REPORT OF
DEPARTMENT OF DEFENSE
ADVISORY GROUP ON ELECTRON DEVICES

SPECIAL TECHNOLOGY AREA REVIEW ON COMMERCIAL OFF-THE-SHELF ELECTRONIC COMPONENTS

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FOREWORD

Periodically, the Advisory Group on Electron Devices (AGED) conducts Special Technology Area Reviews (STARs) to better evaluate the status of an electron device technology for defense applications. STARs strive to elicit the applicable military requirements for a particular technology or approach while relating the present technology status to those requirements. The STAR culminates in a report that provides a set of findings and recommendations which the Office of the Secretary of Defense can utilize for strategic planning. The content of each STAR is tailored to extract the appropriate data through preparation of "Terms of Reference."

This STAR on Commercial-Off-The-Shelf (COTS) electronic components was conducted on 4 and 5 December 1997 at the Naval Research Laboratory, Washington, DC. Its objective was to gather information which would allow the AGED to assist the Department of Defense (DoD) to identify and distinguish between three classes of electronic components for use in DoD systems. These classes of components are: (1) those components which are available as COTS products and can be effectively used without further R&D investment or logistics support, (2) those in which modest DoD R&D investment can extend the performance and/or military robustness (i.e., COTS adapted for military purposes), and (3) those custom electronic and electro-optic ones which have performance or environmental characteristics that will result in clear advantages for DoD warfighting systems compared with those of our potential adversaries. The components in the latter category are ones that may require DoD R&D investment to allow them to meet the performance challenges of DoD systems required by military mission statements. The STAR also sought to examine those factors necessary to create new COTS components, needed by DoD, for availability in the longer term. This report documents the findings of that STAR including a review and assessment of the use and potential use of COTS electronics components in DoD weapon systems.

Presentations were made by a distinguished group of experts from industry, academia and government. The plenary session provided an opportunity to hear the views of Dr. Jacques Gansler, Undersecretary of Defense for Acquisition and Technology; Dr. Richard VanAtta, of the Institute of Defense Analyses; Mr. John Young, a professional staff member of the Senate Appropriations Committee; Mr. John Hartman of the Hughes Aircraft Company who represented the Electronic Industries Association; and Dr. Thomas McGill, a professor at the California Institute of Technology, concerning the use of COTS processes and products in implementing DoD systems. Because of illness, Dr. McGill participated by audio and video hookup from the California Institute of Technology. Following the plenary session, several panels of experts were convened to discuss various aspects of the implementation of COTS technology in DoD systems. This format, used for the first time in an AGED STAR, encouraged maximum interaction between experts on the AGED COTS STAR panels and other participants.

On behalf of the Advisory Group on Electron Devices, I would like to take this opportunity to express my sincere appreciation to all of the people who took part in this study – listed in the following section – for their valuable contributions. This applies particularly to

Dr. Susan Turnbach, ODUSD(S&T)/SS, whose support and encouragement were essential for the successful completion of this effort. I would also like to extend my thanks to Dr. Gerald Borsuk, a member of the COTS STAR Executive Committee, from the Naval Research Laboratory, for proposing this STAR topic and doing so much to assure a successful meeting. In addition, the other members of the COTS STAR Executive Committee, Mr. Robert Bierig, Dr. Barry Dunbridge, Dr. Thomas Hartwick and the Executive Secretary, Mr. Eliot Cohen, are also thanked and commended for significant contributions to this study. Their expertise helped immensely in the preparation of this report.

