Standards for microprocessors are becoming increasingly important for military and industrial market expansion. This view, expressed by speakers and participants alike, emerged as a recurrent theme at the IEEE Computer Society's microprocessor workshop on the application of dedicated microprocessors in military and industrial systems. The consensus held, however, that standards must be objectively chosen with applications engineers and user communities involved in the decisions and must be "technology transparent" to provide continuity and support for microcomputer development without stifling innovation.

The goals of the workshop were (1) to probe for insights into the various barriers blocking use of microprocessor technology in military and industrial applications and (2) to explore approaches that might be effective in overcoming these barriers. The workshop thus established a forum for interaction among device manufacturers, applications engineers, users, and standards setters. Held June 27-28, 1978, at the Johns Hopkins University Applied Physics Laboratory in suburban Washington, DC, it proved to be one of the best attended in this series of annual microprocessor workshops. Participating were over 150 professionals from both industry and the military. Paul Hazan was the general chairman, and Tom Nyman was the program chairman.

The two-day interactive workshop was organized into four half-day sessions. Each session concluded with a panel discussion of key issues and involved active audience participation. The first three sessions, on technology, applications, and logistics, provided an up-to-date appraisal of device capabilities, market projections, and support problems. Session chairmen were Robert Hawkins of the Naval Weapons Center, Roger Bate of Texas Instruments, and LTC John Marcinia of the US Air Force Systems Command, respectively. The concluding session on standards was co-chaired by Gordon Force, National Semiconductor, and Capt. Edward Mahen, Office of the USAF Chief of Staff; it explored the issues, opportunities, and pitfalls that standards present.

Session I—accelerating technology

The pace of advancement in circuit components continues to accelerate, motivated by technical challenge, competitive posture, and perceived market opportunities, in that relative order. Logic density on a single chip is forecast to exceed 64,000 equivalent transistors by early 1979. Development costs of new microprocessor designs, already reported to be $1-2 million, continue to escalate. As microcomputer sophistication increases, the need for capable support systems becomes paramount, further driving up development costs.

Based on the speakers' projections, three trends are emerging. First, chip complexity is forcing reduction in design flexibility, such as is available with bit-slice approaches. Architectures (instruction set, input/output, and memory interfaces) are being frozen in chip designs. The device manufacturing industry—up to this time interested primarily in high-volume production runs of unique designs—now appears to be tempered by a move to design devices which satisfy a broad range of applications, each application involving smaller production runs. Device performance capabilities now exceed the requirements of many potential users, and performance compromises are becoming acceptable. On the other hand, the resulting performance tradeoff compromises are becoming more complex and risky for device manufacturers.

Second, an awareness of the importance of design aids and development systems to help the "user" identify microcomputer solutions to his problems is emerging as a critical aspect of microprocessor design. This is particularly true in the areas of higher-order languages and software development and debugging tools.
preter capabilities are advancing also, but major issues relating to user needs remain unresolved.

Third is the trend toward firmware "replacements" for software. Algorithms and subroutines which are general purpose, and thus highly levered across a wide spectrum of applications, are becoming available as firmware read-only memory modules. This trend forces the chip developer to perform more comprehensive and costly software testing and verification to prevent undetected bugs from reaching large production runs of firmware modules. Consequently, the cost and risk to chip developers increases, but the result is a trend toward software embedded in firmware and a strong trend toward software standardization.

New microcomputer products lead market demand, as witnessed by the introduction of technology components ahead of market development. Automotive applications of microcomputers appear to be one of the most highly demanding on device performance. However, this is most likely the result of the automotive industry's taking advantage of technology opportunity and not driven by firm requirements. For example, the question can be posed: Given that we have paid for the microprocessor, can it do anything more for free? Frequently, the answer is "Yes," until the device memory and cycle time are totally exhausted. With respect to environmental performance characteristics for automotive microcomputers, demands regarding temperature, vibration, and moisture tolerance, for example, are at least as stringent as comparable military specification requirements.

