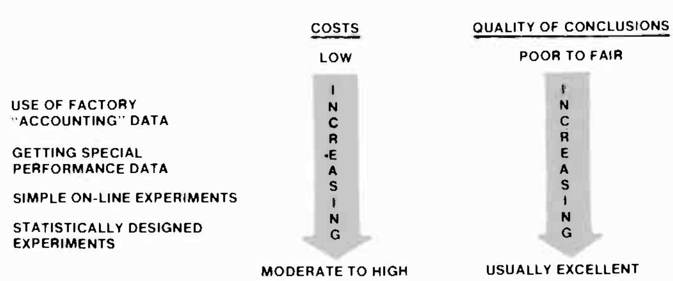
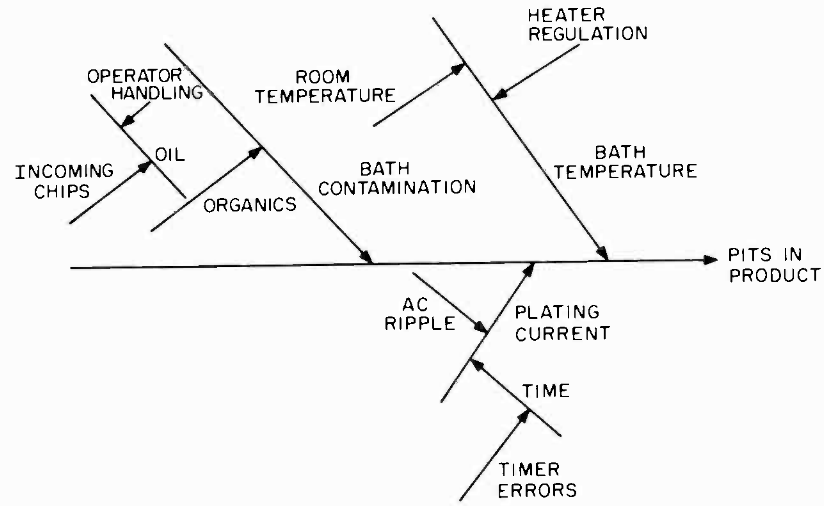


Fig. 1. *On getting good data.*

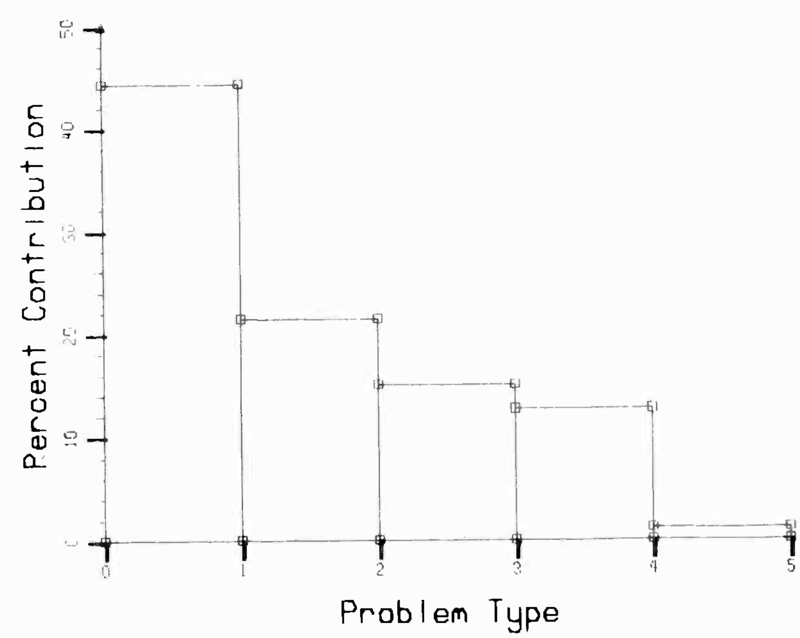
Formal problem-solving methods applied to our example

Cause-and-effect diagrams (fishbone charts). A graphical presentation of the hierarchy of causes that can be assigned to a given effect.



PITTED PLATING
PARTIAL CAUSE-AND-EFFECT DIAGRAM

Pareto diagrams. A graphical presentation of the relative importance of each cause assigned to a given effect. This relative importance may be measured, or it may be arrived at by guesswork in a brainstorming session. The Pareto diagram makes selection of priorities for improvement self-evident.



"Hey, if you're interested in the data and how we use it," continues Tony, "maybe you should sit in on a session of one of our problem-solving groups. We don't have one yet for our grinding and machining operations, but I'm going to school in two weeks to learn how to conduct one. If your guide will take you to meet Joan, I think her group is going to have a meeting shortly . . ."

Our guide takes us through the building to a quiet manufacturing area.

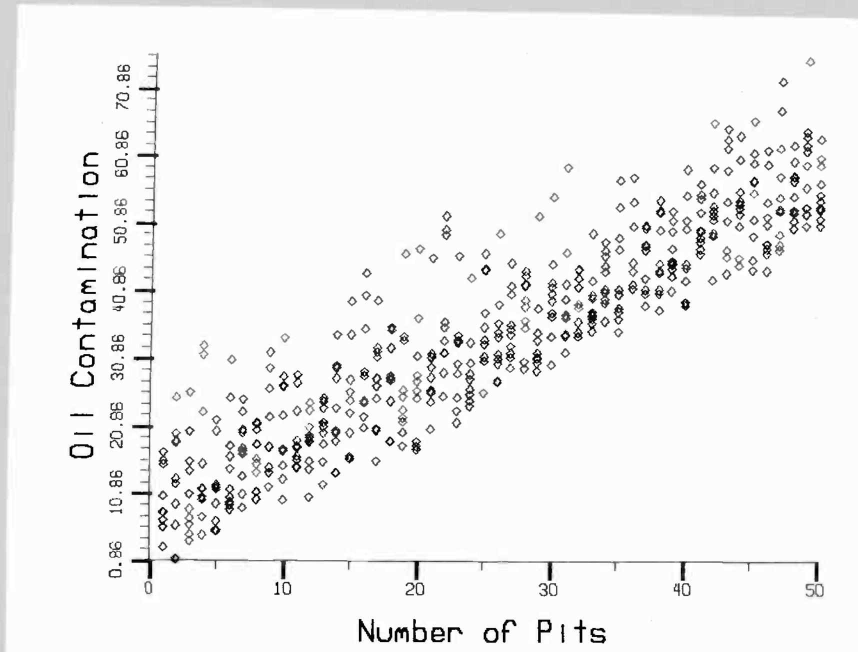
"Ladies and gentleman, meet Joan. Joan works in our plating and tinning group, and has been trained to lead problem-solving groups."

"Hello everybody. Please have a seat here in the back. Our working group will be in from their break in a minute. Don't worry, they're used to visitors. Ours is the first manufacturing area in the building to have our own problem-solving group; and so we've been quite a curiosity.

"The problem-solving group is where we give meaning to the concept that our production staff helps take responsibility for quality improvements. Production-line workers participate fully along with manufacturing supervisors and engineering staff to discuss problems, propose solutions, trade ideas, and conduct studies of the process behavior.

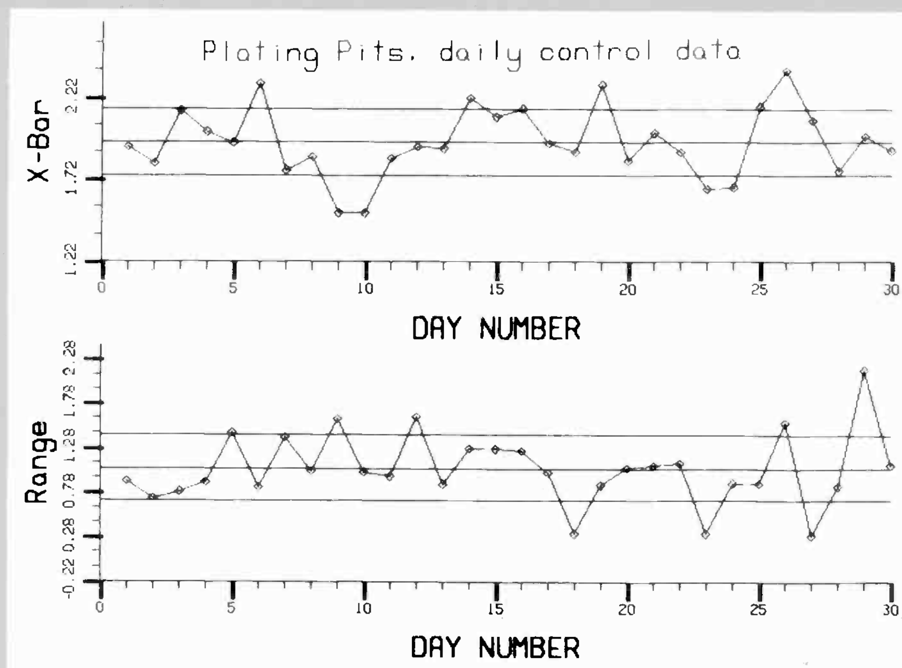
"By training everyone in the same problem-solving methods, and by then listening to their contributions, we have greatly

Scatter plots. A graphical presentation of the quantitative relationship between a cause (independent) variable and an effect (dependent) variable. Measurement pairs are plotted as dots on an X-Y graph, and the resulting pattern is analyzed by eye for positive, negative, or no correlation. This presentation is useful for understanding the results of factory experiments.



Control charts. A graphical presentation showing the behavior of a measure over time. It can be used to spot shifts in the process, trends, and periodic behavior such as daily changes. Thresholds for action are calculated based on the actual behavior of the process (see reference 3).

Reference 2 has more information on these and other problem-solving methodologies.



added to our ability to understand what goes on in production."

That makes sense. Teaching everyone the same language with which to discuss problems must make communications a lot easier.

While Joan speaks, the group has been assembling and is now ready to begin.

"Welcome, everyone," says Joan. "As you can see, we have some visitors today who are interested in how our problem-solving group works. I hope we have some good demonstrations for them. But, how about some old business first? Mary, what's happening on the plating problem?"

"Well, as most of you know, but our visitors may not, we were having problems with unexplained pits in our nickel-plated parts," Mary says. "Sometimes the process would make shiny parts and sometimes we would get pits, and we didn't know why. We used a cause-and-effect diagram to think of everything that might mess up the plating." She points to hand-made chart taped to wall (see box: Formal problem solving). "And then we made some experiments to see which of the causes might be to blame."

That might be one of the techniques they were taught. I don't recognize it as anything I ever learned.

"We tried several bath temperatures and plating currents, and made scatter plots of pits versus current and pits versus temperature. These graphs showed nothing and we were getting pretty discouraged. Anyway, this week we tried a test to see if contamination caused the pits and it looks like we've found the problem." There are big smiles and nods all around from the plating crew.

"Every time the pits started to appear, we changed the plating solution and the problem cleared up right away. Of course we can't afford to continue to do this because the solution's too expensive, but we took a pint jar of each bad solution and sent it to the lab. They're not sure yet, but they've found organic contamination, something like an oil."

Now Joan speaks. "Let's make a new cause-and-effect diagram. Where could oil be coming from?"

"Well, the nickel chips we add to the bath sometimes have an oily coating to protect them," suggests Mary.

"Have you got extra oily skin?" asks Walter. "Maybe it's coming from your handling of the parts?"

Barbara says, "The motor that agitates the bath sometimes drips its own lubricating stuff into the bath, but that's a sort of grease."

"Wait a minute everyone," says Joan. "Let's work systematically. Mary, why don't you start making a new chart?"

What a difference! In the first example, data on machine and operator performance were being collected—lots of it. However, not much in the way of organized action was taken as a result of all the collecting.

In the second example, almost as many data were gathered. Since the users knew why they were gathering them, and knew in advance what problem was being attacked, the organization, the enthusiasm, the interest in the results and the chances for action were all far better. Errors in analysis, such as in our example, where machine breakdowns were not necessarily correlated with low operator productivity, are avoided by knowing in advance which data to gather and then gathering all of them.

Most important of all, the *information* in the second example will be used to feed corrections back to the process. The oil contamination of the plating bath will be eliminated, and surface pitting will be tracked with a control chart so that future pitting problems can be caught even before defective product is manufactured. How to do that is a subject for another tour.

Acknowledgment

The authors didn't invent most of the concepts discussed in this paper. Many of them have been developed as a result of discussions with several of our colleagues. We particularly wish to thank Dave Coleman, Don Fisher, John Gaylord, Bert Gunter, Art Kaiman, and John Stark for their participation.

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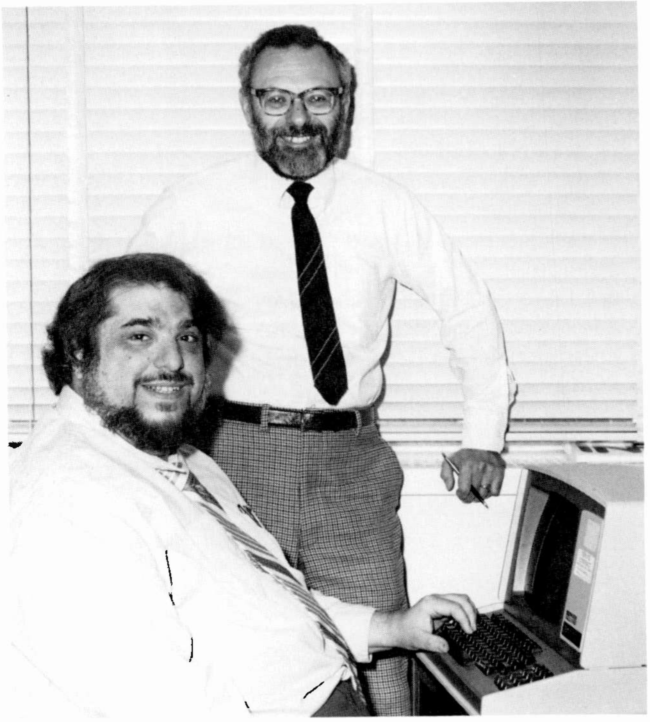

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H.A. Freedman

Information technology management

New information technologies offer opportunities to improve organizational productivity and competitive position; however, these opportunities raise significant management issues that must be addressed if our investments in these technologies are to be profitable.

Every month articles appear in the business and popular press proclaiming the importance of "Office Automation." They usually begin with a lengthy justification of the issue as a cause for management attention. So much has been written and spoken on the subject that it is unproductive to reproduce the efforts. Instead, we begin by identifying the conclusions that appear to be universally accepted.

For example, the U.S. work force continues to shift from one that is blue-collar (agricultural and manufacturing) dominated towards one that is white-collar (information and service) dominated. Figure 1 shows the trend graphically. Automation on the farm and in the factory has so significantly improved productivity that we need no longer deploy as much of our labor force in these areas. Not only are new information-and service-based industries growing, but the white-collar cost component of manufactured goods is also increasing.