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Executive Summary

The Advisory Group on Electron Devices (AGED) held a Special Technology Area Review (STAR) on the use of Commercial Off-the-Shelf (COTS) electronic components in DoD weapon systems. This STAR was held on December 4 and 5, 1997 at the Naval Research Laboratory in Washington, DC. A large number of distinguished plenary session speakers including Dr. Jacques Gansler, Undersecretary of Defense for Acquisition and Technology, presented their views on this topic. Following is a summary of the major findings and recommendations resulting from this STAR:

KEY FINDINGS AND RECOMMENDATIONS FROM COTS STAR

Findings:

It is recognized that appropriate use of COTS electronics components during development of new systems and system upgrades is essential to reduce costs in order to stay within shrinking acquisition budgets, maintain technology currency as system life cycles shorten and balance the needs for high system performance with acceptable costs. However, it is also unequivocally clear that, although COTS usage will continue to expand, the need for military-unique components to maintain warfighter superiority will not disappear. **There is and will continue to be a need for the DoD to invest in electronics R&D. The benefits of this investment are clear and compelling.**

Need for Defense Unique Components:

- **With the continually shrinking market for defense components, it is unlikely that commercial suppliers will develop military unique components without direct funding support and guidance from the DoD.**

- **The following are examples of defense unique components which will require continuing DoD R&D investment in order for the U.S. to maintain military superiority:**

  ⇒ High performance, high frequency, wide bandwidth microwave electronics (2 to 200 GHz)
  ⇒ High bandwidth analog-to-digital converters (0.5 to 20 Gsps)
  ⇒ Devices and components for operation at very high temperatures
  ⇒ Electro-optic IR imaging arrays, EO components for missiles, and related components
  ⇒ UV/IR Detectors
  ⇒ Radiation-hardened integrated circuits for space
  ⇒ High power RF sources - solid-state and vacuum (5 to 100 GHz, 1 to 1000 Watts)
  ⇒ MEMS for miniature UAVs
  ⇒ Electronically steered antenna arrays for multiple agile beam forming
  ⇒ High performance, highly integrated packaging and interconnect MCM technologies

- Without an enhanced continued U.S./DoD S&T investment in these types of military-unique technologies, the military superiority the U.S. has enjoyed in the latter part of the 20th century will gradually disappear in the 21st century, simply because superiority translates to time lead. This 5 to 10 year time lead must be provided by unique technology that is not available to potential U.S. adversaries, and difficult to reverse engineer in a short period of time.

- It is desirable to make use of commercial processes and practices, to the maximum possible extent, to produce needed military-specific electronics parts.

<u>Use of COTS:</u>

- It is desirable to use COTS components to the maximum extent possible when they meet system performance and environmental requirements.

- The balance between COTS exploitation and military-unique electronics technology needs in the 21st century will vary with the type of platform and segment of the weapon system (sensor-processor-network) being built.

- A serious problem encountered with the use of COTS parts is the inability to purchase them as system production progresses because they are discontinued by their manufacturers. This problem often occurs as a result of rapid changes in technology.

- Adequate reliability and durability must be assured when using COTS to meet the requirements for long DoD system lifetimes and to avoid system failure during missions.

Recommendations:

- **A clear U.S. and DoD long-term policy of support for robust military-essential electronics science and technology investment should be established by the DDR&E with Service concurrence by October 1, 1999, traceable to military superiority needs. Responsibility must be assigned within DoD to implement the developed policy, with coordination and contributions from other government agencies (NASA, DoE, DoC).**

- **It is essential that DoD provide sufficient funding to adequately support the development, production and availability of military unique components, needed in DoD systems in order to provide our warfighters with a competitive advantage compared with their adversaries.**

  DoD must continue to make significant and often long-term S&T investments in many electronics technology areas to assure that its competitive military position is maintained – these **investments must include funds to transition successful R&D achievements from proof-of-concept demonstrations to products that are affordable and readily available for use in DoD systems.** A plan for transitioning R&D results to manufacturing should be developed by the DDR&E and implemented by the Services by December 1, 1999.

- **A strategy must be developed for the design and production of dual-use electronic components and processes. By doing so, significant savings and increased efficiency will result as well as improved yield.**

  DoD must innovate and experiment with approaches to leverage commercial processes and production lines to obtain the products it needs at an affordable cost.

- **COTS electronics components should be used, for new systems and system upgrades, when satisfactory levels of performance and reliability can be achieved from them, to reduce costs while meeting needs for high system performance.**

  The scope of parts warranties must be documented in writing by parts manufacturers and clearly understood by DoD system program managers. The organization responsible for meeting warranty obligations and the time period of the warranty must be clearly identified. Parts must not be operated in violation of warranty conditions.

