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GEOTHERMAL BRINE STUDIES

SCIENCE AND TECHNOLOGY

TECHNOLOGY TRANSFER: COMMERCIAL INNOVATION FOR LLL RESEARCH AND DEVELOPMENT

For many years, LLL has been transferring information about nuclear technology to universities, industry, and governmental agencies. Now, under ERDA auspices, these activities have been widened to include other energy technologies and commercial innovation: transfer of our R&D technology to the civil marketplace through and in cooperation with industry. Two recent successes have proved to us the workability of commercial innovation with substantial benefit to ERDA and the marketplace. We foresee the need for new incentives to foster commercial innovation throughout the ERDA organization.

When Congress created the U.S. Energy Research and Development Administration, it mandated a new approach to meeting national energy needs. Gradually this mandate has been given direction through statements by Dr. Robert Seamans, the ERDA administrator, and by other key officials of the federal government (see box on next page). They define ERDA's primary research and development goal as providing the energy technology options to enable the U.S. to meet its growing energy needs. The goal will be achieved through a sweeping technology utilization program that involves developing, demonstrating, and commercializing viable technologies for increasing U.S. energy supplies.

LLL and the other national laboratories have been participating, since 1973, in a technology utilization program started by the U.S. Atomic Energy Commission. But the ERDA program introduces two important changes. First, ERDA's mission has wider scope; it encompasses solar and geothermal energy, fossil fuels, and conservation as well as nuclear energy. The AEC's mission was more narrowly restricted to nuclear energy. Second, ERDA's mission emphasizes commercialization: the process by which technologies reach the marketplace through and in cooperation with industry. Industry is seen as the co-developer and eventual supplier to the user. Responsibilities and, in many cases, the final costs for commercial development are shared between government and industry.[7] Thus ERDA is conceived as an outreaching organization that must be capable – in itself and through its agencies, such as the national laboratories – of dealing with a diversity of constituents and users in civil life.

One emerging emphasis of the ERDA technology utilization program is the systematic transfer of specific technologies. Another is to identify the barriers that inhibit technology transfer and to devise means for overcoming them. Priority is given to people-to-people transfer and to the establishment of effective transfer channels.

Technology Transfer Concept

The ERDA concept of technology transfer is illustrated in Fig. 8. In performing its missions, ERDA creates technologies or areas of technology that must be transferred to the marketplace. But these missions are by no means completed at this point. ERDA still has to foster amplification of the technology through commercial innovation. In general, commercial innovation is viewed as encompassing all activities that help to bring about the first commercial application of an ERDA technology. It begins with a perceived need for the technology and ends when industry delivers the technology to the marketplace.* Contributing to this amplification process are infusions of capital, knowledge, and technology from industry and from other governmental agencies.

Once commercial innovation is accomplished, the aim is for the technology to become a self-sustaining part of the economy. The amplified technology diffuses to the public, strengthening the national economic and industrial bases. Finally, ERDA draws feedback benefits from the amplified technology to optimize its missions, and the process begins again.

This concept is analogous to commercial marketing. The user – the ultimate customer – must need the technology. Industry must provide the practical solutions to large-scale manufacturing and marketing. ERDA must provide the technological options through

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*The full definition is delivery of the technology to the user in the marketplace such as to satisfy the user's objectives in his own operations.

its research and development programs. The aim is to facilitate and accelerate a loop by which concepts and processes mature in the marketplace and are then available to help ERDA in advancing new technologies.

The emphasis here is on commercialization, although technology utilization can involve other transfers such as planned program applications and spinoffs. When a technology is applied in the field for which it was devised, the transfer is defined as a planned program application (mission). When it is applied in a different field, the transfer is a spinoff. For example, we developed atmospheric radioactive-fallout transport codes under the Plowshare nuclear-cratering program. Their use for Plowshare applications was a planned program mission; their use to model nonradioactive air pollution in the San Francisco area is a spinoff. Spinoffs usually entail, as in this case, a certain amount of adaptive engineering to fit the existing technology to the new field.

This example also points up another distinction. By their nature, some program missions and spinoffs are very specific and suited only for social and governmental regulatory purposes. Even though their economic impacts may be sizeable, as in air-pollution modeling, they do not involve commercial innovation. This is not to denigrate such transfers but rather to point out that ERDA's technology utilization program requires an approach of considerably greater scope and magnitude.