The continuing decline in unit costs and increase in functional capabilities of electronic, storage, printing, communication and software technologies will offer management significant new

Abstract: *The management of all businesses will be called on to make significant investment decisions in office-based equipment, communications facilities, software, and training in the next few years. This report was originally prepared by the Corporate Information Systems and Services organization to help provide a framework for making these investment decisions. It raises issues for consideration and suggests possible paths for their resolution. The report has been included in the* RCA Engineer *so that RCA's professional community can better understand and contribute to these decisions.*

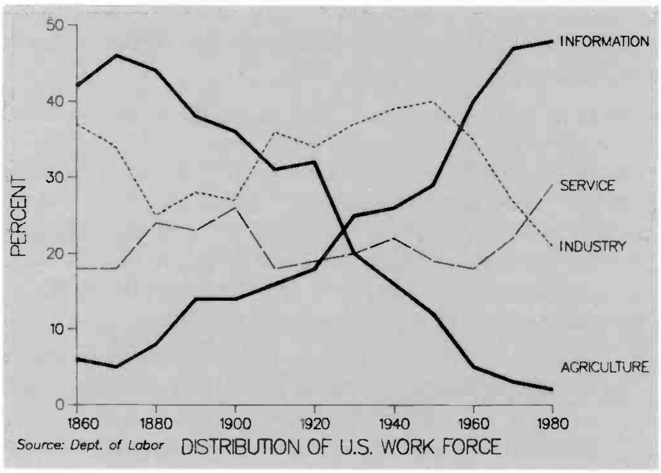

Fig. 1. *The graph illustrates dramatic changes in the composition of the U.S. work force. The continued growth in the white-collar segments provides a stimulus for deployment of new information technologies.*

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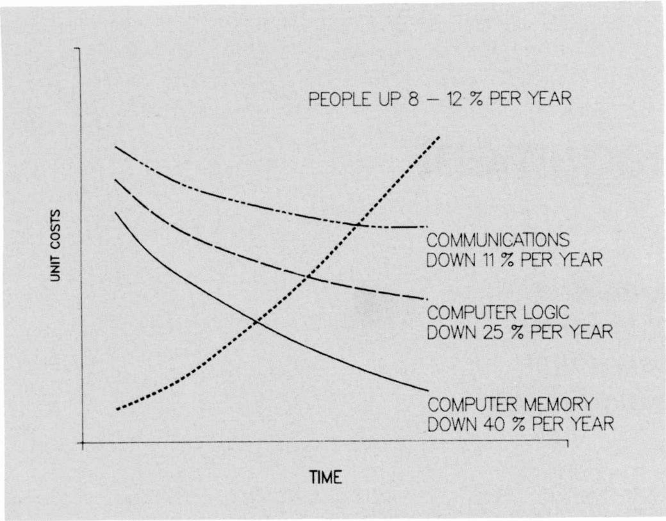

Fig. 2. *Although each author quotes different rates (these statistics are from an IBM study), there is universal acceptance that the technology-cost versus manpower-cost trade-offs will continue to improve.*

opportunities to deploy these technologies within the business processes.

Figure 2 graphically depicts trends in the technology-cost versus labor-cost trade-offs. Tasks that could not be automated yesterday because of function or cost now *must* be automated if one is to remain competitive. In the future, this trend will enable automation of processes that today are not perceived as attractive opportunities.

These technological advances can and must be deployed to produce significant gains in productivity in the management and professional segments of the white-collar work force. Booz-Allen & Hamilton, Inc. has stated, "Firms actively pursuing new technologies will be the winners while those that do not will be the losers . . . . Losing will be disastrous from a competitive and financial viewpoint." Studies have consistently indicated productivity improvement potential in the 10- to 25-percent range. Today's technologies are capable of delivering this kind of improvement. However, organizationally we are not necessarily ready to absorb these technologies.

Why has the actual deployment of these technologies lagged behind all previous predictions? Several significant factors contribute to this delay, and make the introduction of these technologies truly a management issue:

- The term "office automation" itself is much too restrictive and leads many senior managers to believe that word-processing or personal-computer decisions are relatively minor. We prefer the term "information technology," and we include all new technologies that improve the collection, analysis and communication of information. No single definition may be sufficiently comprehensive for these new and dynamic fields. In general, however, by office automation we mean,

  > A business strategy aimed at improving business results through an integrated plan to improve the quantity, quality and timeliness of business information and of the decisions drawn from this information. These improvements are achieved through deployment of new tools made available by advanced electronic, printing, storage and communications technologies and through complementary plans for organizational change.

- The methodologies for evaluating and justifying the promised productivity benefits in the white-collar work force are not mature and are sometimes viewed as "soft" and intangible.
- Although some of the benefits of automation can be in the initial phases of introduction, some of the most significant benefits are achieved only after a critical mass of the organization has been affected.
- To achieve these benefits management must consider basic changes in business processes. These changes involve organization, structure, skill levels and information flow, and they often meet with organizational resistance. In the case of factory automation, management changes the work environment of others; in the case of office automation, management may be required to change their own work environment and that of their staff.

In spite of these impediments, it is certain that the senior management of all businesses will be asked to make significant investment decisions in office-based equipment, communications facilities, software and training in the next few years. This report is intended to help provide a framework for making these investment decisions. It raises issues for management consideration and suggests possible paths for their resolution.

How should personal computers, departmental computers, local computing facilities or large shared computing facilities be deployed? What kind of local communication network should be used? What vendor strategy should be developed? These questions will be answered differently in each business depending on the vision of future requirements of the senior management, on the current investments in equipment, networks and training, and on individual management style. People at each unit need to develop a vision of future requirements and a broad awareness of the issues before they are asked to make these major investment decisions that will have a significant impact, positive or negative, on the future productivity of their business.

Most of the technologies and applications associated with office automation can be placed in the overall architectural framework of the concept of the professional work station. This concept suggests that within a decade over 50 percent of the white-collar work force will have available to them the information, the processing tools, the presentation media and the communications capabilities to significantly improve their productivity and, perhaps even more importantly, their decision-making ability.

These facilities will be provided through a work station located within the professional's own office. It will give access to information and processing capabilities located within the work station itself, in departmental systems, in plant (local) computing facilities, in corporate computing centers and in external facilities offering access to data from many independent information providers.

These capabilities will be available not only in the professional's office but also from other locations in the company, from the home and even from the traveler's hotel room. They will be made available not only to our employees, but also to our customers and suppliers when appropriate.

The concept today includes a large number of applications that can be made available to any professional and assumes that each white-collar worker, or class of worker, would have a work station tailored to meet individual (or group) requirements. The applications most often identified with office automation and the professional work station include:

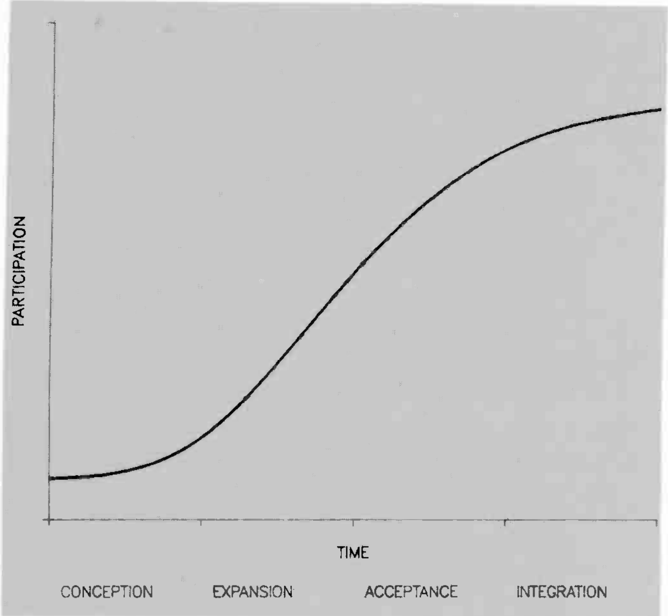

Fig. 3. *In the early phase of any major product or concept introduction, a few innovators lead the way. At some point, successful concepts "take-off" and are accepted in a short time by most people.*

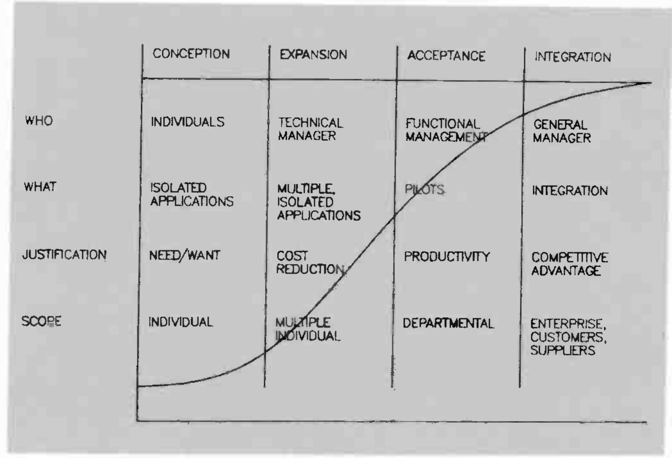

Fig. 4. *The Time Phase Model is used to describe the changing processes occurring during the phases of technology introduction and to provide a framework for identifying and addressing the management issues associated with each phase.*

Word processing
List processing
Electronic mail
Electronic filing
Time management
Business graphics
Presentation preparation
Source data entry
Information retrieval (company data)
Information retrieval (industry data)
Spread-sheet analysis
Decision support (modeling) systems
Voice mail
Telephone management

Although many authors do not include the current time-sharing and transaction-processing applications (order processing, circuit design, and so on) as office-systems applications, these current applications must be considered in planning the future office environment.

Information automation—a time-phase model

A time-phase model, such as Fig. 3, has been used by several authors to identify the issues involved in the introduction of change into an organization. Product life cycles and organizational growth and maturity have been described in this way. Figure 4 identifies four phases in the introduction of information technology that help identify the changing management issues during this process.

Phase 1—conception

In the first phase, Conception, creative employees identify opportunities to improve their own individual (or departmental) productivity by introducing one or a few relatively simple applications. These applications might involve word processing, list maintenance, retrieval from a small data base or use of minor computational aids. Since the typical MIS organization has a large backlog of major development projects, small applications such as these have low priority and the data processing organization may be viewed as unresponsive. However, new technologies and the computer literacy they have created permit creative employees to satisfy their own requirements by acquiring a word processor, a time-sharing terminal or a personal computer. Since the capital requirement is relatively small and the perceived benefits very attractive, the individual finds a way to acquire the investment capital required to satisfy the objectives. Such projects serve as successful visible showcases for the rest of the organization.

Phase 2—expansion

As other individuals or departments begin to identify such opportunities, the Expansion phase begins. In this phase, technical management, normally with either an administrative or information systems background, identifies these uncontrolled equipment and software investments as a management issue and recommends the establishment of either an Office Systems or Information Center organization (or both), depending on the background of the individual or the initial application thrust in the Conception phase. The Office Systems organization, with its administrative systems background, may begin with a word-processing emphasis but typically expands into list processing, information access and financial spread-sheet applications. The Information Center focuses its attention on the introduction of "user-friendly," "fourth-generation" languages and applications that can be used directly, in either a time-sharing or personal-computer environment, by end users. Unlike the traditional MIS mission, the Information Center organization views itself as an end-user support organization rather then an application-development organization.

In the Expansion phase, management is asked to make many small, apparently unrelated, investment decisions. Although each decision involves a relatively small investment, the management requires formal cost-benefit analysis usually focused on cost reduction or cost avoidance for each application. This approach, although necessary at this stage of development, tends to isolate

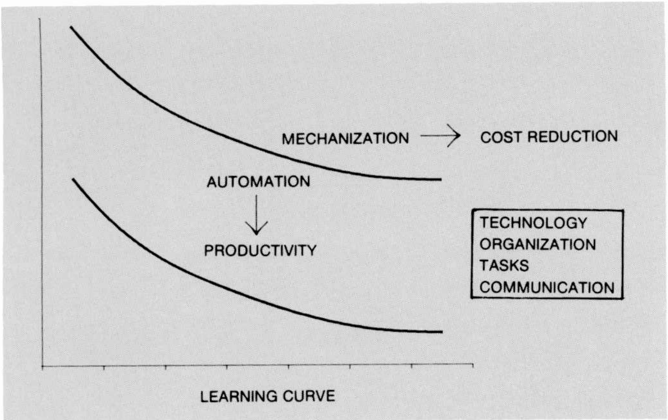

Fig. 5. *Mechanization of tasks has long been recognized as a strategy for moving down the learning curve and improving productivity. Automation is a much more complex task that involves the use of new tools to change the basic process itself.*

further these investments and the individual productivity benefits they generate.

Phase 3—acceptance

Eventually, a senior functional manager (a vice-president of Marketing, Engineering, Manufacturing, or Finance, for example) will identify an opportunity to improve the productivity, not of an individual or single department but of the entire organization. This introduces the Acceptance phase. In this phase the functional manager accepts the concept that, by improving communication, improving information flow, providing more, better, and more timely information, the productivity of the entire organization can be significantly improved. In this phase the functional manager provides leadership and direction, and project members include members of his or her staff as well as representatives from support organizations (Administrative Systems, Information Management and Industrial Relations). In this phase the application focus shifts from mechanization of a single task to automation of an entire business process. For example, electronic mail, voice mail, organizational and industry data bases are used and the quality and flow of information within the organization is improved.

Figure 5 makes this point graphically. As an organization matures and as the cost of technology decreases, management identifies opportunities to mechanize and reduce costs. This process follows the standard learning curve. By contrast, substantial productivity increases come about not by mechanizing existing tasks but rather by using technology to stimulate changes in the organization, structure, tasks and information flows; that is, to change the basic business process itself. These innovative introductions of technology truly automate a process and can dramatically move the organization to an improved learning curve. In these cases, management is looking to technology to improve the flow of information within the organization in order to facilitate faster and more informed decisions. Specific cost reductions may not be immediately identifiable.

Phase 4—integration

In the final phase, Integration, the general management of the organization recognizes the real potential of the available technologies. They consider not only the productivity of one functional area, but the potential impact of information technology on the business as a whole. In this phase, management identifies its critical success factors and asks how information technologies and applications might help achieve them. They seek to identify, for example, how information technology can be used to improve:

Customer service
Customer loyalty
Time to market
Supplier performance
Employee quality
Employee relations
Company image

Today, some businesses are encouraging their customers to access their information systems directly to determine order status; others are issuing their purchase orders electronically; others are providing information services as an added value to their customers. For some, existing communication networks provide a vehicle for keeping employees better informed; for others, it provides a way to use a remote (perhaps home-bound) labor market. These systems are being applied to the most significant business issues, the critical success factors of the business as identified by its senior management.

In the Integration phase, management also recognizes the significant challenges it faces in using information technology effectively:

1. How can the information available in factory systems, engineering design systems, traditional data-processing systems and the new office systems be integrated into an effective information network for use by the professional and managerial staff of the entire enterprise?
2. How can previous investments in equipment, software and training be integrated in a way that will permit a single, multifunction work station to access the wealth of information now available?
3. How can the planning and control of this distributed information environment be integrated to ensure that information vital to the business' long-term success is securely protected?

The ever-increasing impact of information technology on all business functions, the growing computer literacy and the increase in specialization in all aspects of business, are accompanied by a growing trend towards decentralized responsibility for information collection, processing and reporting. Yet without some overall planning-and-control focus, organizations may not be able to achieve the full benefits of their investments, may be paying too much for the benefits they are achieving, and may lose control of vital business information.

In many cases, our current skills and organizational structures cannot satisfy the necessary planning, coordinating, and control responsibilities. The information systems, administrative systems and engineering organizations are technical skill centers and, in some cases, focused narrowly on a few selected technologies, tools or applications.

The specialization required by the complexity of the current information environment has made it much more difficult to train broadly based systems analysts. In many cases, today, management can accurately predict the solution recommended by an analyst based on his or her area of technical specialization rather than on the business requirements. Word processors, personal computers, time-sharing can all satisfy many common problems.

The tool selected is often a matter of individual style rather than thoughtful analysis. Even if these organizations broadened their base of technical expertise, they may be lacking the human-factors, behaviorial-science and organizational-planning skills that will be necessary.

Forward-thinking organizations should begin to plan for an eventual integration of their technology investments. Unfortunately, there is no single architecture, vendor or even technology that will guarantee timely and cost-effective solutions for today's large variety of problems and that will, at the same time, provide for a smooth integration in the future. On the other hand, we cannot afford to wait until the direction is clear before making any investments. The opportunities are here today; certain risks are inevitable.

Management response

With the time-phase model as a framework, what should be management's response? Given the problems identified, what steps should management take today to ensure that opportunities are identified as early as possible and that today's investments reflect both short- and long-term analysis?