  A decision must be made at the inception of a system design to procure a lifetime supply of required parts or plan for periodic upgrades, making necessary hardware/software upgrades to accommodate new part types or technologies as they become available.

- DoD should leverage:
  - ⇒ commercial fabrication capabilities
  - ⇒ commercial system design processes
  - ⇒ commercial management and technology development approaches
  - ⇒ by dovetailing military development with the full spectrum of commercial development processes

REPORT OF SPECIAL TECHNOLOGY AREA REVIEW (STAR) ON COMMERCIAL OFF-THE-SHELF (COTS) ELECTRONIC COMPONENTS

Plenary Session

Dr. William G. Howard, AGED chair, opened the plenary session. Dr. Howard reminded the attendees that the DoD was no longer dominant in the development of electronics technology, such as it was during the Minuteman era of the 1960s. He also drew attention to the Revolution in Military Affairs; in recent years, the acquisition budget has shrunk by 60%, we have vastly different enemies than those of the cold war period, and vastly different warfighting scenarios. The use of COTS is an important consideration in efforts to address more diffuse military tasks and requirements with smaller budgets. Dr. Howard stated a number of important issues facing DoD system designers when making their decisions as to which components are acceptable for use in their systems. These include a determination of what is really available, whether or not the part(s) under consideration will operate reliably, consideration of unique packaging requirements to meet system footprints, whether leading edge specifications will be met, if long range logistics considerations will be satisfied and if the selected hardware and software will be compatible with each other. Dr. Howard next introduced Dr. Jacques Gansler, Undersecretary of Defense for Acquisition and Technology.

Dr. Gansler identified two critical acquisition issues facing the Department of Defense in coming years: what it buys and how it is bought. He drew attention to the fact that the United States has deferred modernization during the past decade, with a procurement account that has fallen by more than 70%. He unequivocally stated that we can no longer continue on this path. Equipment is wearing out and becoming obsolete whereas technology has changed dramatically. There are different threats facing us than in the past. These new threats include terrorist actions, transnational actors and rogue nations, and major urban and theater conventional, chemical, biological, and nuclear warfare. These threats must not only be countered, but the U.S. must stay ahead of them. Our decreasing dollar investment must be made to accelerate the pace of modernization. This is unquestionably a difficult challenge. Dr. Gansler also reminded the attendees that it makes no sense, from any standpoint, either to use out-of-date equipment or to spend money updating equipment that is no longer tactically or strategically relevant. The U.S. must fully exploit its leadership in advanced technology and achieve truly integrated, multi-service operations, at all levels; and increasingly, on a multi-national basis.

A recommended approach to cost-effectively meeting DoD technology needs is for the DoD to engage in a greatly expanded partnership with a revived and prospering commercial industry. Civilian/military integration in the acquisition process is the key to the success of such a partnership. A strategy must be developed for the design and production of dual-use electronic components and processes. By doing so, significant savings and increased efficiency will result as well as improved yield. Dr. Gansler cited the MIMIC program as a favorite example of how a dual-use component strategy can be effectively implemented. In this program, criteria of low cost and high reliability were added to the traditional DoD quest for maximum performance. As military microwave monolithic integrated circuits resulting from the program were deployed in weapons systems, including HARM and GEN-X, commercial circuits were concurrently being put into use, in increasingly larger numbers. These were used by the commercial RF wireless industry for advanced communications and by the auto industry for collision control devices and automated toll collection systems. Thus, the dual-use concept worked with typical chip costs dropping from about $8,000 to approximately $200 and, in some cases, to much lower amounts. Dr. Gansler also cited TRW's production, on its automotive component production line, of military-unique plastic encapsulated circuits and boards for the Air Force's F-22 fighter aircraft and the Army's Comanche helicopter as an example of how to achieve significant cost savings, on the order of 30%-50%, while satisfying DoD needs.