DR. SEAMANS' VIEWS OF THE ERDA MISSION

"We have a very great responsibility to get our programs out into industry. The final result we are trying to achieve is not to carry out excellent development programs but to have the work utilized. The way to do that is to get the major developments carried out by industry working with us....The large demonstration plants, for example, I would not conceive of having done in-house [purely within the ERDA establishment]....On the other hand, the research-oriented jobs lend themselves very well to our existing Government laboratories, and they should be utilized for these tasks....There has to be a proper balance between the two, and here is where the judgment comes in on how we manage our programs.

"All of the information that comes in as a result of Government funding is in the public domain, and it is up to us to make it available. How you make it available, when you have a tremendous body of information, is difficult, and we are still trying to work out more efficient ways of doing this....I am sure we can improve the process...in part by having people in ERDA who have experience – scientific, technical, and industrial experience....We must take into account what industry is doing in R&D and not just duplicate that.

"I think, if we do our job correctly, that industry will inform us of programs they have under way [even] of a highly proprietary nature....We do not have to in any way jeopardize a proprietary interest of a company that comes in to work for us....When it comes to patents, we do observe proprietary interests of companies that have patents, before they initiate work with us....If we enter into a joint arrangement with a company, and patents come out of it, then we can jointly – the Government and industry – share in the licensing arrangements that come of that...on an equitable basis.

"The AEC had very restrictive policies in this area. With ERDA we hope to come up with a more liberal policy [whereby] judgments can be made on the basis of...which corporations are really prepared to use the technology and move it ahead. This does permit the Administrator to exercise waivers that would permit exclusive rights to be given for certain periods of time to a company to make use of patents....It is his job to promote the use of the technology as efficiently and rapidly as possible....But we do not want to take over the contractor's patent rights....I believe that, in a truly proprietary case, the proprietary information would not be revealed.

"My personal view is that [industrial managers and scientists] have been very forthcoming when dealing with the senior people in ERDA, which I think is the right way to do it....The whole advisory function we have set up in ERDA – for example, we have an excellent group advising us in fossil fuel – is a way of keeping abreast of what is going on....I think, by using all the mechanisms that we have to use and using them wisely, that we are reasonably current on what is going on in this country, as well as what is going on abroad."

–Testimony of Dr. Robert Seamans, ERDA administrator, in hearings before a House subcommittee of the Committee on Appropriations, Washington, D.C., 1975.