The forecasts for the future seem to suggest a slowing down in the pace of new product introductions, at least new products which are not extensions of or compatible with existing products. This is due to the mounting cost of new chip development. At the same time, increased attention is being given to development of "engineering aids" to ease the problems of education within the user community of systems designers. The issue of some Department of Defense-sponsored stimulation of R&D was raised. Because of the high development costs, the very competitive market, and the short life of new developments, it was suggested that some significant front-end DoD funding could provide a much needed boost to the semiconductor industry. The new DoD Very High Speed Integrated (VHSI) Circuits Program was the type of initiative envisioned.

Session II — application trends and opportunities

The opportunities have never been greater for microprocessors—in computation, control, logic replacement, and special functions for industrial processing, defense systems, consumer products, transportation systems, medicine, education, and countless other areas. However, a variety of barriers discourages use of microprocessors in many of the lower-volume application areas. Workshop speakers noted that the largest production volumes of microprocessors are used for fixed-function repetitive applications, such as calculators and TV games. For most of these, the applications design work is performed by the microprocessor houses, not by end-product design engineers. Thus, application design resources are high-volume oriented at the expense of important lower-volume applications.

A small but increasing number of military and industrial electronics systems are emerging with embedded microprocessors performing logic and control functions. Some of these microprocessors are being discovered "after the fact" by maintenance personnel. Avionics systems, where volume, weight, and power are at a particular premium, seem to be leading the way. Because of this lead, several participants suggested that DoD could influence the direction of microprocessor-related products, if it accepted mainstream commercial products but emphasized a requirement for comprehensive support (design, testing, maintenance, upgrade) aids. A DoD speaker described ongoing programs, consistent with this suggestion, to qualify commercial microprocessor families for military use.*

The key barriers to rapid introduction of microprocessors into military and industrial systems, as brought out by the speakers, relate to:

1. concerns for life-cycle supportability (for both military and industrial applications where anticipated system life is 15 years or longer).
2. the need for transfusion of microprocessor concepts and design tools to end-product systems design communities (microchip designers do not generally design military and industrial electronics), and
3. the lack of microprocessor software/hardware design, test, and maintenance aids analogous to "engineering handbooks" used in conventional circuit design.

These last two barriers relate to the question of how much risk a user organization should take in training personnel and acquiring design facilities, when microprocessor obsolescence through continuously changing languages, instruction sets, and architectures is rampant. Clearly some order is needed.

In terms of user requirements, DoD and industry appear to have more in common than is generally perceived. Some military systems do require radiation hardened devices. Fortunately, the two primary approaches to radiation hardening—1L and, to a lesser extent, silicon on sapphire—may also provide performance and economic advantages for industrial and consumer markets. However, a number of military applications, such as radar and countermeasures, require very-high-speed signal processing in contrast to the slower, general-purpose computation more commonly found in commercial applications. Perceptions of software support and documentation needs also differ significantly among military, industrial, and consumer users. Yet another major concern is the lack of consistency in definitions and terminology, which tends to block the transfer of microprocessor technology to electronics end-product design communities.

A final view maintained that the military could influence the microprocessor industry in two ways: (1) by seeding money to influence basic technology directions and (2) by consolidating numerous small-quantity purchases into bulk buys, using functional standards to achieve commonality. The second point was debated thoroughly during Session IV. The consensus was that, while the choice of standards is difficult and major uncertainties remain, standards work is crucial and must be vigorously pursued.

*Already MIL qualified are the 8080A, 6800, 2900; in progress are the 1802 and 9900 families.
Session III—life-cycle supportability

This session brought together speakers from a number of support organizations which are "suffering" through the logistics aspects of microprocessors after they "reach the field." According to the panelists, microprocessor life-cycle support issues tend to be ignored during the design and acquisition phases of new equipment. This is a particular problem for those organizations practicing user maintenance rather than a throwaway philosophy.

Software support presents a much larger dilemma than hardware, although device obsolescence will undoubtedly surface as a future problem. Users who have enjoyed the "luxury" of being able to accommodate mission or requirement changes by making software changes are now discovering software with firmware, this flexibility disappears unless the user maintains special equipment and skills to produce or reload read-only memory hardware modules. This constraint, however, may be a blessing in disguise. The workshop probed a key question: Who should have the capability to rewrite firmware? Support organizations, at least those represented at the workshop, would like to have firmware reprogramming capability as part of field support.