Dr. Gansler drew attention to a recently initiated cost savings program called COSSI – the "Commercial Operations and Support Savings Initiative." This program offers incentives to prime contracts to help the DoD identify commercial parts and services that can be used in its fielded, legacy systems.

Dr. Gansler stated that meeting the DoD needs of the future will require both COTS and some defense-unique systems, subsystems and components. He emphasized that **there is and will continue to be a need for the DoD to invest in electronics R&D and that the benefits of this investment are clear and compelling**. He closed by stating: "I do not see COTS as a process whereby DoD simply buys electronic equipment and components off-the-shelf when it is convenient to do so and when it happens to meet the requirements (or nearly meet the requirements) for the job. We want to see systems and subsystems designed with commercial and military applications in mind and built on integrated production lines wherever possible. Only then can we achieve the most effective use of our limited investment dollars. And only then can we really provide our commercial industry with the resources and incentives to keep ahead of our competitors and our enemies."

The next speaker was Dr. Richard VanAtta of the Institute for Defense Analyses. Dr. VanAtta examined two technology areas of current importance: flat panel displays and semiconductor manufacturing. For flat panel displays, concerns centered upon sustainability of supply, assured supply (since nearly all flat panel displays used by DoD are foreign made), life cycle costs, adequacy of test data, adequacy of qualification procedures, the role of DoD R&D in future display development and application, and the robustness of the U.S. display manufacturing infrastructure. For semiconductor manufacturing, he cited a recent study which concluded that, **to meet DoD microelectronics needs, there must be sustained investment in the semiconductor manufacturing and equipment infrastructure**. Dr. VanAtta commented upon the importance of the DoD proceeding with an effective dual-use strategy to meet its needs. He cited key concerns about COTS, including mismatches between commercial and military product cycles and the likelihood of needing to rapidly ramp-up military technology and industrial capabilities if a war or major conflict occurs. He concluded by stating that **COTS doesn't mean not investing (in electronics R&D) – it means changing the way DoD invests.**

Mr. John Young, a professional staff member of the Senate Appropriations Committee, emphasized the need to focus upon meeting the needs of DoD systems with R&D resources that have been shrinking every year. He noted that contingency operations have taken a toll on RDT&E budgets as well and will probably do so during the coming year. Mr. Young challenged

the DoD to procure more efficiently and less expensively. He commented that use of COTS was part of an appropriate strategy for meeting DoD needs but that adequate reliability and durability must be assured. He also cited DARPA as a leader in adapting commercial products for military use but said that many program managers are of the opinion that this approach will not always meet military requirements. Mr. Young also commented on displays for military use. He cited a desire to incorporate larger displays into AWACS. Progress has been very limited and very slow; necessary ancillary investments are not being made. He expressed hope that industry would augment the initiative. He expressed concern about the slowness of the "time lines" for military system developments compared to commercial ones. He mentioned a DoD program (believed to be RASSP) that had made a good attempt to accelerate DoD system development to meet that of commercial development but stated that it had not been entirely successful.
Mr. Young also raised the issue of how adversaries will harness commercial capabilities to their military advantage. He commented that this question must be addressed in developing the DoD investment strategy. In closing, he emphasized that DoD must carefully select the electronics R&D areas it will pursue in the future based upon meeting its most important needs – it must make the fundamental decision to get out of certain R&D areas.

Mr. John Hartman, of Hughes Aircraft Company, represented the Electronic Industries Association. Mr. Hartman first covered a number of concerns that must be addressed when considering the use of COTS for military applications. These include the recognition that there is no universal quality standard (i.e., each part and manufacturer must be evaluated for the application at hand), data sheets typically list performance only over limited temperature ranges, environmental effects may not be adequately addressed, effects of long term unpowered storage are often unknown. On the other hand, there are many advantages that may accrue from use of COTS. Some of these are the possibility of a significantly greater choice of packages, lower cost and lighter weight. He stated that contractors such as Hughes Defense Communications had used commercial/industrial components for military applications for many years. In particular, for Hughes, these included COTS components use in communications applications and in sonobuoys. He concluded by endorsing sensible use of COTS in military applications with the admonition that supplier selection and component evaluation are key elements when choosing commercial and industrial components to meet the DoD's needs.