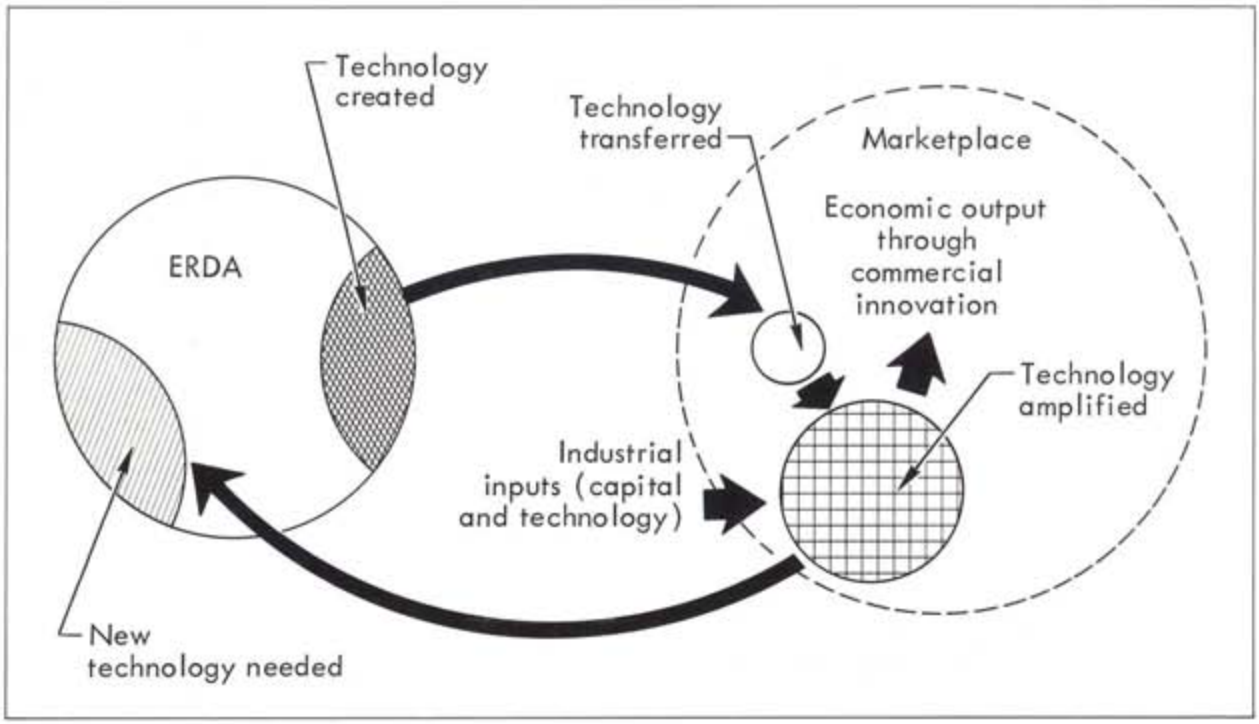


Fig. 8. The ERDA concept of technology transfer. In performing its missions, ERDA creates technologies that must be transferred to the marketplace and amplified through commercial innovation. Amplification begins with a perceived need for the technology by industry and ends when industry delivers the technology to the marketplace. The amplified technology then diffuses to the public and is available to help ERDA in advancing new technologies.

LLL Activities

From its inception in 1952, this Laboratory has been transferring information to universities and industry as an indirect consequence of work with faculty and graduate students and with vendors supplying hardware and services. These activities have expanded in recent years. We have established strong ties with various industrial and trade associations and with the states of California and Hawaii. Livermore is frequently the site of technical workshops, symposia, tours, etc., related to the purposes of technology utilization.

Now these functions are being further expanded and channeled by a comprehensive Laboratory-wide technology transfer program that includes selected reimbursable projects, sponsorship of conferences and topical workshops, and activities aimed at encouraging potential suppliers and users of LLL technology. These activities include personal contacts, special training courses, and the dissemination of technical information on request. As we gain experience in technology transfer – as for example from the following two case studies – our local program is taking shape.

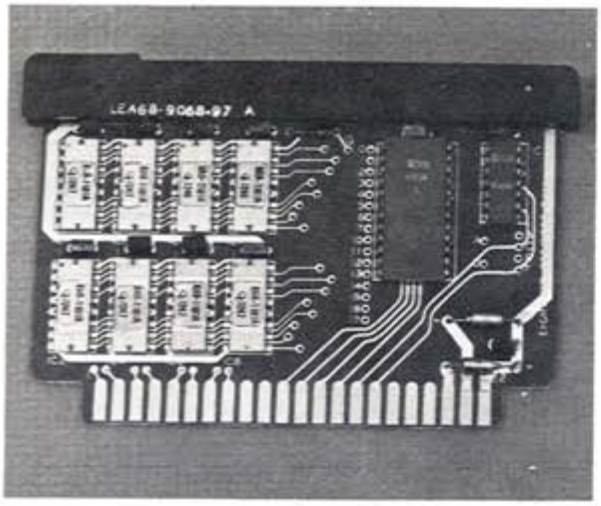
Microcomputers. By the early 1970's, LLL had become a large user of digital microcomputers and control systems in its laboratories and shops. Because of many unique requirements, nearly all these systems were custom-designed and assembled by our engineering departments. Facing increasing costs and complexities, we undertook to develop a relatively small number of standard digital-circuit modules (Fig. 9) that could be combined into a large variety of system configurations. This approach, described in greater detail in the article beginning on p. 12, proved very successful. By adopting the standardized modules as regular stock items, LLL was able to buy them in large enough quantities to offer a substantial market for interested vendors.

Certain vendors, recognizing the broad commercial potential of the modular system approach, took advantage of the LLL market to create commercial versions of our designs. These then formed the basis for spinoff catalog items now commercially available and in widespread use. Many of the commercial units, incorporating the most recent advances in chip-semiconductor technology, are less expensive than

the original LLL designs. Some units have been altered to reflect specific needs of users in the marketplace.