Another important operational question discussed was testing—in the field. DoD experience indicates that 69% of recent solid-state electronic equipment removals were unnecessary, that is, the failures could not be reproduced in test, and the equipment was reinstalled without repair. With microprocessors, will the problem be even worse?

But perhaps the key supportability issue is the matter of describing in a functional manner what the processor actually does. In the past, when all else failed, the field technician could trace and test the circuit point by point. This approach is not possible with microprocessors. Thus, formal descriptions of some sort will be needed, but the nature of this documentation has not been established. In fact, with respect to the entire life-cycle support area, problems are recognized but approaches to solving them have not yet been defined or accepted, let alone implemented. The session closed with a discussion of issues and areas requiring more analysis and community interaction.

Session IV—standardization or chaos

This final session presented the ongoing efforts to evolve microprocessor-related standards and, based on issues generated during the three earlier sessions, debated the benefits versus drawbacks of various standards and commonality approaches.

In general, it appears that the user community, as well as the microprocessor manufacturing industry, would accept (even welcome) some standards. The issues are what standards to adopt and who might benefit competitively. The suggestion that DoD could provide the impetus for some standardization surfaced many times. The consensus appeared to be that standards for hardware should be functional or interface standards, not "build to print" standards. Thus, new technology could be introduced without requiring changes to standards, and increasingly expensive R&D could be focused and levered along fewer divergent paths.

Several approaches to standardization were discussed. First, a master plan featuring a family of standard buses for interconnection of processor, memory, and I/O functions was described. A second approach highlighted a modular architecture, which emphasized a common bus and permitted attaching various combinations of simple to complex memory, processors, and I/O components to the bus. This approach has been demonstrated in hardware, and thus validates the concept of a microprocessor bus standard serving a variety of processing applications. The idea of a standard military microprocessor architecture was also debated. Advantages included volume purchasing power and logistic support cost savings; the disadvantage appears to be a risk of not following the commercial mainstream. An alternative approach focused on high-order language standards rather than architecture standards. The DoD Ada HOL is being developed to serve programming needs for real-time processing including microprocessor applications, and is an example of one potential microprocessor HOL standard.

Finally, participants were exposed to the considerable scope of IEEE standards initiatives now underway, specifically microprocessor instruction sets, microprocessor relocatable software formats, and microprocessor buses. Progress has been made in drafting standards, but much coordination work remains. The IEEE Microprocessor Standards Committee, under the leadership of Robert G. Stewart of Stewart Research Enterprises, Los Altos, California, will continue to lead the way by providing a forum to exchange views, discuss standards proposals, and champion acceptance of uniform standards. Bob Stewart or Paul Hazan should be contacted for additional information.

Summary—three main barriers

Of the many barriers restricting the rapid, beneficial application of microprocessor technology to military and industrial use, three surfaced as particularly significant. The first relates to the long development cycle, especially for DoD applications, which delays the fielding of new hardware. One method described at the workshop to partially overcome this development cycle delay would take advantage of the logistics maintenance and upgrade process, wherein old circuit boards are replaced with new boards containing microprocessors. The benefits in reliability, power, weight, cost, and self-diagnosis capability could be significant.

The second barrier relates to education of the end-products design community. Microprocessors would certainly be used more widely in new designs if designers felt comfortable using them. Design aids, such as software development systems, logic analyzers, emulators, and high-order languages, will help. In addition, some stability in languages and architectures is needed.

The third, and probably most meaningful, conclusion was that some microprocessor standardization can be beneficial and needs to be proposed, and that the microprocessor industry is becoming increasingly willing to accept it. Central to this need for standards is user concern for life-cycle supportability of industrial and military electronic systems which contain embedded microprocessors and microcomputers. Such standards as bus interfaces and protocols, language, component interchangeability, or functional description can play a key role in overcoming these concerns, as long as the standards are intelligently applied and not unilaterally decreed.