The final speaker of the plenary session was Dr. Thomas McGill of the California Institute of Technology. Dr. McGill reviewed the results of a 1997 Defense Sciences Research Council study of Just in Time Electronics for Weapon Systems conducted for DARPA. Two specific technology areas were examined in considerable detail: A/D converters and multi-chip packages. The findings for A/D converters were as follows: **A COTS only approach to A/D converters will substantially limit advanced military information processing systems.** Empirically current A/D converters are "limited" principally by "sampling gate timing uncertainty." A fundamental understanding of "sampling gate timing uncertainty" and attempts to address the issues could lead to substantial improvements in A/D converter performance. "Out of the current box" approaches such as resonant tunneling devices, optically generated clock and sampling circuits, or circuits employing superconductors may be required to overcome empirical limits. Filters were also found to be important but were not included in the study.

For packages, it was clear that major system capabilities of revolutionary importance to the DoD would be unlikely to be met by the commercial industry. This part of the study, led by Dr. Barry Gilbert of the Mayo Foundation, urged the U.S. to continue making large investments in military research and development to guarantee an ongoing military advantage. It cautioned that the U.S. is rapidly "eating its seed corn" i.e., the technology reserves built up during the 1960s - 1980s. Specifically, the study stated that **increased electrical performance from packages needed for use in DoD systems would only be achieved through improved manufacturing processes that lead to complete control of metal and dielectric structures, shapes, layer thickness and properties.**

Some key conclusions of the study were that **although the DoD must make hard choices about its S&T investments, there is no question that the military will require electronic components beyond those that are or will be available as COTS. Specifically, further work is needed to develop high power microwave components and A/D converters for microwave systems.**

Synopsis of Panel Sessions

Acquisition and SPO Perspectives Panel

Introduction:

The nominal purpose of the Acquisition and SPO Perspectives panel was to provide a forum in which past experiences, current activities and future plans, concerning use of COTS assets in military systems, could be presented and discussed by representatives of existing and developmental defense Systems Program Offices (SPOs). Panel membership was intended to include SPO representation from each military Service (Army, Navy, Air Force) plus a representative of the multi-Service JSF program and a member of an existing Service specific COTS steering group. The participating panel membership included Col. Chris Fornecker, Army Digitization Office; CDR Danny Stevenson, Navy Advanced Architecture Section, AEGIS program office; Robert Gibler, Air Force F-22 program office; and Niles Riegle, Director of Electronics Development, Naval Surface Warfare Center, Crane, IN. The representative from the JSF SPO declined to participate.

Each of the panel members was requested to address the questions listed in the Appendix for the Acquisition and SPO Perspectives Panel. The time allocation for this panel was intended to be approximately equally divided between panel member presentations and audience questions and comments. However, audience participation was very active and the discussion period extended beyond the time allotted. Speaker presentations are summarized below, together with an attempt to represent "the sense" of audience consensus.

Presentation Summaries:

Col. Fornecker described a recent Advanced Warfighting experiment, Task Force XXI, conducted by the Army to evaluate applicability of COTS digital componentry and software for tactical digital information use and communication. The experiment involved use of Pentium based COTS computers, Sun workstations, COTS routers and a variety of COTS software applications, interconnected via wire or VHF and UHF radio links into a "Tactical Internet." COTS assets were installed in locations ranging from relatively benign fixed sheltered locations; e.g., command posts, to mobile, high shock, high temperature range environment weapon platforms. Both standard "off-the-shelf" computers and "ruggedized" versions were evaluated during the exercise. The speaker noted that, in no case, were "system" operational or reliability requirements compromised to accommodate the use of COTS.

A variety of COTS software applications were also employed, ranging from vehicle movement tracking systems to Internet software wherein commercial standards and routing protocols were implemented. Software use problems noted resulted only from the restricted bandwidth of military communication systems, not from inherent COTS software limitations.