From this experience, we gained several insights. First, a feedback-loop transfer was created with substantial benefit to LLL and the marketplace, at little cost to LLL. Second, we learned that although we can effect cost savings and operating efficiencies by standardizing the production of, say, 50 units, manufacturers experienced with 5000-unit production runs can make considerable further economies and performance improvements. In this case, these benefits obtained from the interaction between suppliers and users; LLL was not involved. This is an aspect of technology transfer that is often overlooked.

We can foresee situations, however, in which the Laboratory should remain involved in the supplier-user interaction: for example, in the event of patent complications or where the function of the unit might be impaired by production changes. But neither situation applied in this case.



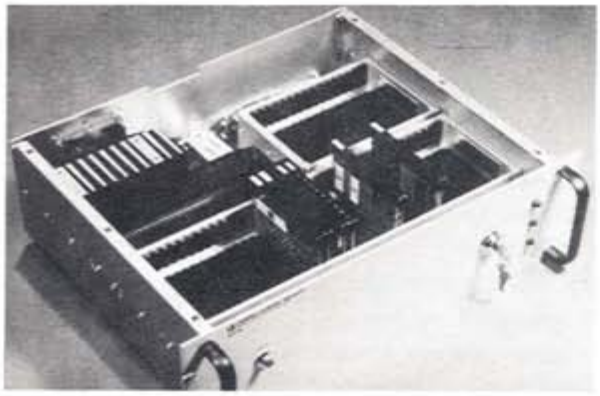


Fig. 9. Typical RAM – random access memory – circuit module (top) originally developed by LLL and later marketed commercially. Memory and special-function modules are added to the basic computer section, tailoring the computer to specific research needs. All modules fit into a standard chassis (bottom) that also houses the basic computer circuit boards.

Laser Fusion Symposium. Another example of successful commercial innovation by LLL occurred last December in our laser fusion program. We conducted an intensive two-day symposium on solid-state laser components, assembly problems, and design details for a specific high-power laser amplifier. Invitations were sent to 250 top-level managers at firms and institutions with a known interest in laser technology. We also advertised the meeting in *The Wall Street Journal* to reach firms whose possible interest in lasers was unknown. In all, 32 companies and institutions responded, sending 56 representatives to Livermore for the meeting.

The purpose was to consolidate information and to transfer practical technology from our 14-year-old laser fusion program, which has grown from a modest weapons-program adjunct into a $22-million effort.[8] The range of developments included coordinated engineering and fabrication projects in optical components, greatly improved optical materials and processing techniques, and major advances in several supporting technologies (e.g., precision machining, fast-transient diagnostic systems, and large high-energy pulsed power systems) originally devised for nuclear weapons work. LLL spearheaded these laser-related developments but, wherever possible, assigned the fabrication designs and the actual building of components and subsystems to outside companies through regular procurement procedures. Several firms thus became proficient as suppliers of advanced-state components and subsystems, but none had enough information to build complete high-power systems of the kind needed by LLL.

As the first step in filling this gap, LLL prepared a set of papers describing our current solid-state laser technology to the level of detail needed by hardware manufacturers, for distribution at the meeting. This was an intensive one-month task. LLL's legal and patent offices and ERDA's San Francisco Operations Office completed arrangements for authorizing the symposium, clearing the papers for public release, and providing standard agreement forms for use by companies seeking further information and assistance.

Arrangements were made for tours through the laser facilities and the shops making the laser equipment.

An important feature of the symposium related to the steps taken to ensure maximum interaction among the visitors and LLL personnel. For example, the Laboratory provided at least one technical staff person for every two visitors to answer questions, join in discussions, or guide the visitors' attention to important details. In the facility and shop tours, the visitors were encouraged to converse with engineers and shop personnel so as to become acquainted with experiences of the individuals who build and use the laser systems (Fig. 10). We also arranged various activities that encouraged an informal exchange some participants found even more valuable than the formal exchanges (Fig. 11).

It is now known that – as a result of the symposium, previous experience with LLL as a vendor, and subsequent exchanges of information – one of the attending companies successfully bid on delivery of a high-power laser amplifier system to the United Kingdom. Two or more of the other attending companies are expected to receive subcontracts for components. Thus there has been a commercial innovation for LLL laser technology in the full sense defined earlier.

Fig. 10. Facility and shop tours during the laser fusion symposium were conducted in small groups, such as the one shown above. Visitors were encouraged to talk with LLL engineers and shop personnel to learn firsthand their experiences in building and using laser systems.