Responsibility

Even though office technologies have been introduced at a rate slower than previously predicted, introductions are occurring in most organizations today on a broad front, and recent trends indicate an explosion of interest in these areas. The introduction of the personal computer, the availability of "user-friendly" software targeted at the end-user marketplace, and increasing functional capabilities on the word-processing and time-sharing facilities already in place are all significant factors in this process. Management should focus responsibility for planning and control of this area and the investments we will make in it. Strategically, identifying a single responsible person is appropriate; however, in many organizations the appointment of a single person or organization may not be immediately feasible or practical. In these cases a management committee, with all its flaws, may be necessary. In either case, those responsible should be able to balance between the strategic and tactical objectives of the organization and between the technical and organizational disciplines required for success.

In the next few years, every organization will be making difficult investment decisions. They will be difficult because the justification methodologies will not identify solid cost reduction/avoidance benefits and difficult because the best short-term, tactical investments may not integrate well in the organization's long-range, strategic plans. Every organization will face these difficult decisions and should be prepared with appropriate organizational structures and procedures for these decision processes.

Focus

Today, most businesses find themselves in the Expansion phase of the model. Attention is being given to end-user computing and isolated office-systems applications. Although the trend to broaden the availability of information technology is clearly positive, management should focus this effort on areas and issues that have the greatest potential for contribution. Today, some organizations are focusing on the easy applications rather than the important ones. The growth in demand for both capital and for scarce technical skills requires identification of the critical success factors or strategic issues of the business. This focus should include addressing professional and managerial productivity issues; improving the management decision processes; improving the flow of consistent, timely information throughout the organization; and providing competitive product and service advantages.

Plan

A wise man once said, "If you don't know where you're going, any road will take you there." If we are to make profitable investments we must have some view of the future environment. In particular, it is important to consider, now, certain key issues that will affect short-term decisions:

1. What is the architectural structure of our future information environment? That is, How should we distribute the storage and processing of our business information (personal computers, department computers, local computing facilities, corporate shared facilities, external facilities) and how will we provide access to this information by employees, customers and suppliers from our offices, from our homes and from other remote sites?
2. What vendors, products, applications or standards should we identify as strategic, today, in order to move towards this future environment?
3. What policies and procedures should be in place to ensure protection of our business information in this new distributed environment?
4. What significant organizational impacts will accompany this technology introduction? What education and training processes should we develop now to smooth the transitions?

These questions don't have unique answers and certainly, in today's changing environment, they don't have precise answers. Yet it is important to develop a plan that addresses these kinds of issues and that is discussed, reviewed, and accepted by the entire organization.

Justification methodology

Perhaps the most difficult issue to deal with today is the determination of an appropriate justification methodology for these technology investments. Our traditional methodologies do not seem to apply; yet to do nothing may risk the competitive position of the business. There are no simple solutions but there are some reasonable approaches. If an organization has identified Responsibility, Focus and Long-Range Plan, then projects can be categorized as either tactical or strategic.

Tactical projects address today's productivity problems. They must be justified using traditional cost/benefit analysis and must provide a rapid and high return on investment. In particular, one should assume that today's investments in equipment will have a relatively short (3- to 5-year) life. Although consideration of longer-range integration issues should be made, it will often be necessary to minimize this issue in order to achieve the short-term benefits of these tactical projects.

On the other hand, we must establish an ongoing commitment of resources (capital and manpower) to develop more strategic projects. Strategic projects are those that offer the organization the more significant, but perhaps longer-term and higher-risk payoffs. It is important that each organization take some of these risks to protect its future; however, we should assure ourselves that we're taking the right risk and minimizing the chance and impact of failure. Such projects should clearly identify their objectives in terms of the focus of management direction previously identified. They should contain an initial pilot phase to test the concepts. Even though we cannot yet measure the true productivity of our professional and management work force, we should insist, in each project, on the measurement of productivity indicators. By productivity indicators we mean factors which by themselves do not guarantee improved, bottom-line performance, but that can give management a sense that their investments do have positive, even if indirect and non-quantifiable impact. Examples could include time through approval cycles, time savings on individual tasks, organizational response times and measures of employee satisfaction. For strategic projects we should also insist on a clear understanding of the longer-term integration issues and on the organizational impacts if the project is successful.

Summary

Even though information technology offers an enormous potential, its full benefits cannot be achieved without the awareness, direction and support provided by management. Without this involvement the process of introducing new technologies will still undoubtedly take place. However, its impact will be bottom up and tactical. With an awareness of its true potential, these technologies can become an important component in the organization's strategic planning for the future.

Acknowledgments

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J. Lewin

The challenge of multi-satellite system management

Effective management of large numbers of in-orbit satellites requires the recognition of implications of scale in spacecraft and ground-control system designs.

The domestic satellite communications industry is in its second evolutionary growth phase. The acceptance of satellites as a proven reliable and economical communications medium has created excess demands that have stimulated new entrants on the supply side of the marketplace, and has created the impetus for expansion by established carriers.

Abstract: *Acceptance and consequential rapid growth in demand for satellite communications channel capacity has currently been met by U.S. commercial carriers with the in-orbit deployment of 17 spacecraft, and more as yet to come. The 45 or so orbital slots recently allocated for U.S. domestic service by the F.C.C., an order of magnitude above that flown during the mid-1970s by RCA Americom and Western Union, portends the future.*

Management of a large number (say, 8 to 12) of commercial communications satellites in-orbit creates new challenges for any given carrier. These challenges translate into changes that permeate spacecraft operations, spacecraft design, as well as design of ground control systems. This paper briefly summarizes implications of scale vis-a-vis satellite in-orbit management, and suggests changes to meet the challenge in an economical and effective manner.

This paper was presented at the 9th AIAA Communications Satellite Systems Conference (April, 1982) in San Diego, Calif., and is listed in the *Proceedings*.

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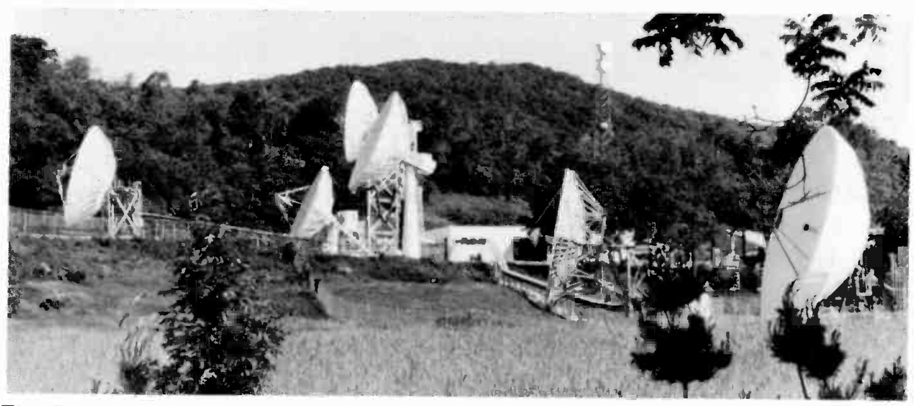

The five satellite communications antennas and one TT&C antenna (center), along with two more antennas not visible in this photo, allow the Vernon Valley TT&C activity to monitor and control up to eight C-band communications spacecraft in-orbit. Currently, Americom's satellite fleet comprises six in-orbit spacecraft and one additional satellite scheduled for launch in late-summer 1983. Three more Ku-band satellites will be deployed in the 1985-1986 time frame.

Among existing carriers, the early operational concept of two spacecraft in orbit plus one ground spare has long since given way to scenarios for expansion to six in-orbit spacecraft and to consideration of as many as nine spacecraft, the FCC and the availability of orbital slots permitting. The addition of K-band Fixed Satellite Service and Direct Broadcast Satellite Service, as well as the FCC ruling for two-degree spacing, further enhances the likelihood of expansionary growth. The above scenario creates the need to anticipate and provide for the effective management of a larger and varied number of spacecraft in orbit.

An increase in the number of spacecraft to perhaps three times the previous count implies an expanded ground telemetry, tracking, and command (TT&C) capability to cope with the extra information and control workload. The increase also gives rise to the consideration of new TT&C approaches and new spacecraft designs for greater controllability, leading to a more closely coordinated space/ground system approach.

Unlike new entrants, an existing carrier with substantial investment in control facilities is often compelled to integrate old and new capabilities. This is RCA's task. Achieving this task with minimal cost and disruption to ongoing spacecraft operations poses an added dimension to the challenge of multi-satellite system management.

Table I. *Major satellite control functions.*

1.	*Attitude Control*	
	(a) Momentum adjust	As required and in conjunction with stationkeeping
	(b) Roll/pitch/yaw control	As required and in conjunction with stationkeeping
2.	*Orbit Management*	
	(a) Ranging/orbit determination	Ranging is performed hourly over a 25-hour period, post-stationkeeping maneuvers, from each of two sites
	(b) North/south, east/west and eccentricity corrections	26 maneuvers/year/satellite
3.	*Power Management*	
	(a) Battery operations (reconditioning)	2 times/year over a period of 7 days
	(b) Eclipse operations	2 times/year over a period of 44 days each
	(c) Load management	4 times/year at vernal and autumnal equinoxes and summer and winter solstices, and at other times as necessary
4.	*Thermal Management*	
	(a) Heater control	As necessary and during eclipse
	(b) Temperature	Continuously
5.	*Fuel Management*	
	(a) Maneuver planning	26 times/year per spacecraft
	(b) Corrections to thruster performance	Post maneuver
	(c) Blow down curve corrections	
6.	*Commanding*	10,000 commands/month
7.	*Telemetry Monitoring*	Continuously 43,200 frames/day

Background

The in-orbit control of a three-axis-stabilized momentum-bias spacecraft depends on a number of typical operations, as shown in Table I. A look at some selected statistics and averages amassed during the last seven years of operation shows, for example, that approximately 10,000 individual commands are sent monthly to each spacecraft. Telemetry is processed at a minimum of 43,200 frames (128-to-256 channels/ frame) per spacecraft per day.

Stationkeeping to within $\pm 0.1°$ in longitude (east/west) and latitude (north/ south) results in approximately 26 maneuvers per spacecraft per year (approximately 18 east/west and eccentricity corrections, and 8 north/south adjustments). Maneuvers typically take 2 hours, and may include spacecraft setup time (that is, thruster warm-up), and attitude-disturbance corrections that might be induced during stationkeeping. Each spacecraft is maintained to within $\pm 0.15°$ pointing error. Typically, older spacecraft demand a great deal of operator interaction during stationkeeping to ensure that attitude errors do not exceed the prescribed limits that are designed to ensure uninterrupted communications in fringe areas.

At RCA, each stationkeeping maneuver entails a minimum of 25 hours of post-maneuver ranging, followed by orbit determination and emphemeris generation. In a number of instances, pre-maneuver ranging and orbit determination may also be practiced.

Power management demands attention, particularly in conjunction with semiannual eclipse operation. To ensure longevity, batteries are usually reconditioned before each eclipse period. Batteries are discharged and recharged close to the commencement of the eclipse period; this is particularly significant in older spacecraft, where the available ampere-hours are more closely matched to required loads. Currently, only one of three batteries is reconditioned at any one time, requiring approximately 7 days for completion per spacecraft, followed by 44 days of eclipse operation. Stationkeeping typically is avoided during reconditioning, and this creates some additional challenges in planning to skirt this period.

Existing control operation

For the United States domestic carriers, the first-generation control facilities were designed and built in the early 1970s. A comprehensive discussion of the first-generation ground-control system for Satcom satellites, by the author, can be found in the *Proceedings* of the 7th AIAA Communications Satellite Systems Conference, and the *RCA Engineer,* Vol. 22, No. 4 (Dec. 1976/Jan. 1977). A brief summary follows.

Each RCA Satcom TT&C facility embodies a high degree of automation and redundancy. Two physically separate facilities—one at Vernon Valley, N.J., and one at South Mountain, Calif.—minimize disruption and ensure continuity of operation in the event of catastrophic failure.

Commanding is generally carried out on one spacecraft at a time. Thus, a single command uplink is provided and shared among all the spacecraft. Two stations would be used, therefore, should simultaneous commanding to two spacecraft be desirable. All this, plus generally stable spacecraft dynamics coupled with redundancy of spacecraft subsystems, comprises an acceptable low-risk operating environment.

Ranging with Satcom spacecraft is accomplished via the spacecraft command receiver and the beacon transmitter interconnected in transponder fashion. Ranging and commanding are mutually exclusive.

Telemetry from each spacecraft is continuously processed every two seconds at one 128-channel/frame. Spacecraft telemetry parameters are operator-monitored on CRTs and stripcharts. Typically, one CRT displaying critical parameters had been provided for each spacecraft. All parameter values are limit-checked and an alarm is given when out-of-limit conditions are detected.

Each spacecraft in orbit has a dedicated ground antenna that serves a dual role: communications and control. An autotrack-equipped antenna with high-resolution azimuth and elevation readouts and a high angular velocity (3° per second) facilitates transfer-orbit operations.

Two Hewlett-Packard minicomputers designated "Data" and "Control" provided the necessary real-time/on-line commanding, ranging, and telemetry-processing capability. An off-line Perkin-Elmer 8/32 is used for orbit-control computations—for example, orbit determination and predictions, maneuver planning, and so on. Typically, during normal activities exclusive of stationkeeping, only one operator mans the control console. During stationkeeping, an analyst may also be present to direct the maneuver.

The design objective, well met over the years of operation, has been to control three satellites in geostationary orbit. Now, a number of changes and improvements have been made and are yet to be made in anticipation of the need to control a greater number of spacecraft.

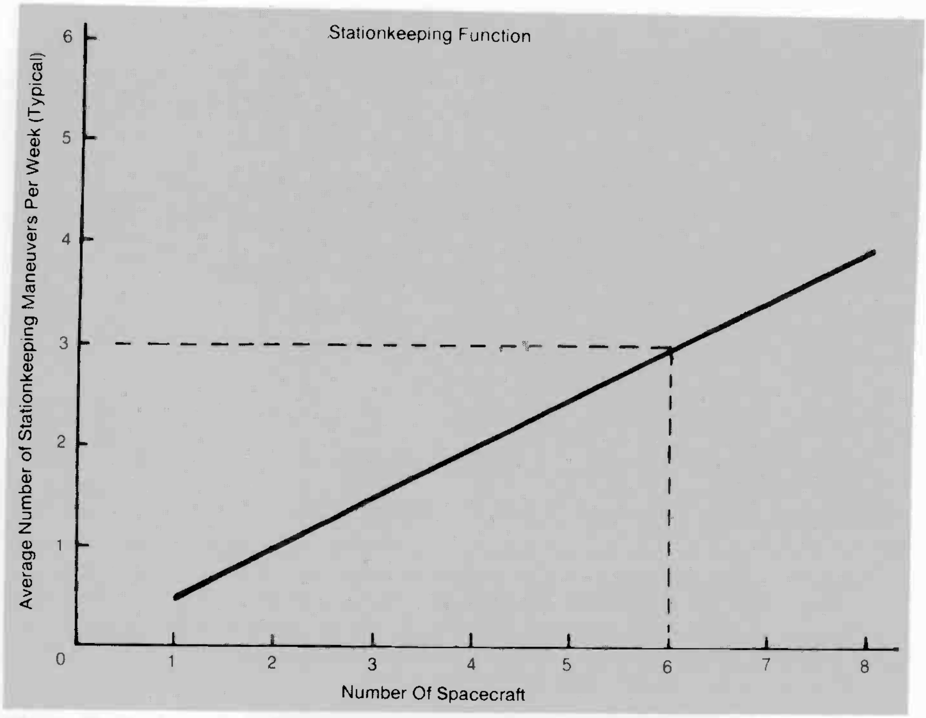

Fig. 1. Typical, average frequency of required stationkeeping (longitude and inclination angle corrections) for geosynchronous satellites for a nominal "box" of 0.1°. In practice, an "average" rate is unlikely. Greater-than-average satellite stationkeeping during some weeks is quite common.