Possibly the most impressive application of COTS computing was provided by the application of a COTS computer to the "Paladin" fire control system. "Paladin" is a mobile artillery weapon system. No operational problems were noted and cost reduction for the fire control system was reported to be 3:1 with a projected 6:1 reduction in the future. Additional cost reduction accrued for software maintenance was estimated to be about 2:1.

The conclusions from this experiment are:

1. COTS can meet most performance requirements.
2. COTS will reduce acquisition and life-cycle costs and reduce acquisition lead time over that associated with the use of custom military products, in large part because COTS assets are implemented using "open" commercial standards.
3. COTS provides an easier upgrade path.
4. COTS can play a beneficial role, even in demanding battlefield environments.

CDR Stevenson indicated that current use of COTS in the AEGIS system includes a variety of processors, connectivity equipment, displays and peripherals. AEGIS experience indicates that COTS assets can be employed to advantage in non-mission critical applications and even in some mission critical applications where they meet requirements. He noted that accommodation for use of COTS hardware has been facilitated by development of a "standard" cabinet enclosure ("Citadel") which provides flexible shock-isolated equipment mounting bays. A number of AEGIS system requirements which cannot currently be met with COTS assets were identified, e.g., the SPY radar antenna subsystem, SPY radar signal processor, and the fire control system illuminator. His presentation concluded with tabulation of a number of "use of COTS lessons learned" which seemed to indicate that COTS acquisition procedures in the "AEGIS Navy" are still a "work in progress" but that COTS can be expected to play an ever increasing role in military system development and acquisition. It is expected that formalized COTS selection methods will evolve over time.

F-22 experience with COTS use, as presented by Mr. Gibler, indicates that both commercial and industrial grade COTS parts can be selectively applied to this weapon system as long as appropriate qualification methods are used; e.g., testing, screening procedures. Some cost saving examples were presented which indicate that cost savings for specific parts can range from 2x to as much as 10x, without loss of operational functionality. The speaker noted that COTS use poses a variety of "new" issues for military system acquisition and maintenance. He specifically noted that mixed use of custom and COTS parts in military systems imposes requirements for "two level maintenance procedures" and that COTS parts usage carries some system weight and functional density penalties. Specific attention was given to implementation of selected military products using COTS processes and COTS semiconductor production lines; e.g., TRW's automotive semiconductor production line. Cost savings of 2:1 were noted from use of this methodology. The speaker represented use of COTS parts in military systems as a "fact of life" dictated by the recognition that these systems must be affordable. However, he indicated that acquisition methods must change to meet unique challenges associated with this procurement paradigm – and that this change is happening.

Mr. Riegle is currently a member of a COTS steering board whose mission is to address COTS policy on a NAVSEA-wide basis. He described some of the many questions and issues which will be addressed by this group. They include making acquisition management a continuous process, development of specifications for COTS parts, maintenance issues associated with (partly or completely) COTS implemented systems (absence of "normal" parts lists, non-repairability, possible obsolescence of the line replacement unit concept, etc.), system configuration management with configuration control, development of processes for COTS parts selection, and a variety of changes which will occur in "technical management" of systems procurements. The scope of this undertaking clearly demonstrates the serious commitment being made by the Navy to systems implementation and maintenance in an age of increased use of COTS products.

Summary Responses to AGED Questions:

Overall there was little difference in the answers provided by the speakers to AGED questions. Their collective responses are summarized as follows:

Q1. All speakers indicated that current COTS acquisition policy definition and implementation are in a state of development within all Service organizations. It was clear from all presentations that use of COTS products, methods, and processes is considered by all military Services to be critical for realizing "affordable" military electronics systems and development of COTS acquisition procedures is a matter which will continue to receive considerable attention from the DoD.

Q2. Definition of COTS products closely follows the FAR definition; e.g., COTS refers to "products of a type which are customarily used for non-governmental purposes and which are offered for sale, lease or license to the general public."