Fig. 11. Many symposium participants found informal exchanges as valuable or perhaps even more valuable than the formal talks and discussions.

Needs and Incentives

These two examples of the commercial innovation of ERDA/LLL technology show that technology utilization works under past and present policies and organizational structures. But, as indicated earlier, ERDA expects a great improvement in the effectiveness of the process. For this to be accomplished, changes in policies, attitudes, and practices will be required not only within ERDA but also in the national laboratories. We must become more knowledgeable and sensitive to the needs as viewed by our ultimate user – the marketplace customer. We will have to appreciate our necessary involvement as sources of technology and learn to work effectively with the suppliers: those who deliver the technology to the marketplace.

From our vantage at LLL, we believe that ERDA and the national laboratories should establish small cadres of people trained and experienced in marketing and should foster arrangements for working with outside marketing organizations, both public and private. We believe that many new incentives are needed to encourage commercial innovation, such as improved patent policies and practices, and recognition of the key individuals who facilitate the innovative process. Finally, the funding support for commercial innovation should be appreciably increased. This last change is crucial if the successes described here are to become routine achievements of the ERDA organization.

Key Words: technology transfer; technology – utilization; technology – commercialization.

LLL has pioneered a system for making user-designed microcomputers, from off-the-shelf modules, that are tailored to specific research needs. The system is based on stockpiling standard printed-circuit modules containing the major computer functions: central processing units, memories, and input/output interfaces. Backing up the system is a video-taped instruction course enabling potential users to design their own microcomputers, draw the necessary components from stores, plug them together into standard connector cages, test and debug the resulting systems, and produce working microcomputers uniquely suited to their needs.

In one generation, computers have undergone a remarkable transformation. Bulky, power-consuming vacuum tubes have yielded to transistors and these in turn to integrated circuits. Large-scale integrated circuits containing thousands of individual circuit elements have been introduced. Now it is possible to compress an entire programmable computer onto a single printed-circuit card that can be held in one hand.

This trend has had its drawbacks. A lot of effort and money must go into designing such computers. Once done, it is natural to try to spread the investment over large numbers of identical units. Designs have tended to become fixed. Users seeking anything out of the ordinary have often faced three choices: buy unnecessarily complex and expensive units to get the desired features, work within the limitations of inadequate equipment, or redesign a new computer from scratch.

The problem has been especially acute here at LLL, where out-of-the ordinary requirements are routine. Dozens of applications for microcomputers can be discerned, each ideally involving a specific design. Moreover, design requirements often change during the process of laboratory experiments, requiring the addition of new functions or a redefinition of the old.

Modular Approach

Eventually we began to question whether the trend toward ever smaller and more completely integrated computers had gone too far. Instead of putting all the computer-subsystem chips on a single panel, we reasoned, why not separate the major functional segments onto smaller printed-circuit cards? These could then be plugged into a standard array of connectors to make up the complete computer system. Not only would this provide extraordinary flexibility – in that the computer could be fitted with as many memories, interfaces, multiplexers, etc., as needed – but the support electronics would not have to be continuously generated and regenerated. This approach also offered the considerable advantages of standardization, modular maintenance, updatability, and component salvagability.

It was this thinking that led us, in 1972, to develop a standard, modular approach to designing, building, and implementing microcomputer systems at LLL.[9] The primary goal was to provide a complex logic function that could be used for many different research applications without requiring a major microcomputer design for each application.

To realize this "plug-in" concept, each printed-circuit board performing a major subfunction (processor, memory, input/output control, multiplexer) had to be a functionally self-contained unit. It had to be able to draw power from a common power line, feed information (instructions and data) signals throughout the system over a common bus, and provide all the necessary drivers, buffers, timing circuits, etc., for interfacing with the other subsystems by physical connection into any one of a cage-mounted set of connectors.

Based on these requirements, we developed a set of self-contained printed-circuit computer modules. The basic system is an eight-bit microcomputer set that includes the modules shown in Fig. 12. The modules fit into a standard, prewired card-frame assembly suitable for rack mounting, that also houses the cooling fans and power supply. The card frame has a central section for mounting the basic cards – processor, input/output control, and memory address buffer – plus prebussed slots for additional memory and peripheral functions. These include a teletypewriter interface, a paper-tape reader, and a TV-type display. The system requires only minimal backplane wiring.