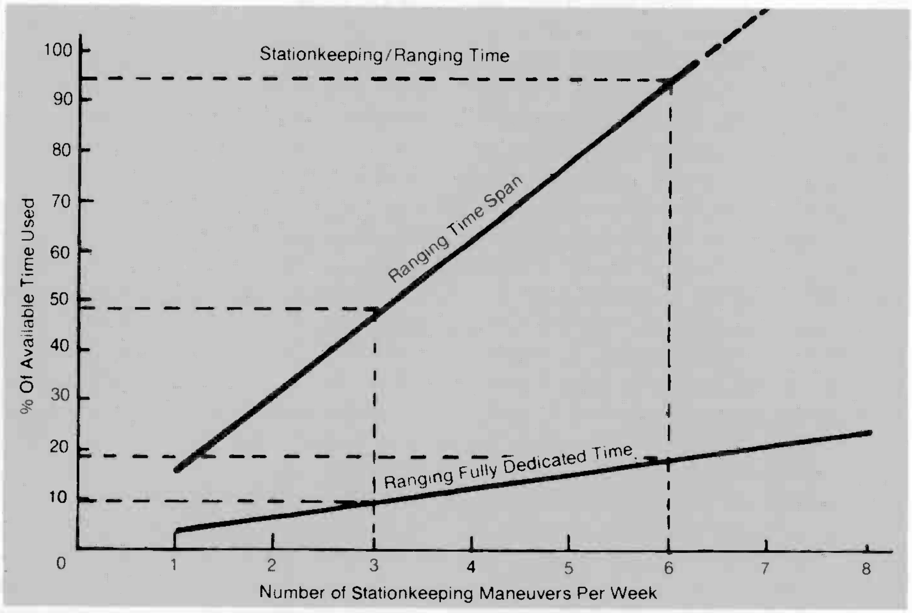

Fig. 2. Ranging load associated with the stationkeeping function. Ranging activity spans 25 hours after each stationkeeping maneuver. Station saturation occurs with six continuous (non-overlapping) maneuvers per week. Time span would be reduced with overlapping ranging: that is, phased ranging to two spacecraft per 25-hour period.

Implications of scale

Operating concepts, spacecraft design, and TT&C design have to be reviewed and perhaps modified if the functions given in Table I for one satellite are to be scaled to six to nine spacecraft, all managed from a single TT&C facility.

Consider the implications of stationkeeping six satellites from one TT&C site. Assume a simplified and highly unrealistic scenario of executing 26 maneuvers per spacecraft at equally spaced intervals during the course of the year. This yields an average rate of three maneuvers per week (Fig. 1). Assume also that ranging is performed only after each maneuver. Thus, post-maneuver ranging, spanning a 25-hour period and taken hourly at 8 minutes each, results in the TT&C site being fully dedicated to stationkeeping/ranging roughly 9.5 percent of the time, while spanning a period equal to 48 percent of the available time (Fig. 2). Further, during this 25-hour post-maneuver period, other activities might have to be rescheduled, because 13 percent of every hour is needed for ranging.

The situation clearly gets more complicated during weeks when it may be necessary to stationkeep six satellites (as may occur from time to time), and perform pre-maneuver ranging as well.

The commanding function is another consideration. The load-verify-and-execute method for commanding spacecraft incurs a delay of approximately 5 to 8 seconds. This time delay consists of command-uplink and telemetry-downlink command-verify propagation time, as well as computer-processing time.

Each spacecraft requires about 10,000 commands per month. With six spacecraft, this rate translates to roughly 133 hours per month, or 18.5 percent of available time when the TT&C facility is in a commanding mode. This figure excludes the time required to set up command lists for

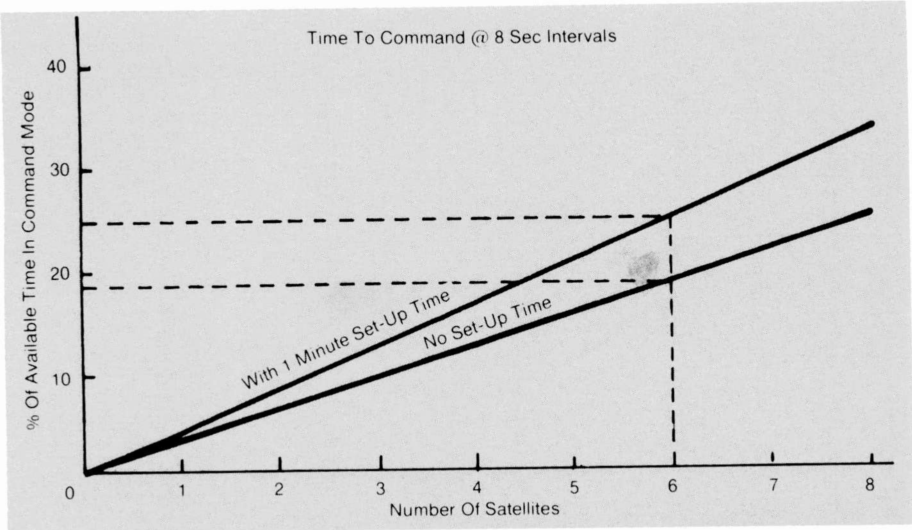

Fig. 3. Commanding load, as a function of the number of satellites in-orbit is based on 8-second intervals between commands to allow for processing and propagation delays. With six satellites in-orbit, given an assumed 20-command string and a one-minute set-up-and-wait time, the TT&C site is dedicated to commanding approximately 25 percent of the time. With eight satellites, nearly 35 percent of the time is spent in the commanding mode.

timed execution. Nor does it include time-dependent command sequences where the interval between commands is necessarily longer, such as during active (thruster-firing) roll-correction sequences. Here, for example, commanding intervals are separated by spacecraft half-nutation periods that are typically 300 seconds apart with the newest spacecraft. Thus, if one assumes that a typical command sequence comprises approximately 20 commands, and that setup-and-wait time for each sequence takes 1 minute, the time that the TT&C spends in the command mode increases from 18.5 percent to 25 percent (Fig. 3).

Another consideration with regard to commanding a large number of satellites from one TT&C site is the possible need to command two spacecraft simultaneously. If there are only two in-orbit spacecraft, the probability of such a need arising could be assumed to be very small. Although the probability of such an event occurring is greater with a larger number of spacecraft (that is, nine), it may still be very small. Anxiety and speculation about the risks of possible catastrophic loss or of interruption of service could stimulate this need.

Telemetry is the "first line of defense" in satellite management. The ability to respond quickly to spacecraft anomalies with appropriate corrective action depends on how fast the operator becomes aware of a problem and how fast he is able to isolate that problem. Although alarms alert the controller to problems needing his immediate attention, quite often the ability to determine trends of critical parameters (such as spacecraft roll angle disturbance) can provide additional time, particularly during dynamically changing situations to anticipate and resolve problems, rather than to react to them.

The amount of incoming telemetry information increases directly with each additional satellite. But, the newer, more sophisticated satellites downlink significantly more data. For example, Satcom V, launched in October 1982, and future spacecraft provide up to 256 telemetry channels with potentially greater numbers of information channels per frame. This is twice the capacity of previous Satcoms, and about nine times that for the first-generation Westars and ANIKs. This amount of data tends to quickly saturate equipment and operators, decreasing operator effectiveness. Alternatively, more operators and more equipment increase the cost.

Heretofore, one set of displays was provided per spacecraft. These displays (updated every two seconds) depicted instantaneous spacecraft parameter values. In turn, the operator had to periodically scan two or three displays to reassure himself that the spacecraft was alive and well. Six or nine spacecraft provide significantly more information to monitor, and make the linear expansion of this concept of one CRT screen per spacecraft impractical for the operator to cope with.

Solutions

The preceding discussion highlights only some of the implications of managing a large number of satellites. Additional operating implications also stem from design differences between "old" and "new" spacecraft. Accommodation of the increased number of satellites is further complicated by existing TT&C facilities, techno-economic considerations bearing on integration of old and new requirements, and the need to provide undisrupted operation of the existing satellites.

Possible approaches in meeting the challenges posed fall into several broad categories:

- **Linear expansion concept**—Add or expand TT&C facilities (physical plant, equipment, personnel) to meet directly the expanding workload, retaining current operating concepts.
- **Integrated systems concept**—Reduce required workload to achieve a closer alignment with existing control capabilities by modifying current operating concepts, and increased automation.
- **A combination** of the above concepts.

Linear expansion concept

The linear expansion concept presents economic rather than technological challenges. Given existing matched space/ground capability, twice the number of satellites requires twice the control capability. This can be achieved either by direct expansion of existing capability or by construction of a parallel, incremental, composite, but separate capability. The latter option affords the advantage of leaving current operation totally undisturbed. This approach, although costly, can be justified under circumstances where disruption cannot be tolerated (one TT&C site, fully loaded), or when there exists no potential for modifying current operating concepts. This composite or "leap-frog" approach incurs a greater "one-time" capitalization cost. In other circumstances, the cost incurred in the linear expansion approach is difficult to justify.

Integrated systems concept

The integrated systems concept is feasible when operating concepts can be modified to fit within the existing framework, even though some redesign and minor incremental hardware addition might be required. This approach is practical where disruption due to on-line integration of new capabilities can be contained and/or where a backup is available, as is the case with RCA's two TT&C facilities. The benefits of pursuing this approach are twofold:

Table II. *Suggested changes.*

1. *On-board Automation*	(a) More effective stationkeeping. (b) Reduces need for real-time commanding.
2. *Automated Ranging*	(a) Cuts down operator time needed for setup/execution/restore. (b) Allows more time for monitoring and responding to telemetry.
3. *Provide Transponder Ranging*	(a) Frees up spacecraft command channel (b) Does not disrupt telemetry; eliminates need for second channel to be turned on.
4. *Turnaround Ranging*	(a) In the event that the second site is not available, allows more accurate orbit determination than ranging and Az/El from one site. (b) Frees second site for other tasks with other spacecraft.
5. *Reduce Ground-Command Processing Time*	Reduction to one second between commands requires 9.3 percent of available time to command six spacecraft, equivalent to a two-spacecraft operation load.
6. *Two Command Capability*	Enables each TT&C to simultaneously command two spacecraft should it be desired.
7. *Telemetry Processing*	Reduces volume of telemetry by deleting diagnostic type data from continuous transmission; off-loads ground processing.
8. *Telemetry Monitoring*	Alert concept to focus operator attention to one display. Display to indicate spacecraft subsystem, telemetry channel, and values that are "out-of-limit."

- Maintain low capital outlays for new systems by reuse of existing hardware/software.
- Keep continuing operating expense down by simplifying and automating satellite operating requirements to fit the available manpower and facilities.

In keeping with this concept, the following suggested changes in operations could produce a cost-effective, more closely matched multi-satellite control capability within existing TT&C capacity. These changes are not necessarily new. Some in fact are already employed by satellite operators. Others are yet to be put into operation. A summary of suggested changes is given in Table II.

On-board automation

With the availability of space-qualified, lightweight, reliable microprocessor and memory chips, the balance in selected cases has tipped in favor of on-board automation of functions previously reserved for ground operations. On-board automation is particularly justified in cases where closed-loop operation is required, and the loop is shortened by on-board feedback, as is the case with stationkeeping maneuvers and correction of attitude disturbances. Such a device, referred to as the Attitude Logic Processor (ALP), is currently in use on all RCA Satcoms since IIIR (launched in 1981). The ALP controls the thruster firing based on on-board sensor inputs.

In addition to the obvious advantage of more efficient execution of maneuvers, the command burden is lessened because the ALP can be preprogrammed. This is accomplished via ground command, as convenient, and executed with a "start" command rather than via the previous real-time ground-controlled, highly interactive maneuver execution. The net result is a more routine demand on TT&C real-time resources.

Ranging

The single most time-consuming (though routine) activity is ranging. As shown in Fig. 2, with three stationkeeping activities per week, post-maneuver ranging spans a period of 48 percent of available time. If pre-maneuver ranging is performed as well, as is likely for north/south stationkeeping, the TT&C site could eventually be limited to little more than ranging activity.

A period of roughly 8 minutes is required for ranging. Approximately half of this time, however, is devoted to spacecraft and ground system preparations before and after ranging occurs. Automation of this procedure would free the operator for essentially the entire period, and allow him to focus on other matters, such as looking after the health of all the spacecraft under his care.

As discussed earlier, ranging on Satcom spacecraft takes place via the Command Receiver/Beacon, preempting normal commanding and telemetry function. If transponder ranging were to be used (similarly to Westar) in lieu of the Command Receiver/Beacon, these functions would remain uninterrupted. Command response time would be enhanced should the need arise to command during ranging.

The availability of two TT&C sites provides the advantages of two-station ranging, which results in greater orbit-determination accuracies. Greater accuracy, in turn, makes maneuver scheduling more efficient. However, during ranging, both sites are tied up for long periods, potentially denying station availability for other functions. Turn-around ranging, although somewhat less accurate, could free one TT&C site to tend to other requirements.

The combined effect of these measures would be a drastic reduction in operator workload and the freeing of the command and telemetry channels for their primary functions.

Commanding

With a fixed transmission delay for a given command rate and format, the ground-processing time can be reduced. On the basis of the typical command rates and formats, commands can be transmitted and verified at 1-second intervals. This reduces the required command time for six satellites to approximately 9.3 percent of available time. A review of Fig. 3 shows that 9.3 percent is equivalent to the time currently needed to command only *two* satellites. Other improvements can be gained by increasing the command bit rate. However, these improvements diminish as you increase the bit rate, because the transmission time asymptotically approaches and is limited to the propagation delay time. A bit rate compatibility problem with existing spacecraft and ground equipment is also created. Nevertheless, some benefit could be gained when dealing with very long command lists, such as might be required to program large on-board computers.

Simplification of required spacecraft operation plus automation could further desensitize any commanding-related issue. Finally, two independent command uplinks would enable each TT&C site to anticipate the possibility of simultaneously addressing two spacecraft, however small the probability of such a need.

Telemetry

Telemetry tends to fall into two broad categories: operational and diagnostic. Diagnostic telemetry is looked at only in conjunction with a problem; it is ignored by operations at other times.

Critical operational telemetry can be defined as that which, if it were to change beyond prescribed limits and were not corrected quickly, would result in some potential loss of satellite capability, including life, or would impact service. A sudden displacement in roll or pitch angle is an example, impacting service.

With a larger number of channels, telemetering all channels indiscriminately tends to unnecessarily burden the ground system. Subcommutation could reduce the ground-control load, while still retaining accessibility to data when needed.

Continuous operator monitoring of a large number of telemetry-laden CRTs and stripcharts tends to make the system counterproductive. With nine spacecraft to monitor, doubling of the operator staff may be implied. On the other hand, little changes during non-maneuver activities to require continuous scanning of a large number of parameters. An "alert" concept is suggested as more effective than a multi-display monitoring technique. Here the operator would be alerted by an audible and visual alarm to a condition requiring his attention. He would be given the information he requires on a central display. The central display would summarize which spacecraft and what subsystem or channel caused the alarm. Other, sub-tier, displays could then be used to broaden the view of the problem, and provide instructions for corrective action.

This alerting concept facilitates effective management of multi-satellites. It also eliminates the need demanded by the linear expansion approach for more eyes to watch more displays containing largely invariant telemetry information.

The "alert" concept is incorporated in a newly designed Satellite Operations Control Center (SOCC) Console. The human-factors engineered console centralizes on a single screen a multi-satellite eight-spacecraft display, focusing the operator's attention. The display alerts the operator as to which spacecraft and major spacecraft subsystem requires response. Other displays are used to broaden the view of the problem as needed, and can give advice to aid in the resolution of the problem.

Conclusion

Our assessment of the various approaches to the effective control of a multi-satellite system yields several observations and conclusions.

The communications satellite business is in a dynamic state of change, spurred on by increasing demand for existing and new services, by competition, and by a rapidly changing technology. It is likely to continue in this way for some time to come. There are, therefore, inevitable and continuing changes in the concepts of satellite design, operation and management. It is difficult, if not impossible, to anticipate all the ramifications of this trend. A flexible approach toward facilitating expansion in ground-control systems is therefore a prudent objective, if disruption and cost are to be low.

Given the above, a greater integration of space/ground-control approaches is indicated. Spacecraft designs need to reflect, to a greater extent than heretofore, the implications of scale in managing a large number of satellites from one TT&C.

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W. Kern

Hydrogen peroxide solutions for silicon wafer cleaning

The "RCA Standard Clean" process is so well known throughout the semiconductor industry that many may not know its RCA origins. Further refinements are described in this article.

Abstract: *Clean silicon wafer surfaces suitable for device fabrication have been prepared successfully for nearly 20 years by the simple and safe sequential process described in this paper. The process is based on oxidation and dissolution of residual organic impurities and certain metal contaminants in a mixture of H_2O-NH_4OH-H_2O_2 at 75 to 80°C, followed by dissolution and complexing of remaining trace metals and chemisorbed ions in H_2O-HCl-H_2O_2 at 75 to 80°C. The effectiveness of the method was demonstrated originally by radioactive-tracer techniques, and was later confirmed by extensive analytical studies and device reliability tests.*

The RCA method has become widely accepted in the semiconductor industry. The original paper, published in 1970, is one of the most frequently cited publications in its field. The present report traces the development of the process since its origin in 1961, notes the supporting data from radioactive-tracer studies, and summarizes the essential facts underlying the effectiveness of the process. Additional information obtained more recently on the process and its implementation is briefly presented. An outline of the processing procedures that are now recommended has also been included.

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The RCA method for chemically cleaning silicon wafers has become widely accepted in the semiconductor industry. The original paper[1] is one of the most frequently cited publications in its field, according to the *Science Citation Index.* The Institute for Scientific Information has requested a commentary on this work for publication in the "Citation Classics" section of *Current Contents.*[2] The present paper traces the historical development of the process since its origin in 1961, notes the supporting data from radioactive-tracer studies, and summarizes the essential facts underlying the procedures. An outline of the recommended processing procedures has been included in an accompanying box.

Need and requirements of a cleaning procedure

The work published in our 1970 article originated in 1961 at the RCA Solid State Division in Somerville, New Jersey, when it was realized that residual trace impurities on silicon surfaces prior to high-temperature processing—particularly diffusion, thermal oxidation, and epitaxial growth—can have detrimental effects on surface stability, reliability, electrical performance, and production yield of devices, especially sensitive metal-oxide-semiconductor types. It became clear to me that a highly effective yet simple and hazardfree process was needed for purifying pre-cleaned silicon wafers, as well as thermally oxidized patterned or unpatterned wafers.

The procedures used up to that time involved hot mixtures of concentrated sulfuric acid and hydrogen peroxide, or of concentrated sulfuric acid and chromic acid. The first was suspected of causing sulfur contamination and was extremely hazardous when used by operators in a production environment. The second was suspected of leading to chromium contamination and posed serious ecological problems of disposal. Clearly, a procedure was needed that was effective, free of contaminants introduced by the reagents, safe, economical, and ecologically acceptable.

Chemical considerations

The new cleaning method to be developed had to be based on first removing organic contaminants (such as grease films and photoresist residues masking the surface) to expose the wafer surface and render it hydrophilic ("water-loving"), thereby rendering it accessible to aqueous chemical reagents. This step would then be followed by the removal of inorganic contaminants (such as trace metals and chemisorbed ions). Ideally, the reagents to accomplish these objectives had to be completely volatile and commercially available at high purity and low cost.

On the basis of reaction chemistry and reagent purity, water-diluted, unstabilized hydrogen peroxide at high pH, attained by the addition of ammonium hydroxide solution, appeared to be the ideal reagent for removing residual organic contaminants by oxidative breakdown and dissolution, if used at an elevated temperature for a suitable period of time. In addition, this solution would also remove several types of metals such as Cu, Ag, Ni, Co, Cd, and Au, due to complexing by the ammonium hydroxide.

For the second solution, I selected diluted hydrogen peroxide at low pH, prepared by adding hydrochloric acid solution. Used again at elevated temperature, this solution was to remove alkali ions and remaining metallic impurities. Displacement replating of heavy metals from solution would be prevented by the formation of soluble complexes with the resulting dissolved ions.

Deionized, distilled, and microfiltered water served as the diluent and rinsing agent. To prevent leaching of alkali and boron from Pyrex® (Corning Glass) glassware during the cleaning process, I introduced the use of vessels of fused silica and of wafer holders of Teflon® (DuPont), and conducted systematic experiments for establishing optimal processing conditions and solution concentrations. Surface chemical analysis techniques and radioactive-tracer measurements served as very sensitive analytical methods for evaluating the efficiency of various cleaning processes in the course of this development.

The results of these experiments subsequently showed that the solution compositions are not critical for the effectiveness of the process, as long as one operates within volume ratios of 4:1:1 to 6:1:1 of H_2O, 30 w/w % H_2O_2, and 29 w/w % NH_4OH (as NH_3) for the first mixture, and 4:1:1 to 6:1:1 of H_2O, 30 w/w % H_2O_2, and 37% HCl for the second mixture. Treatment periods of 10 to 20 minutes are sufficient. The solution temperature can be maintained at 75 to 85°C, but preferably should not exceed 80°C. A higher temperature would cause rapid decomposition of the hydrogen peroxide.

Radiochemical contamination and cleaning efficiency studies

Concurrent with these studies I investigated the origin, cause, type, and concentration of contaminants by adding trace quantities of radioactive cations (Na^{22}, Na^{24}, Au^{198}, Cu^{64}, Fe^{59}, Cr^{51}, Zn^{65}, Sb^{122}, Sb^{124}, Mn^{54}, Mo^{99}) and anions (F^{18}, Cl^{38}, I^{131}, C^{14}-organics) to numerous etchants and reagent solutions. Radioactivity measurements, autoradiography, and gamma-ray spectroscopy of electronic solids (Si, SiO_2, Ge, GaAs) treated with these tagged solutions allowed quantitization of the resulting surface concentrations of specific impurities, both initially and after various rinsing and cleaning steps with the hydrogen peroxide mixtures noted.[3-8]

Application to silicon device production

By mid-1960, the peroxide cleaning technique (dubbed "SC-1" and "SC-2" to denote "Standard Clean, Solutions 1 and 2"—see box, page 102) was well established and widely applied at RCA in the fabrication of silicon devices. A process patent that incorporated the $HCl\text{-}H_2O_2$ desorption process was issued to RCA in 1966.[9] Also in 1966, I received an RCA Outstanding Achievement Award shared with James A. Amick and Arthur I. Stoller "for new technological advances for processing integrated circuits," which included the peroxide method for attaining practically clean silicon surfaces in conjunction with glass-passivation and tungsten-metallization processes.

Publications

In 1970 I succeeded in obtaining permission to publish the series of papers on the radiochemical studies and the peroxide cleaning process; the latter incorporated the contributions of my coauthor, David A. Puotinen, who had studied in some detail several aspects of peroxide cleaning as applied to silicon device processing.

Several of my colleagues contributed also to the success of this work, particularly Norman Goldsmith and James A. Amick[10] during the development and implementation that extended over several years, and Alfred Mayer who introduced megasonic (ultrahigh-frequency) peroxide cleaning at low temperature (explained below), effectively combining the removal of particulates with the desorption of adsorbed contaminants.[11]

Introduction of additional process step

An additional step in the procedure, which was not explicitly noted in our original paper because of insufficient data at that time, is the application of a brief etch in dilute HF solution after the SC-1 cleaning. I reasoned that removal of the hydrous oxide film formed during the SC-1 treatment to reexpose the silicon surface for the subsequent SC-2 desorption step should further increase the purification efficiency. However, this etching should be done with a very dilute high-purity HF solution and for a very short period of time to avoid replating of the metallic contaminants from the HF solution on the silicon surface.

Experiments have shown that a 10-second immersion in 1:50 $HF\text{-}H_2O$ is sufficient to remove this film, as evidenced by the change of the hydrophilic oxidized surface to a hydrophobic surface, which is characteristic for a fluoridated, organic contaminant-free silicon surface. Subsequent water rinsing should also be kept very brief (30 seconds), serving only to remove HF solution from the wafer assembly in order to minimize regrowth of a new hydrous oxide film. Fortunately, change of a ≡Si-F surface to a ≡Si-OH surface in cold H_2O is very slow, minimizing rapid regrowth of a hydrated oxide film.[5] We believe that this additional step does indeed enhance the effectiveness of the subsequent SC-2 treatment, and should be part of the cleaning sequence.

Reasons for popularity of cleaning procedure

The original paper of 1970 has been highly cited because extensive analytical studies and device reliability and life testing by many independent researchers have confirmed the process, now widely known as "RCA Standard Clean," to be the most effective cleaning method known for attaining the degree of purity that is imperative in the fabrication of sensitive silicon semiconductor devices. Furthermore, the process is safe and relatively simple, has attractive economic and ecological advantages, uses readily available high-purity solidfree and volatile reagents, and was accepted by the American Society for Testing and Materials as a standard procedure.[12] Actually, the process is so widely employed that most authors refer to it without citing our original work, apparently assuming it to be common knowledge.

Developments since 1970

The following section reviews the more important literature references on silicon wafer cleaning with SC-1 and SC-2 hydrogen peroxide solutions. These references confirm our original statements and contribute additional new information on the subject.

Henderson[13] published results in 1972 on the analytical evaluation of the SC-1/SC-2 cleaning process by high-energy electron diffraction and Auger electron spectroscopy. He concluded that the process is well suited for silicon wafer cleaning prior to high-temperature treatments, as long as quartzware is used for processing, according to our specification, to avoid boron contamination from Pyrex® containers. He also examined the possible benefits of an additional final etch treatment in concentrated HF after completion of the SC-1/SC-2 steps, but found that it enhances carbon contamination and causes surface roughening during vacuum heating at 1100°C due to loss of the protective 15-angstrom-thick carbonfree oxide film remaining after the SC-2 step. Reexposure of a bare silicon surface to HF after SC-2 would, of course, be ill advised because of recontamination with metallic impurities, obliterating the advantages of peroxide cleaning.[5,6]

Meek *et al.* (1973)[14] investigated the removal of inorganic contaminants, including copper and heavy metals, from chemically/mechanically polished silicon wafers by several reagent solutions. Using Rutherford back-scattering with 2-MeV He^+ ions as an analytical tool, they concluded that the SC-1/ SC-2 as preoxidation cleaning process always removed all elements heavier than chlorine to below the level of detectability. Sulfur and chlorine remained after either SC-1, SC-2, or other cleaning procedures studied at levels of about $10^{13}/cm^2$. SC-1/SC-2 cleaning eliminated calcium and copper much more reliably than did HF-HNO_3 treatments.

Murarka *et al.* (1977)[15] studied methods for oxidizing silicon without the formation of stacking faults. They concluded that chemical cleaning of the wafers with SC-1/SC-2 prior to an oxidation is an essential requirement to ensure the complete elimination of stacking faults after the high-temperature processing.

In 1978, we published a review[16] of the entire field of surface contamination and semiconductor cleaning techniques as part of a book chapter on the chemical etching of thin films and substrates.

Gluck (1978)[17] presented a paper in which he discussed the removal of radioactive gold from silicon wafers by a variety of baths containing H_2O_2, H_2O, NH_4OH and/or HCl. The desorption efficiency of SC-1 solution was more effective than that of SC-2, but the usual sequential treatment of SC-1 followed by SC-2 was the most effective removal method at higher gold surface concentrations (in the $10^{14}/cm^2$ range).

Peters and Deckert (1979)[18] investigated photoresist stripping by numerous solvents, chemical agents, plasma stripping, and heat treatment in air at 650°C (combustion, or ashing). They found that film residues remain on wafers in all cases except ashing. The SC-1 procedure was the only technique by which the residues could be removed consistently and completely. They recommended that SC-1 cleaning be applied routinely to SiO_2-patterned silicon wafers after photoresist stripping operations in oxide masking.

In a 1981 review article on wafer cleaning, Burkman[19] reported results of desorption tests for radioactive gold from silicon wafers with several reagent solutions. A centrifugal spray cleaning machine by FSI Corporation was used rather than bath immersion. An SC-1 type of H_2O-NH_4OH-H_2O_2 solution was much more effective than H_2SO_4-H_2O_2 mixtures, but an H_2O-HCl-H_2O_2 solution alone showed poor efficiency, probably because an organic film masked the surface, thereby preventing efficient gold desorption.

Phillips *et al.* (1983)[20] applied, in preliminary tests, secondary ion mass spectrometry to determine the relative quantities of contaminants on silicon wafers. Cleaned wafers were purposely contaminated with gross quantities of numerous inorganic impurities and then cleaned by immersion or spray techniques with various aggressive reagents (aqua regia, hot fuming nitric acid, sulfuric acid-hydrogen peroxide, and SC-1/HF/SC-2 type of solutions). The lowest residual concentrations for most impurity elements were obtained by spray cleaning with a sulfuric acid and hydrogen peroxide mixture as used for photoresist stripping, followed by the SC-1/ HF/SC-2 cleaning sequence.

Watanabe *et al.* (1983)[21] measured the dissolution rates of SiO_2 and Si_3N_4 films in H_2O-NH_4OH-H_2O_2 mixtures. The etching rate of thermally grown SiO_2 in SC-1 (5:1:1 of H_2O-NH_4OH-H_2O_2) during a 20-minute treatment at 80°C was a constant 4 angstroms per minute. The authors state that this rate of dissolution is significant for structures incorporating thin (200 angstroms or so) oxide layers (one might argue that the processing of such layers should be designed to use as-grown films to make chemical treatments unnecessary). The etch rate of high-temperature chemically vapor-deposited Si_3N_4 was 2 angstroms per minute under the same conditions.

Measurements done in 1981 in the author's laboratory at RCA, however, indicated much lower oxide-dissolution rates under nearly identical conditions. Changes in film thickness were measured by ellipsometry after each of four consecutive treatments in fresh 5:1:1 SC-1 at 85°C and totaled only 70 angstroms per 80 minutes, or 0.9 angstrom per minute for oxides grown thermally on polished silicon wafers that were lightly or heavily doped with boron or phosphorus, respectively. At 98 to 100°C, the dissolution rates averaged only 0.5 angstrom per minute, whereas in solution without peroxide (1:6 H_2O-NH_4OH) the rates were 1.6 angstroms per minute. Under the same conditions, 6:1:1 SC-2 solution showed pratically no change in the film thicknesses, as would be expected.

Alternative processing techniques using SC-1/SC-2

The original and widely used RCA cleaning procedure is based on simple immersion techniques. Two alternative and attractive techniques have been introduced in recent years: centrifugal spray cleaning[19] and megasonic cleaning.[11,22]

In centrifugal spray cleaning, developed by FSI Corporation, the wafers are enclosed in a chamber purged with nitrogen. A sequence of continuous fine sprays of reagent solutions, including hot SC-1, SC-2, and high-purity water, wets the spinning wafers; N_2 finally dries them for removal. The main advantages of this automated system are the reduced volume of chemicals needed, the continuous supply of fresh reagent solutions to the wafer surface, and the controlled environmental conditions during processing. The cleaning efficiency of the centrifugal spray system is comparable with that obtained with the RCA immersion technique, according to claims by FSI Corporation.

The megasonic cleaning system was patented in 1975 by RCA Corporation[11,22] and is manufactured under license by the Process System Division of Fluorocarbon Company. It is a noncontact, brushless scrubbing machine designed primarily for safely removing particulate contaminants from both sides of silicon wafers by use of ultrahigh-frequency sonic energy. Sonic waves of 850 kHz are generated by an array of piezoelectric transducers, providing a highly effective scrubbing action on batches of wafers immersed in the cleaning solution. Particles ranging in size from several micrometers down to about 0.3 μm can be efficiently removed with input

Hydrogen peroxide-based immersion cleaning procedures for silicon wafers

A. Preliminary cleaning (if necessary)

1. Remove bulk of photoresist film (if present) by plasma oxidation stripping, or immersion in organic photoresist stripper, or with a hot 1:2 v/v H_2O_2-H_2SO_4 mixture if adequate safety[23] precautions are exercised.