Microprocessors. The heart of the microcomputer system, the processor, is a programmable, general-purpose integrated circuit equivalent to the central processing unit of a conventional computer. The new microelectronics permit assembly of the thousand or more logic-function elements (gates) that compose a central processor onto an inexpensive semiconductor chip only a few millimetres on a side. This tiny chip is then embedded in a small plastic slab with a row of stiff conductor leads projecting from each side to form a "dual-in-line package." These leads and the flat shape of the slab facilitate the mounting of this package onto a printed-circuit board.

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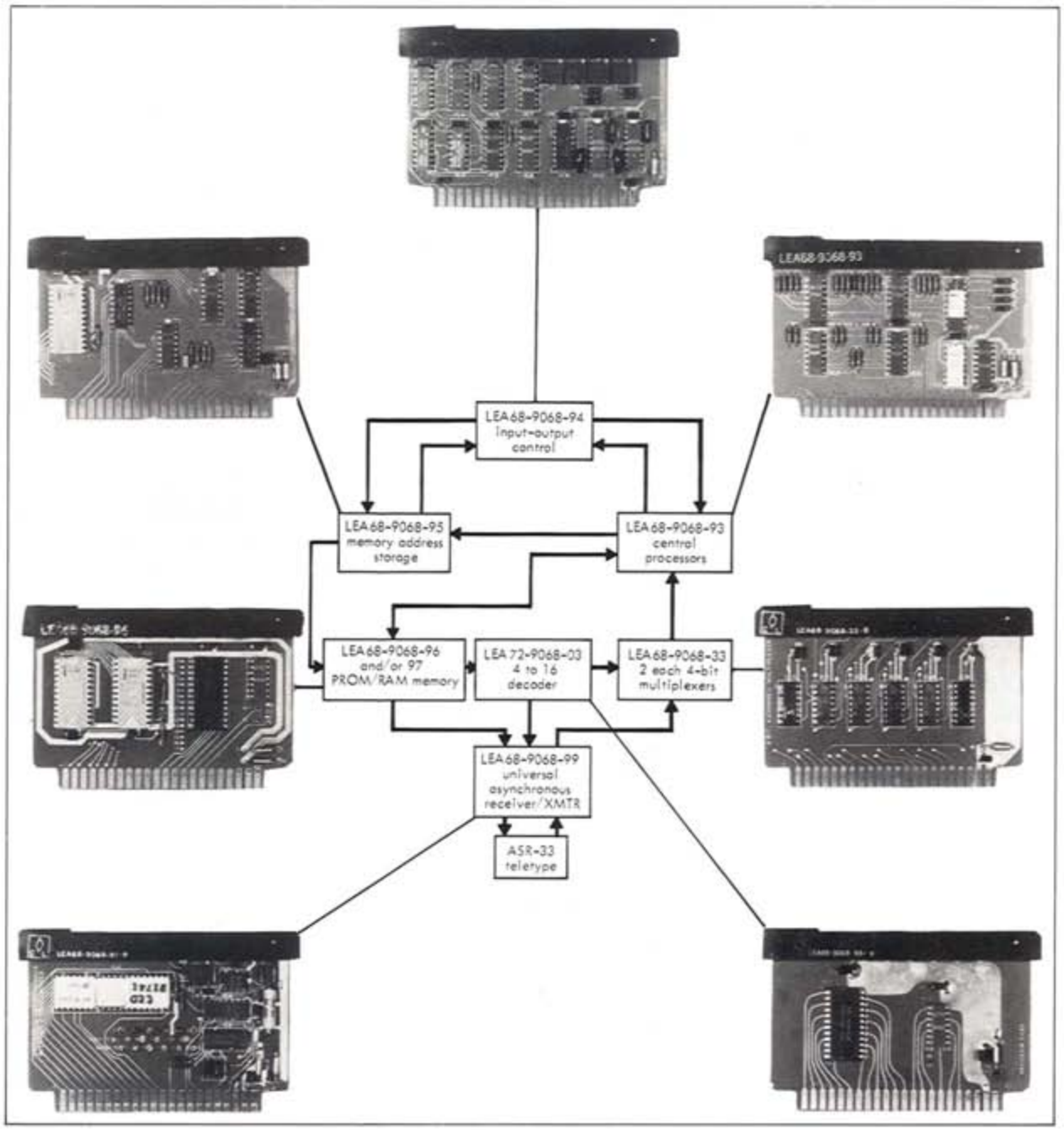

Fig. 12. LLL's modular MCS-8 microcomputer system. Each card is functionally self-contained, drawing power from a common power source, feeding information signals throughout the system from one major functional unit to another over a common bus, and providing the necessary input/output units for interfacing with other computer subsystems.