2. Rinse with water (see note on water purity for entire processing).

3. Transfer the wafers to a clean Teflon® holder. Pick up wafers with Teflon® or polypropylene plastic tweezers.

B. Removal of residual organic contaminants and certain metals (SC-1)

1. Prepare a fresh mixture of H_2O-NH_4OH-H_2O_2-(5:1:1) by measuring the following reagents into a beaker of fused silica (opaque silica ware is acceptable):
   a. 5 volumes of water
   b. 1 volume of ammonium hydroxide (29%, electronic grade, w/w % based on NH_3)
   c. 1 volume of hydrogen peroxide (30%, unstabilized electronic grade, w/w %)

2. Stir the solution with a clean rod of fused quartz.

3. Submerge holder with wafers in the cold solution and place the beaker on a hotplate.

4. Heat to 75 to 80°C. Then reduce heating to maintain the solution at 80°C for an additional 10 minutes. (The vigorous bubbling is due to oxygen evolution. Make sure *not* to boil the solution so as to prevent rapid decomposition of the H_2O_2 and volatilization of the ammonia.)

5. Overflow-quench the solution by placing the beaker under running water for about one minute.

6. Remove holder with wafers and immediately place it in a cascade water rinse tank for 5 minutes.

C. Stripping of thin hydrous oxide film (1:50 HF-H_2O)

1. Submerge wafer assembly from step B.6 directly in an agitated mixture of 1 volume hydrofluoric acid (49%, electronic grade) and 50 volumes of water.

2. Allow to remain in the solution for only 15 seconds. Exposed silicon (but not SiO_2) should repel the HF solution.[24] Use a polypropylene beaker for this step.

3. Transfer the wafer assembly to a water tank,

power densities of 5 to 10 W/cm^2. For comparison, ultrasonic systems that operate typically at 25 to 80 kHz require power densities of up to 50 times that of the megasonic system, and are much less effective for removing very small particles.

An interesting additional aspect of this machine is its ability to operate effectively with SC-1 and SC-2 cleaning solutions for the removal of organic and many inorganic contaminants, similar to the RCA immersion technique, even though the bath temperature rises to only 35 to 42°C during operation. Initial experimental data of desorption efficiencies for metallic and ionic contaminants are impressive, but an extensive and quantitative evaluation has not yet been carried out to assess the extent of effectiveness. At present, any degree of chemical cleaning and desorption of contaminants resulting simultaneously with particulate removal, the main function intended of the machine, can be considered a highly desirable additional benefit of this system. Photographs of a typical machine are shown in Figs. 1a and 1b.

Comments and recommendations

It is important to stress that the wafers during processing must never be allowed to dry, because dried residues may be difficult to redissolve and may mask the surface during subsequent treatments. Removal from a hot bath should therefore be done only after cooling or quenching the solution by dilution with cold water. This technique also minimizes contamination from the solution/air interface.

Vapors of NH_3 and HCl form a smog of NH_4Cl when brought in close proximity to each other. Therefore, the SC-1 must be separated from SC-2 processing by the use of two separate exhaust hoods to avoid wafer contamination from colloidal NH_4Cl particles. Disregard of this recommendation has repeatedly led to problems in production application.

Pyrex® glassware should not be used with the SC-1 and SC-2 procedures because substantial amounts of sodium, potassium, boron, and impurities are leached out of the glass by the hot solutions. As noted, beakers of fused silica should be used instead; high-quality opaque fused silica is much less costly than clear fused quartz, and is acceptable for wafer-cleaning vessels. Rinse tanks and vessels for HF solution should be constructed of high-grade polypropylene plastic.

Operators frequently believe that if a hot SC-1 solution is good for processing, a boiling solution must be better. This fallacy is remarkably difficult to correct. As noted, the solutions, especially the SC-1, should be used at a temperature in the range of 75 to 80°C because, at higher temperatures, H_2O_2 rapidly decomposes and there is increased volatilization of NH_3 from the NH_4OH solution. Fortunately, for SC-1 solutions the rates of H_2O_2 decomposition and of NH_3 volatilization under the recommended processing conditions are similar; ammonia in the absence of H_2O_2 would immediately etch silicon. In the case of SC-2 solutions, the decomposition of the H_2O_2 and volatilization of HCl proceed at a much slower rate than for SC-1, and there is no danger of silicon etching under any conditions. Nevertheless, excesbut rinse for only 20 to 30 seconds with agitation to remove the HF solution (this minimizes regrowth of a hydrous oxide film).

4. Transfer the wafer assembly immediately, without drying, into the hot SC-2 solution of step D.

D. Desorption of remaining atomic and ionic contaminants (SC-2)

1. Prepare a fresh mixture of H_2O-HCl-H_2O_2 (6:1:1) by measuring the following reagents into a beaker of fused quartz:
   a. 6 volumes of water
   b. 1 volume of hydrochloric acid (37%, electronic grade)
   c. 1 volume of hydrogen peroxide (30%, unstabilized, electronic grade)
2. Place the beaker on a hotplate and heat to 75 to 80°C.
3. Submerge the still-wet wafers in the holder (after step B.6 or C.3) in the hot solution.
4. Maintain the solution at 80°C for 10 to 15 minutes.
5. Overflow-quench as in step B.5.
6. Continue the rinsing at this stage for a total of 20 minutes in a cascade rinsing system.

E. Drying of the wafers

1. Transfer the holder with the wet wafers into a wafer centrifuge.
2. Apply a final water rinse during spinning.
3. Allow to dry while gradually increasing the spinning speed (to avoid aerosol formation from the water droplets).
4. Remove the wafers by dump transfer for high-temperature processing. If single-wafer handling must be used, handle the wafers only at the edge with plastic tweezers.

F. Storage

1. Avoid storage of cleaned wafers, preferably by immediate continuation of processing. If storage is unavoidable, store the wafers in closed glass containers cleaned with hot SC-1 solution, followed by water rinsing and over-drying.

Note concerning processing water and reagents

All water used for preparing the reagent mixtures or for rinsing should be thoroughly deionized and ultrafiltered, with a resistivity in the 10- to 20-megohm range at 18 to 23°C. All reagents should be electronic grade, preferably ultrafiltered for freedom from particulate impurities.

sive heating should be avoided for safe operation.

To illustrate the degree of decomposition of hydrogen peroxide in an SC-1 solution as a function of extreme temperature and time conditions, the graph from our original paper[1] is reproduced in Fig. 2. It can be seen that the half-life of the solution at 88 to 90°C was approximately 5 minutes (versus 50 hours at 23°C), and the time for the concentration of peroxide to be reduced to the etching threshold

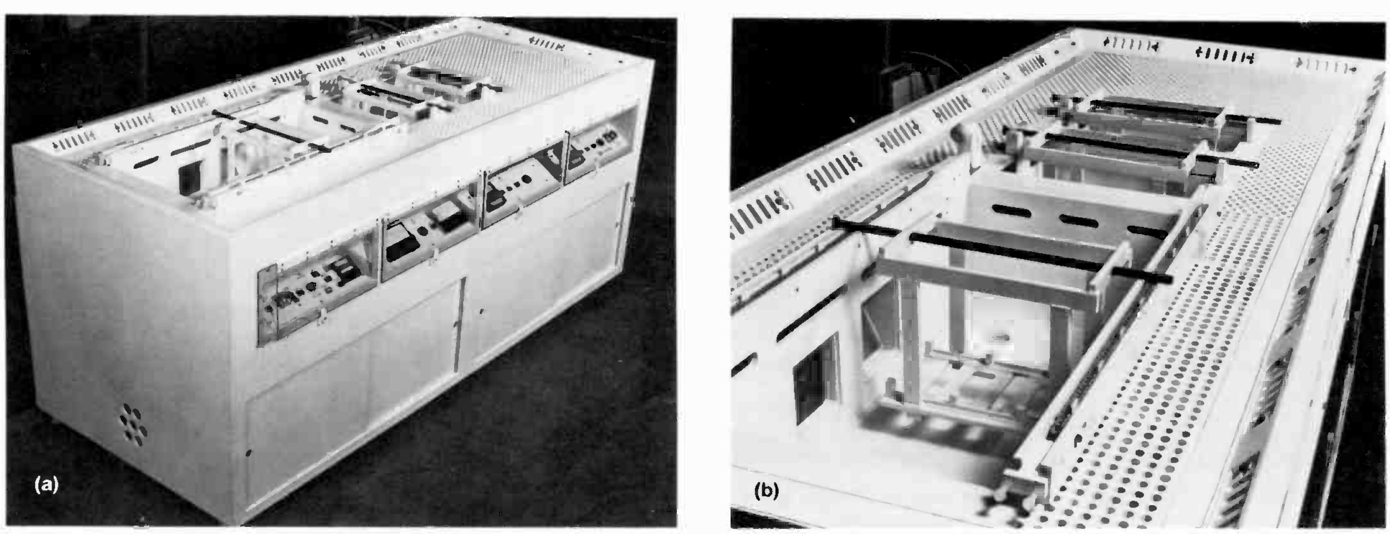

Fig. 1. *Photographs of the Fluorocarbon Megasonic "Electronic Scrubber" Cleaning System. Courtesy Fluorocarbon Company.* **(a)** *Without air dryer.* **(b)** *Detailed view of the continuous feed of wafers through the sonic-energy field.*

level for (111)-oriented silicon was more than 40 minutes after the solution reached 79°C. Since the preferred recommended cleaning time is 10 minutes at a temperature of 75 to 80°C, there is an adequate margin of safety if the initial peroxide concentration is at the recommended level. Recent measurements, which we conducted with SC-1/SC-2 reagents that are now available at much higher purity than before 1970, have shown considerably lower rates of decomposition.

A wide range of SC-1 and SC-2 solution compositions has been used successfully by many engineers. The recommended ratios of 5:1:1 for H_2O-NH_4OH-H_2O_2, and of 6:1:1 for H_2O-HCl-H_2O_2, are effective and economical ratios used by most people. Repeated use of the solutions, or reconstitution of the reagent composition, is not recommended because it would prevent the safe technique of overflow-quenching with cold water. Besides, impurities accumulate in the solution and accelerate the decomposition rate of H_2O_2.

The use of unstabilized H_2O_2, that is H_2O_2 without stabilizer additions, has been specified. Principal additives in commercial stabilized H_2O_2 are sodium phosphate and/or sodium stannate, compounds that are highly undesirable contaminants in our application.

Occasionally, etching of silicon areas in device wafers during SC-1 cleaning has been encountered The most likely explanation for this effect is a catalytically accelerated decomposition of the H_2O_2 due to trace impurities, especially heavy metals from tweezers or containers, or impurities in the reagents. Decomposition may then take place even at a low temperature, or on mixing of the solutions. In the absence of sufficient quantities of H_2O_2 (initial concentrations of less than 50 percent of what we recommend), the ammonium hydroxide will etch silicon at rates dependent on crystallographic orientation, dopant types and concentrations in the silicon, and proximity of *p*- and *n*-type areas.[1] The light intensity during this treatment may also be a factor. A detailed outline of the exact, updated processing procedures that are recommended is presented in the accompanying box (page 102).

Acknowledgment

I wish to thank Richard E. Berger for carrying out the experimental work and measurements, Stanley Shwartzman for providing the megasonic system photographs, and George L. Schnable for reviewing the manuscript and making valuable comments.

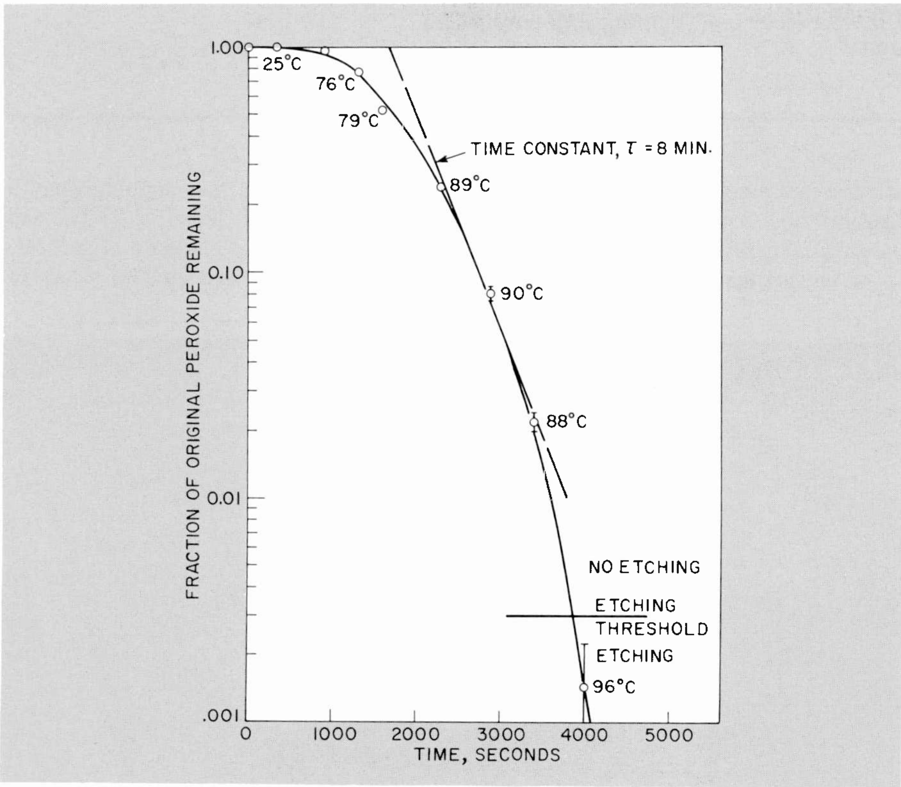

Fig. 2. *Fraction of hydrogen peroxide remaining as a function of use time and recommended, and then excessive, temperature for SC-1 cleaning solution (H_2O-NH_4OH-H_2O_2). The appropriate etching threshold indicated is for (111)- and (100)-oriented silicon.[1] The rate of decomposition of solutions prepared with reagents of the now available higher purity is lower than shown in this graph.*

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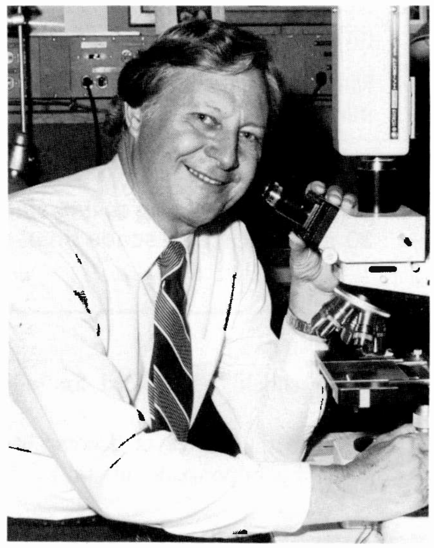

Werner Kern is a Senior Member Technical Staff, Integrated Circuit Research Laboratory at the RCA Laboratories in Princeton, New Jersey. He has been with RCA for over 24 years. He has been working in semiconductor process research, specializing in the preparation and characterization of dielectric films, radioactive-tracer applications, chemical vapor deposition, and etching processes. Mr. Kern received three RCA Laboratories Outstanding Achievement Awards. He coedited and coauthored *Thin Film Processes*, published by Academic Press in 1978. Mr. Kern is Chairman of the Electrochemical Society's Dielectrics and Insulation Division, is an active member of several scientific societies, and is the author or coauthor of over 80 scientific publications and seven U.S. patents.
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G. Poletti

Missile and Surface Radar's Microcomputer Club

As microcomputing power per dollar increases, engineers are using informal networks—such as this club—to stay abreast of fast-moving applications and developments.

Although many professionals head for the golf course during their spare time, members of the Microcomputer Club of RCA Missile and Surface Radar (MRS) at Moorestown can be found at home extending their work environment into their new-found hobby. They spend many hours devising a new computer program, designing a new architecture, or planning a new combination of peripherals and chips for recreation.

The club was formed in July 1979 by Stan Goliaszewski with a total of three people. Today the club has more than 40 members who meet whenever a demonstration or project is scheduled. Paul Ray is the current president. The purposes of the club are the following:

- Develop microsystem capabilities.
- Exchange microsystem information.
- Provide understanding of microsystem applications.
- Furnish training and assistance in microsystem technology.
- Research the nature of microsystems.
- Acquire products and services relating to microsystems.
- Cooperatively develop projects within the membership.

To date, these objectives have been met and are continuing to be met through personal contact among members, meetings and presentations, and displays and cooperative projects.

Most personal computers today are sold for the following purposes:

- An entertainment center for playing games requiring manual dexterity or a gambler's interest.
- A tool for getting schoolchildren interested in mathematics.
- Information storage, for example, the maintenance of mailing lists and other record-keeping chores.
- Home-environment control—turning on lights or music when one is away from home.
- Small-business applications, such as bookkeeping.
- Word processing.

Club members use their personal computers for each of these categories.

Abstract: *The activities of the Missile and Surface Radar Microcomputer Club are outlined. Personal contact among members, meetings and presentations, and displays and cooperative projects are the mainstays of the club. Several uses of microcomputers are described, and educational activities are detailed. Future plans include joint educational sessions with the local IEEE chapter. Names and telephone numbers of some of the members are included.*

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Reprint RE-28-4-10

Demonstrations

When the club meets, demonstrations are a very popular form of sharing information. Typical demonstrations have included the following:

TRS-80. Hank Rouland shared his thoughts on how he decided he wanted a computer and, once he owned one, how the uses for it multiplied. In addition to playing video games, Hank can prepare his income tax return more easily, and he can sort family address lists by alphabetical order, by zip code, or by any other category he would like. His family also uses the computer for word processing to enhance term papers, for example. Hank also addressed fundamentals of computer programming at a later meeting of the club membership.

Apple. Phil DeVicci enthusiastically entertained a group of about 80 interested onlookers as he explained the joys of using his Apple personal computer. Although some technical difficulties had to be overcome because another manufacturer's monitor was being used, Phil rose to the occasion, solved the interface problems, and showed what could be done with his computer. He particularly appreciates the color and graphics features of his Apple (Phil recently was elected president of the Southern New Jersey Apple User's Group, which has over 200 members). Apple Computer, Inc. invited him to be their guest in California to tour their plant and see the manufacture of Apples first hand.

Home brew. Mike Ward explained to an overflow crowd how he selected components and peripherals to assemble his own microcomputer system. His system may well be the envy of some well-known manufacturers of personal computers because of its sophistication and advanced capabilities. Mike uses a Cromenco Z80 card (with a 4-MHz clock) and two 8-inch double-density, double-sided Shugard floppy-disk drives each providing 1.1 Mbytes of on-line storage. Besides using his computer for word processing, he also calculates ballistic coefficients and trajectory tables for use in high-power rifle shooting—another one of his hobbies.

Commodore Model 64. A recent demonstration arranged by Rich Camlin featured a local computer sales organization discussing the virtues of the Commodore Model 64. An overflow crowd eager for information was present.

Educational activities

In addition to informal demonstrations, several outstanding educational sessions have been conducted during the club's tenure. Notable among these has been a one-year course, meeting weekly, that covers the intricacies of digital circuit design and includes discussions of the realities of home construction of these circuits. The course was ably conducted by Joe Corrado (Fig. 1) and held the attention of about fifteen potential computer designers. The course started with the basics of Boolean algebra and progressed to some very complex considerations of digital circuit design. Joe presented some original ideas that were worthy of recognition by his RCA peers; these have been published in a substantial report entitled, "Digital Transforms, Part 1."

To quote the author's introductory remarks to the report, "The report describes a systematic technique useful in the design and development of synchronous and sequential digital circuits. This technique can be applied to such devices as counter, shift register, timing sequence circuits, code generators, and convertors."

As an indication of the depth of interest of club members in their hobby, Fred Wuebker, Manager of the Military Computer Family Operating System project, was guest speaker at one meeting. His talk, "Design Principles to Make Home Built Programs More Fun," emphasized that most home programs today are built but not designed. He stressed the fact that many hours should be spent in designing a computer program before one succumbs to the temptation of dashing off an ill-conceived and poorly thought out program, and then entering it into the computer. Much grief spent in debugging and patching can be avoided by a planned design. Top-down design and structured programming were addressed and aptly illustrated.

Members' interests go beyond the purely technical. Like most people, a member's financial condition is of acute concern. To satisfy this anxiety, Ed Behrens presented a lecture on financial planning for tax considerations when buying a personal computer. Ed discussed tax deductions that can be made, under certain conditions, for owners of personal computers. The aspect of the professional use and the business use of the computer was addressed.

Cooperative projects

In addition to events of individual member interest, groups of members sometimes work together on projects of broader community concern. The most recent illustration of this effort occurred at the 1982 MSR Open House. Three members of the Microcomputer Club volunteered their time and set up their computers and circuits for demon-

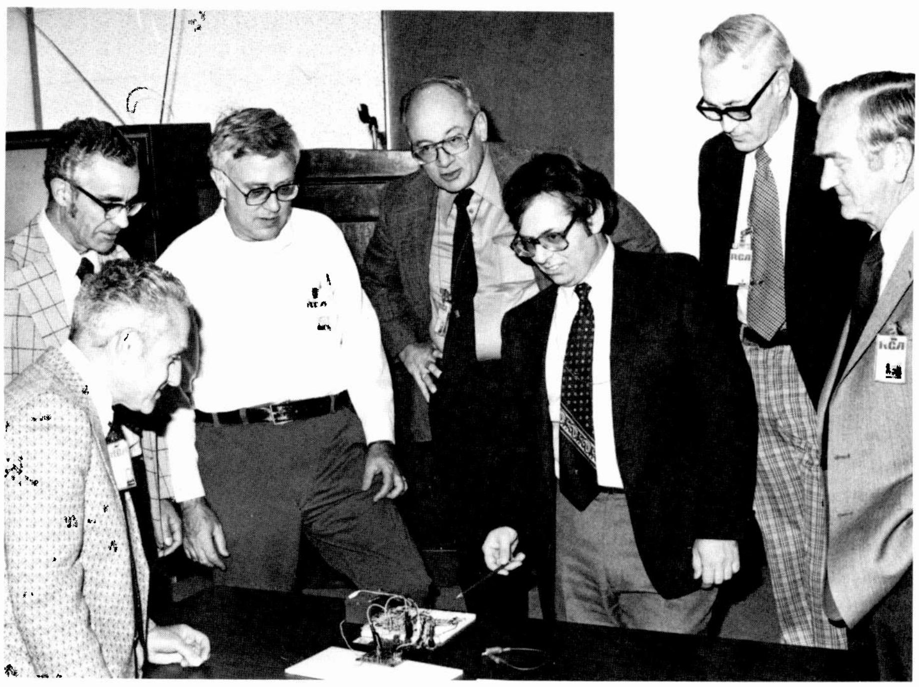

Fig. 1. *Joe Corrado discusses the perils of home microcomputer system construction. Class members are (left to right) John DeFranco, Ray Chatelain, Charlie Carpenter, Bob Scarlata, Claude Ely, and Jim Falkenstein.*

stration to visitors. Dave Phillips, Ray Chatelain, and Phil DiVicci spent an intense but satisfying Saturday answering questions, demonstrating their computers, and providing helpful suggestions for the many visitors to their display. Dave Phillips illustrated his personal design and integrated system using a VIP, whereas Phil and Ray used commercial products, the Apple and an Ohio Scientific, respectively. In another project, information was gathered for a display to inform co-workers at the Moorestown plant about the club. The display showed pictures and charts of various efforts of the members.

The club welcomes users of all personal computers regardless of the manufacturer. In this way, information exchange can be enjoyed by all personal computer owners. Nevertheless, owners of specific brands have their own particular problems unique to the computer and software that they own. This condition gives birth to "user groups." Several user groups interested in a specific computer meet regularly throughout the Delaware Valley. Through the efforts of Glen Merritt, user groups within the club have emerged to discuss and share their particular discoveries. Currently, there are two known user groups, for the VIP and Sinclair.

Future plans

The club expects to continue to assist those requesting information on products, technical problems, and computer-programming issues. More ambitious plans in the embryonic stage are applications by members of microprocessor techniques to automobile pollution control and increased fuel efficiency.

Preliminary discussions have been held with a representative of the Update Committee of the Philadelphia Section of the IEEE to conduct joint educational sessions here at RCA. The Update Committee has had a very successful record of holding informative meetings and seminars on the use of microprocessors in industrial applications. The committee members also present state-of-the-art information on microprocessors and related hardware and software to allow engineers in the area to stay abreast of the fast-moving technology. The committee's motto is "We teach the skills that will help IEEE members keep their jobs or find new ones."

People in this article

If you are interested in pursuing further some aspect of Microcomputer Club activities, the list below contains names and telephone numbers of members mentioned in this article.

Member	*MSR organization*	*MSR extension*
Ed Behrens	Computer Control & Software Systems	2645
Rich Camlin	Engineering Operations	2708
Ray Chatelain	Engineering Operations	2396
Joe Corrado	Naval Systems Department	3016
Phil DeVicci	Computer Control & Software Systems	2995
Stan Goliaszewski	Kwajalein, Marshall Islands	— —
Dave Phillips	Naval Systems Department	3700
Paul Ray	Naval Systems Department	2800
Hank Rouland	Naval Systems Department	2663
Mike Ward	Naval Systems Department	2178
Fred Wuebker	Computer Control & Software Systems	3908

Conclusion

The beginning of this century saw us tinkering with the steam engine. We are entering its final decades with technology that sends people into space and back to earth in a routine manner almost comparable to catching the 5:02 from New York City to Connecticut. These space odysseys could not take place without the development of many computers. More progress is yet to come as microprocessors become ubiquitous. By the end of the century, we will be talking to computers and they will be talking back. A great variety of video displays will be possible. Experiencing the activities discussed, as well as anticipating exciting achievements in the future, makes members of the Microcomputer Club feel they are participating in a history-making process.

George Poletti joined RCA as a Senior Engineer in 1976 as a member of the AEGIS System Test group. He is currently with the NSD System Assurance organization. Although not a microcomputer owner himself, he is using the knowledge gained at club meetings and activities to help in determining which model would be best for his purposes.

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Engineering News and Highlights

Olson is Consumer Electronics Editorial Representative

Larry A. Olson is the newly appointed *RCA Engineer* Editorial Representative at Consumer Electronics (CE) Division, Indianapolis, Indiana. An RCA employee since 1962, his specialty is manufacturing and test technology, and he has held various positions in engineering and manufacturing operations at RCA throughout his career. Mr. Olson was recently appointed Manager, Manufacturing Technology Center at CE, after serving as Manager, IC Test, Test Technology. Mr. Olson attended Bethany College and Kansas State University. He received his M.S.E. in Electrical Engineering from the University of Pennsylvania, Philadelphia, Pa.

Contact him at:
Manufacturing Technology Center
Indianapolis, Indiana
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Miller is Staff Vice-President for Manufacturing and Materials Research

Appointment of **James L. Miller** as Staff Vice-President, Manufacturing and Materials Research, has been announced by **Dr. William M. Webster,** Vice-President, RCA Laboratories, in Princeton, N.J. In his new position, Mr. Miller is responsible for RCA Laboratories materials and processing research, manufacturing technology, and manufacturing systems.

Mr. Miller joined the RCA Tube Division in Camden in 1948 as an engineer. In 1953 he transferred to the Home Instruments Division, where he worked on the design of color TV systems. He moved to the Computer Division in 1960, working on high-speed tunnel diode circuits. In 1962 he was promoted to Manager, Optical Character Reader and Card Reader Engineering.

From 1966 to 1969 Mr. Miller served as Managing Director of the RCA Engineering Laboratories in Tokyo, Japan. Upon his return to the RCA Corporate Staff in Cherry Hill, he became Manager, and later Director, of Manufacturing Systems and Technology.

Mr. Miller transferred to RCA Laboratories in 1975 as a Laboratory Director. Four years later he was named Director, Systems and Test Engineering, for RCA "SelectaVision" VideoDisc Operations in Indianapolis. He was appointed Division Vice-President in 1981, the position he held until his new assignment at RCA Laboratories.

A native of Havelock, Iowa, he received a B.S. degree in 1948 from Iowa State University and an M.S. degree in 1964 from Drexel University, both in Electrical Engineering.

Criscito Named RCA Solid State Division VP, Marketing

Herbert V. Criscito has been appointed Division Vice-President, Marketing of the RCA Solid State Division's worldwide sales, advertising, and marketing organization effective July 11, 1983. Mr. Criscito will report directly to **Dr. Robert S. Pepper,** Vice-President and General Manager of the RCA Solid State Division. He was most recently the National Sales Manager for Zilog, Inc., Cupertino, California.

Mr. Criscito is a former RCA Solid State employee having worked as a product development engineer from 1960 to 1966.

Prior to joining Zilog, Mr. Criscito spent 11 years at Intersil, Inc., first as the Eastern Area Sales Manager and then as Director of Sales; two years at the Raytheon Semiconductor Division as Commercial Sales Manager; and two years at Fairchild Semiconductor selling to computer accounts.

After graduating from St. Peter's College, Jersey City, N.J. with a degree in Physics, he spent three years in graduate studies in Physics and Math at the University of Delaware and New York Unversity.

Staff announcements

Consumer Electronics

D. Joseph Donahue, Vice-President and General Manager, Consumer Electronics Division, announces the appointment of **Leonard J. Schneider** as Division Vice-President, Operations.

Leonard J. Schneider, Division Vice-President, Operations, announces the appointment of **Bennie L. Borman** as Division Vice-President, Manufacturing.

Jack S. Fuhrer, Director, New Products Laboratory, announces the appointment of **Alfred L. Baker,** as Manager, Television Digital Systems, and the appointment of **Aaron C. Cross, Jr.** as Manager, Advanced Mechanical Engineering.

Willard M. Workman, Director, VideoDisc Player Engineering, announces his organization as follows: **Todd J. Christopher,** Manager, Electrical Design; **Edward W. Curtis,** Manager, Product Engineering; **Ned J. Kiser,** Manager, Digital Control Systems; **Roger L. Lineberry,** Manager, Project Engineering; **Michael E. Miller,** Manager, Stylus/Cartridge Design; **Frederick R. Stave,** Manager, Mechanical Design; and **Marjorie K. Ullery,** Manager, Engineering Services.

Eugene E. Janson, Manager, Product Safety and Reliability, announces the appointment of **Patrick D. Griffis** as Manager, Reliability Engineering.

Corporate Technology

William C. Hittinger, Executive Vice-President, Corporate Technology, announces the appointment of **Allan D. Gordon** as Staff Vice-President, Licensing.

John D. Bowker, Director, RCA Frequency Bureau, announces his organization as follows: **Kathleen M. Madrazo,** Administrator, FCC Authorizations; **Norman Mills,** Manager, New York Office; **Joseph P. McConville,** Administrator, Technical Projects; **Edward E. Thomas,** Manager, Washington Office; and **Constance S. Keller,** Administrator, FCC Liaison. Ms. Madrazo and Messrs. Mills and Thomas will continue to report to the Director, RCA Frequency Bureau.

Hans K. Jenny, Manager, Engineering Information, Technical Excellence Center, announces the appointment of **Geraldine Moss** as Manager, Technical Information Systems.

Frank E. Burris, Manager, Engineering Education, Technical Excellence Center, announces the appointment of **Robert A. Terrano** as Administrator, Engineering Education Programs.

Laboratories

William M. Webster, Vice-President, RCA Laboratories, announces the appointment of **Brown F Williams** as Vice-President, Display and Optical Systems Research.

William M. Webster, Vice-President, RCA Laboratories, announces his organization as follows: **Jon K. Clemens,** Staff Vice-President, Consumer Electronics Research; **James L. Miller,** Staff Vice-President, Manufacturing and Materials Research; **Kerns H. Powers,** Staff Vice-President, Communications Research; **Richard E. Quinn,** Staff Vice-President, Administration; **William M. Webster,** Acting, Solid State Research; **Brown F Williams,** Staff Vice-President, Display and Optical Systems Research; and **Dominick A. Zurlo,** Staff Vice-President, Industrial Relations.