Micromemories. The other major functional subdivision of a computer system – memory – is also available on chips. Micromemories come in two general types: random-access read/write memory (RAM) and read-only memory (ROM).

Of particular importance is the PROM, a programmable ROM. This micromemory can be erased and reprogrammed as required, thus allowing program modification after debugging. The PROM is often credited with making microprocessors practical by providing this kind of semipermanent memory.

Micro-Interface Elements. Coordination of the processor and the memory requires interfacing elements such as multiplexers, input/output controls, buffers, and clocks. These elements can also be made

in the form of tiny semiconductor chips assembled in dual-in-line packages.

Software. A hidden, vital feature of the LLL microcomputer system is its user orientation. Much effort has gone into providing documentation and instructional materials that enable potential users to design their own systems, on the theory that each individual is the best judge of his own needs and desires. A video-taped lecture series teaches design principles, outlines the broad range of available choices, and offers methods for testing, debugging, and streamlining microcomputer systems.

To facilitate the design process, we have developed a large assortment of logic modules, equipment for programming PROM's, a test bed for checking system configurations, programming aids including simulators and an octal debug technique, and equipment and methods for building new plug-in modules. Standard modules available to the user are fully described in a looseleaf designers' handbook.

A complete line of developed computational routines (software) is also available to LLL microcomputer users on the Laboratory's Octopus time-sharing computer network. Thus the latest software is available to microcomputer designers at a one-time installation cost. The standardization of microcomputer hardware (modules) has greatly facilitated this software-sharing capability.

Evaluation

This modular approach has proved to offer many advantages beyond flexibility. Standardization has simplified over-inventory problems and permitted bulk-quantity buying instead of expensive, time-consuming, one-of-a-kind special purchasing. Also, modular maintenance is a far cry from the laborious point-to-point circuit testing required for some hard-wired systems. We simply isolate an offending circuit card and replace it with an identical card from stock. The cards themselves are so inexpensive that it is seldom worthwhile to spend time for repair. In any case, the computer is back in service while the component awaits salvage.

Another advantage is the ease of incorporating microcomponent advances as they become available, without redesigning the rest of the equipment. Our new MCS-80 unit is a case in point. This ten-times-faster microcomputer system was produced from the older MCS-8 simply by designing a new central processor that incorporates a faster microprocessor chip and by speeding up the timing circuit. All existing memories and input/output devices from the MCS-8 system remain compatible with the new system.

Component salvagability deserves special mention. When a microcomputer has outlived its usefulness or its special function is no longer in demand, its components can be returned to stock as building blocks for a future microcomputer. Even within the microcomputer, salvagability has a role. While the system is in design and evaluation, it is often convenient to keep the program in RAM for easy access and revision. However, once the program is set, it can be transferred to PROM, freeing the RAM for removal from the computer and use elsewhere. This capability provides the extra advantage of indestructibility: the equipment can be turned off indefinitely without losing its program.

The Future for Microcomputers

Where does the future point? Microcomputers are now, and will increasingly be, huge timesavers in solving engineering problems. Future experiments will be made on instruments that can interpretively interact with the experimenter. Virtually every research instrument could contain a microcomputer.

Some indication of the system's value is its rapid user acceptance. At this Laboratory alone, the last four years have seen the development of more than 100 individually designed microcomputers. These systems have ranged from simple programmable monitors to complex arrangements linking two or more microcomputers in combined control and computation functions.

As described in the preceding article, microelectronic manufacturers have been quick to adopt the system, include various modules among their own products, and offer them for sale throughout the world. The resulting economies of large-scale manufacture have reduced the costs of the microcomponents.

Institutions outside LLL have begun to take notice. At least two other laboratories and universities have used the modular LLL microcomputer system (and its documentation) for prototype systems or teaching aids. Local community colleges have offered courses based on this system.[10] This trend may be expected to continue.

Key Words: microprocessors; microprocessors – equipment; integrated circuits.