Brown F Williams, Staff Vice-President, Display and Optical Systems Research, announces his organization as follows: **Carmen A. Catanese,** Director, Picture Tube Systems Research Laboratory; **Curtis R. Carlson,** Head, Image Quality and Human Perception Research; **Charles H. Anderson,** Fellow, Technical Staff; **David L. Staebler,** Head, Electron Optics and and Applied Mathematics Research; **Roger L. Crane,** Fellow, Technical Staff; **Ralph W. Klopfenstein,** Fellow, Technical Staff; **Peter J. Wojtowicz,** Head, Magnetic Deflection Research; **William H.Barkow,** Fellow, Technical Staff; **Bernard Hershenov,** Director, Optical Systems and Display Materials Research Laboratory; **Robert A. Bartolini,** Head, Optical Systems Research; **Michael Ettenberg,** Head Optoelectronics Research; **Henry S. Sommers, Jr.,** Fellow, Technical Staff; **P. Niel Yocom,** Head, Display Materials and Processes Research; **Joseph J. Hanak,** Fellow, Technical Staff; **Karl G. Hernqvist,** Fellow, Technical Staff; **Simon Larach,** Fellow, Technical Staff; **Richard Williams,** Fellow, Technical Staff; **Brown F Williams,** Acting Director; **Louis S. Cosentino,** Head, Display Technology Research; **Thomas L. Credelle,** Head, Advanced Display Systems Research; and **Wilber C. Stewart,** Fellow, Technical Staff. Drs. Catanese and Hershenov will report to the Staff Vice-President, Display and Optical Systems Research.

Richard E. Quinn, Staff Vice-President, Administration, announces his organization as follows: **James A. Goodman,** Manager, Information Systems Planning and Computer Services; **George C. Hennessy,** Director, Marketing, Procurement and Public Affairs; **Jerome Kurshan,** Manager, Administrative Projects; **Ralph H. Myers,** Director, Finance; **Walter A. Schmidlin, Jr.,** Director, Laboratory Services; and **John L. Vossen, Jr.,** Head, Thin Film Technology.

Arthur Kaiman, Director, Digital Products Research Laboratory, announces the appointment of **Philip K. Baltzer** as Head, Consumer Knowledge-Based Systems Research.

Istvan Gorog, Director, Manufacturing Technology Research Laboratory, announces his organization as follows: **David P. Bortfeld,** Head, Systems Research; **Arthur H. Firester,** Head, Advanced Technology Research; **James P. Wittke,** Fellow, Technical Staff; and **Martin Rayl,** Head, Productivity and Quality Assurance Research. Messrs. Bortfeld, Firester and Rayl will report to the Director, Manufacturing Technology Research Laboratory.

William M. Webster, Acting, Solid State Research, announces the appointment of **Robert D. Lohman** as Director, Integrated Circuit Technology Research Laboratory.

William M. Webster, Acting, Solid State Research, announces his organization as follows: **Robert D. Lohman,** Director, Integrated Circuit Technology Research Laboratory; and **Walter J. Merz,** Director, Research, Laboratories RCA, Ltd. (Zurich).

Robert D. Lohman, Director, Integrated Circuit Technology Research Laboratory, announces his organization as follows: **Norman Goldsmith,** Head, Lithography and IC Processing Research; **Gary W. Hughes,** Head, LSI Imagers and Special Devices Research; **Walter F. Kosonocky,** Fellow, Technical Staff; **Louis S. Napoli,** Head, LSI Memories and Devices Research; **Charles J. Nuese,** Head, Silicon Device Research; **Jacques I. Pankove,** Fellow, Technical Staff; **John P. Russell,** Staff Scientist; **David E. O'Connor,** Senior Project Manager; and **George L. Schnable,** Head, Device Physics and Reliability Research. Messrs. Goldsmith, Hughes, Napoli, Nuese, O'Connor, and Schnable will report to the Director, Integrated Circuit Technology Research Laboratory.

Solid State Division

S. Paul Davis, Director, Power Operations, Electro-Optics and Power Devices, Solid State Division, announces his organization as follows: **Donald E. Burke,** Manager, Power Engineering; **Joseph V. Colarusso,** Manager, Materials, Planning and Operations Support; **George W. Ianson,** Manager, Device Fabrication; **Allen L. Sands,** Manager, Quality & Reliability Assurance-Mountaintop; **Joseph R. Spoon,** Manager, Industrial Relations-Mountaintop; **Parker T. Valentine,** Manager, Product Marketing-Power; and **Gerald S. Worchel,** Manager, Wafer Fabrication.

George W. Ianson, Manager, Device Fabrication, Power Operations, Electro-Optics and Power Devices, Solid State Division, announces his organization as follows: **Daniel A. August,** Superintendent, Device Manufacturing; and **Keith E. Loofbourrow,** Manager, Device Engineering.

Professional activities

Forty-four RCA scientists honored at RCA Laboratories

Dr. William M. Webster, Vice-President, RCA Laboratories, Princeton, announced that forty-four scientists have been given RCA Laboratories Outstanding Achievement Awards for contributions to electronics research and engineering during 1982. Recipients of individual awards are:

John G. Aceti, for development of automated inspection systems for VideoDisc caddies.

Leslie R. Avery, for the invention of novel devices for protecting bipolar integrated circuits against electrical overstress.

Dr. Charles W. Magee, for contributions to the field of secondary ion mass spectrometry.

Arye Rosen, for the development of high-performance silicon *pin* diodes for application to communication systems.

Elvin D. Simshauser, for the development of a stereo VideoDisc cartridge.

Recipients of team awards are:

Dr. Roger C. Alig, Dr. Dennis J. Bechis, Hsing Y. Chen, and **Richard H. Hughes,** for the development of advanced electron guns for color picture tubes.

Brian Astle, Michael Keith, Lawrence D. Ryan, Robert J. Siracusa, and **David L. Sprague,** for contributions leading to the development of a recommended industry standard for broadcast teletext in North America.

John P. Beltz, Kenneth W. Hang, Charles J. Nuese, and **Gerard Samuels,** for implementing cost-effective techniques for the production of silicon epitaxial wafers and fully passivated power transistors and thyristors.

Jon B. Berkshire, Bobby J. Rooks, and **Howard G. Scheible,** for contributions to conception, development, and implementation of a novel soldering technique leading to significant reduction in manufacturing defects.

Dr. Scott C. Blackstone, Werner Kern, and **Joseph M. Shaw,** for developing a technology for deposition and control of borophosphosilicate glass films on semiconductor devices.

Anthony W. Catalano, Dr. Joseph Dresner, Dr. James Kane, and **Dr. George A. Swartz,** for optimization of material properties leading to high-performance amorphous silicon solar cells.

Michael T. Cummings, Raymond J. Menna, Robert W. Paglione, Dr. Barry S. Perlman, Stewart M. Perlow, and **Herbert J. Wolkstein,** for the transfer of essential technologies and skills for the fabrication of solid-state power amplifiers for RCA's all-solid-state communications satellite.

Dr. Ronald E. Enstrom, Maxwell M. Hopkins, Dr. Arthur Miller, and **Dr. Rabah Shahbender,** for the elucidation of measuring techniques useful in strengthening glass vacuum structures such as color television picture tubes.

Peter D. Gardner, Stuart T. Jolly, Dr. S. Yegna Narayan, and **John P. Paczkowski,** for contributions to the development of gallium indium arsenide field-effect transistors for microwave and logic applications.

Dr. Srinivas T. Rao, and **Louis Trager,** for contributions to the technology of copper electro-deposition leading to improvements in VideoDisc mastering.

Two Laboratories scientists are officers

Albert P. Pica is the new Chairman of the Princeton Chaptaer of the ACM. **Douglas F. Dixon** will continue as Chairman of the IEEE Computer Society.

Credelle is program chairman

T.L. Credelle has been named Program Chairman for the 1984 Society for Information Display International Symposium, which will be held June 4-8, 1984 in San Francisco, Calif. This conference is a forum for the presentation of new developments in all types of display technologies including CRTs, liquid crystals, electroluminescence, and plasma. In addition, new display systems and applications are described.

Technical excellence

MSR announces first-quarter 1983 technical excellence award winners

At Missile and Surface Radar, the Technical Excellence Award review for the first-quarter 1983 yielded four winners.


Jankowski


Judd


Maron


Miamidian

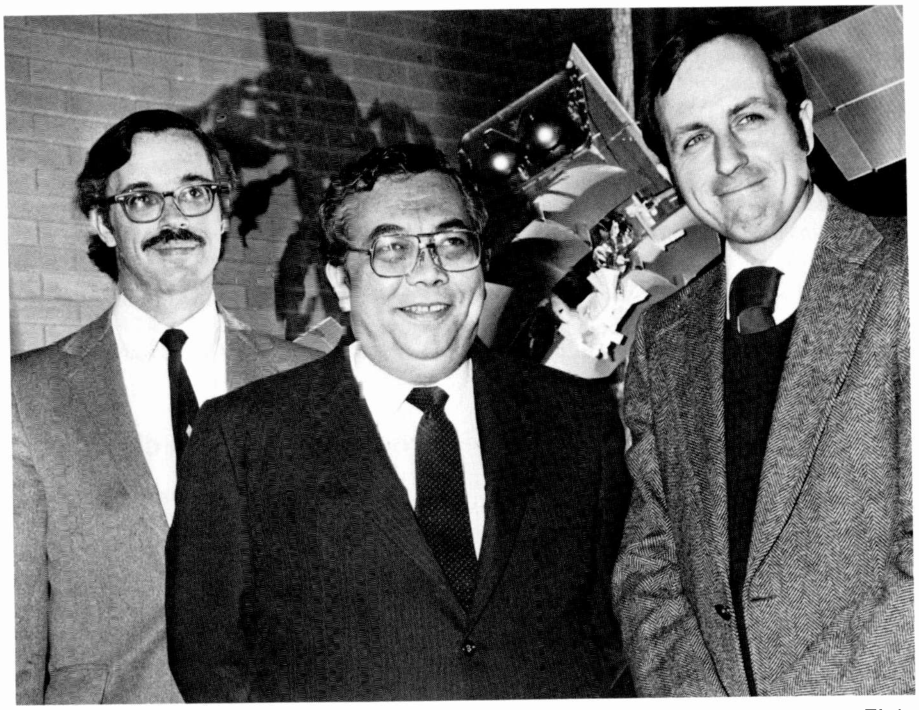
Margaret M. Jankowski—for innovative approaches to determining levels of availability to be expected from off-the-shelf computer candidates under consideration for the FAA Air Traffic Control Host Computer System. Using actual reliability/maintainability/availability (RMA) data, she applied analytic and extrapolation techniques to obtain failure rates. The results provided a sound basis for FAA evaluation and modification of RMA requirements for the Host Computer System.

James E. Judd—for outstanding achievement in the design and development of a floating-point arithmetic unit to augment the RCA Control Processor (RCP) in support of the R-76C5 Gun Fire Control Program. He was presently responsible for all phases of unit development, including generation of 500 lines of microcode. Mr. Judd's innovtive design exceeded expectations and will significantly enhance the overall capability of the RCP in its application in planned military systems.

David E. Maron—for developing a 1200-line FORTRAN ballistics program to generate gun fire control orders for the R-76C5 project. His work also involved development of simulators and testing the program against published range tables. In the process, he discovered and corrected a significant error in the Navy report used as the basis for the program. Mr. Maron's program is successfully being used to generate gun orders for the R-76C5 project, with planned use for similar systems.

Leon R. Miamidian—for creative development of an adaptive target tracking filter for use in the R-76C5 system to smooth target data and predict target position. With no previous experience in track-while-scan systems, he studied the available literature and developed the program using the best features of several candidate systems. He also simulated and tested the program to optimize it and to determine filter performance. The resulting program is being used directly in the fire control computer of the New Zealand R-76C5 system.

RCA Americom announces first-quarter 1983 technical excellence awards

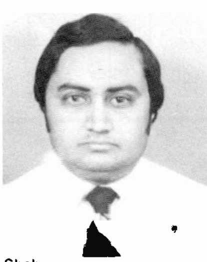


Americom's Technical Excellence Award team of (left to right) John Kornele, Field Operations; Edward Maxey, Manager, Field Operations; and James Colonna, Systems Engineering.

Jim Colonna, John Kornele, and **Ed Maxey** received the first-quarter 1983 Technical Excellence Awards given by RCA American Communications, Inc. **John Christopher,** Vice-President, Technical Operations, cited these engineers "for excellence in developing and implementing plans to switch traffic from satellite to satellite or transponder to transponder so that Americom's high-quality traffic standards continue to be met under a variety of anomalous spacecraft conditions."

This team's efforts required detailed engineering, precise timing and execution, and the coordination of many different functions and activities within Americom under tight schedule. Team accomplishments included the shifting of Government traffic from the F2 to the F1 spacecraft when power on that spacecraft was diminishing; the switch of traffic from the F2 to the F5 when that satellite became operational; and the switch of traffic from the F1 to the F2 as was required when the F1 stationkeeping ability was degraded. All of the above was accomplished with no service outages or inconveniences to customers. In addition, the team continues to respond to real-time service problems.

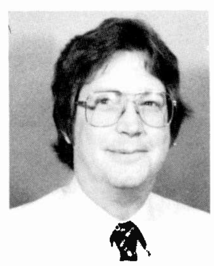
Consumer Electronics gives first-quarter 1983 technical excellence awards



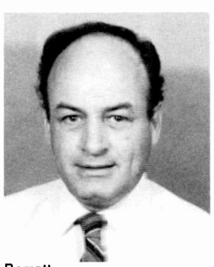
Shah

Benson

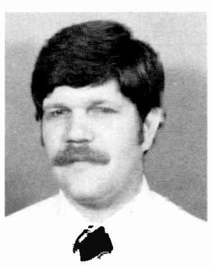
Chen



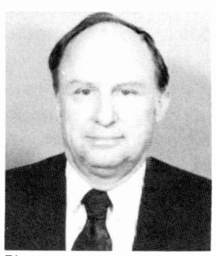
Jackson



Barrett



Eastlake



Rigsbee

First-quarter Technical Excellence Awards were announced by **Dr. J.E. Carnes** at Consumer Electronics. Based on managers' recommendations, the recipients' work was researched by the Technical Excellence Committee. The nominating managers were then interviewed and selections for awards were made.

Kashyap Shah and **Walt Benson**—for outstanding effort in the design, development, and implementation of RCA's first fully automated robotic spray-painting system.

Joseph Chen and **Jim Yu**—for exceptional team effort and innovation in the development of a cost-effective, yet feature-enhanced signal-seek tuning system for television.

Dave Jackson—for exemplary dedication and thoroughness in analyzing deflection and power-supply reliability problems that led to an improved understanding of and corrective action for a number of complex failure mechanisms.

Robert Barrett, Dan Eastlake, and **William Rigsbee**—for outstanding innovation and thoroughness in the development of a unique high-voltage-transformer mold-cleaning machine.

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*Murray Kaminsky	Cherry Hill, New Jersey	222-6247
Dick Dombrosky	Cherry Hill, New Jersey	222-4414
Ray MacWilliams	Cherry Hill, New Jersey	222-5986

"SelectaVision" VideoDisc Operations

*Nelson Crooks	Indianapolis, Indiana	426-3164

Solid State Division (SSD)

*John Schoen	Somerville, New Jersey	325-6467

Power Devices

Harold Ronan	Mountaintop, Pennsylvania	327-1633 or 327-1827

Integrated Circuits

Dick Morey	Palm Beach Gardens, Florida	722-1262
Sy Silverstein	Somerville, New Jersey	325-6168
John Young	Findlay, Ohio	425-1307

Electro-Optics and Power Devices

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J.R. Reece	Marion, Indiana	427-5566

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RCA Engineer

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