Q3. A few "mission critical" system attributes were identified as requiring custom implementations; in general, these are functions which are associated with "front end" sensing or particularly critical and demanding signal processing requirements. However, this response was tempered by the acknowledgment that "COTS", as represented in these talks, included a number of product types ranging from pure COTS to "ruggedized" versions of COTS derived products. It was clear from the presented material that beneficial outcomes, in terms of system cost and maintainability, can be realized by treating "COTS" as representative of a broad range of capabilities, including methods, processes and products.

Q4. **In all cases, the system SPO participates in COTS vs. custom decisions but the primary selection process is implemented by contractors. It was also apparent that SPO's recognize that expanded use of COTS-based system implementations will require major changes in the methods and practices by which the military system acquisition process is managed.**

Q5. All speakers appeared to agree on the following lessons learned to date:

1. Substantial cost and time-to-deployment savings are realized from intelligent use of COTS components in military systems.
2. Expanded use of COTS components is and will continue to be a "fact of life" among military system acquisition agencies.
3. Carefully selected COTS products can meet stringent requirements of many military system applications; it is not necessary to compromise system performance requirements in order that beneficial consequences result from COTS based system implementations.

4. Considerable benefits (life cycle cost and maintainability) result from use of COTS products based on widely implemented commercial standards.
5. Increased use of COTS assets in military systems will impose significant culture changes on military system procurement/maintenance management procedures and these changes are still being recognized. Formalized methods and procedures for COTS use are in an active state of development within all branches of the military services.

Question and Answer Summary:

The general sense of the questions posed by members of the audience appeared to challenge the speakers' consensus message that COTS products can be effectively used to implement defense systems without compromising operational military effectiveness; e.g., "COTS products are, by definition, available to all buyers. How can the U.S. military expect to maintain combat advantage without exploiting the enhanced functionality provided by custom military products?"

The speakers' responses acknowledged that there are some specific military requirements which cannot now be met by COTS parts. However, Col. Fornecker, in particular, presented the argument that battlefield results are as much (or possibly more) determined by strategies and tactics employed to implement strategy. He noted that during the Battle of Britain (World War II), the British employed a tactic of holding their defense aircraft on the ground until "the last minute" to save fuel and to enable the use of more efficient attack tactics against radar-guided German bombers. Some in the audience suggested that an appropriate example of "decisive" impact of custom technology in this scenario was the British invention of the cavity magnetron, which enabled airborne radar and allowed Allied defense aircraft to better locate and target enemy aircraft. (Author's note: Unfortunately, what did not become apparent during this interchange was the time relationship of the Battle of Britain and deployment of magnetron implemented airborne radar. The Battle of Britain lasted from mid-1940 to early 1941. The British invention of the magnetron occurred in late 1940 and airborne radar became a decisive military asset only after the Battle of Britain was decided in favor of the Allied Forces.)

It appears, from the information presented by this panel of speakers that, at the SPO level, the U.S. military has relegated custom electronic technology development to only those system functions which, if implemented using COTS products, would measurably compromise system performance requirements. It also appears that the attendant cost and time to deployment savings which accrue from use of COTS are considered to be highly valuable benefits for U.S. military defense capability.

Defense Systems Industry Panel

The Defense Systems Industry panel included representatives from five major suppliers of defense systems: Lockheed-Martin (Sanders Division), Raytheon, TRW, Northrop-Grumman and ITT Defense. Each panelist made a short introductory presentation to set the stage for further discussion. Summaries of these are as follows:

Dr. John Kreick of Sanders emphasized that system engineering considerations will, of necessity, change significantly from those traditionally employed in the development of DoD systems. For example, the use of open architecture design will become increasingly important. Design margins will have to be larger. System developers will have to form closer relationships with COTS vendors and, perhaps, become α and β test sites for component evaluation. Comprehensive databases of component information will have to be assembled. Software considerations will play an increasingly large role. Tremendous cost savings may accrue from the use of commercial software but only if operating system changes can be accommodated without deleterious effects on the overall system. In the past, detailed design to MIL-specs provided a safety margin for DoD systems. A major challenge of effective COTS usage will be to either provide sufficiently ruggedized individual components or provide a ruggedized housing to meet environmental requirements. Dr. Kreick stressed the fact that although COTS usage often provides a significant initial cost savings, a much longer logistics tail will occur. He further stated that **although use of COTS will be dominant for digital applications, microwave wideband components for DoD systems will always have to be custom-made as will most electro-optical parts. With regard to packaging,** he said that **COTS developments must be closely monitored and used whenever appropriate. However, it is highly likely that, for military applications, custom packages will be needed to provide necessary functionality and to accommodate military system constraints.**

Mr. Randy Smith of Raytheon discussed a large number of considerations that must be addressed when selecting components, either COTS or custom parts. These included package style and footprint, supplier viability, uniqueness of technology and intellectual property aspects, logistics support/life cycle costs, the need for common operating environments and standard interfaces, an assessment of the reliability of each component both in operating and storage environments, availability of the supplier base, acquisition cost and development cycle type, flexibility of system performance requirements and anticipated production volume/minimum buy requirements. He commented that Raytheon often adopts the approach of using multiple cycles to develop its products; final products may take 6 years to reach fruition but releases occur more frequently, approximately every 18 months. He stated that the "bottom-line" in component selection was ability to meet performance requirements and that use of COTS must be tempered with an effective system level risk mitigation strategy. Some attractive payoffs of COTS usage are reduced non-recurring-engineering (NRE) costs for component development, broader component availability and increased opportunity for common interfaces and operating systems. Mr. Smith agreed with Dr. Kreick that **DoD support for custom components would be essential for microwave devices and circuits and for optical components used in missiles.**

Mr. Mark Bever of TRW discussed the use of COTS parts from a MILSATCOM perspective. He cited the following system features as those of highest importance: security, assured access, anti-jam protection, nuclear protection, terminal locations and facilities, and required coverage. He noted that in the MILSTAR system about 60% of the components used are derived from commercial components. Mr. Bever supported the contention that **DoD must continue its investments in millimeter-wave components, particularly for power MMICs and phased array antennas.** He also cited **a need for continuing investment in radiation hardened digital ICs.** In addition, he noted the pressing **DoD need for investing in high performance A/D converters which will not be available as COTS.** Mr. Bever commented that commercial (satellite communication) systems will drive military expectations and their development will reduce military system costs but, military systems will always require additional security.

Mr. William Eikenberg of Northrop-Grumman cited the importance of performance discriminators vs. adversaries achieved through the use of state-of-the-art components. He embraced the use of commercial practices and processes to create critical non-standard components. As an example, he pointed out that in one UAV development approximately 65% of the parts were COTS. He suggested that perhaps 50% of RF parts could be COTS and, eventually, 100% of the non-RF parts.

Mr. Eugene Hammer of ITT also endorsed the use of commercial processes. He cited the importance of close interaction between system suppliers and component suppliers to assure that requirements are met.

The following major perspectives and conclusions arose from the panelists presentations and subsequent discussions with the STAR attendees.

A. MAJOR PERSPECTIVE #1

- **Electronics technology can significantly leverage U.S. military superiority in the 21st century only if S&T investment is enhanced and continues.**

The history of the last 20 to 30 years of the 20th century, incontrovertibly showed U.S. military superiority based increasingly on superior tactical and strategic electronics subsystems. This outcome was rooted in a DoD electronics investment policy of 50 years, the first half of which also spawned a worldwide commercial electronics industry, now the largest industry as we approach the 21st century.

An important question, in this age of DoD downsizing is: **"Does the policy of DoD (S&T) electronics investment need to continue to maintain 21st century defense superiority, given the large commercial electronics industry?"**

This issue is often oversimplified, to coincide with the increasing use of COTS (commercial-off-the-shelf) components and modules. There is no question that maximum COTS usage is economically useful to DoD and will provide enormous cost savings, perhaps as much as 50%. Therefore, use of COTS is essential and necessary to maintain

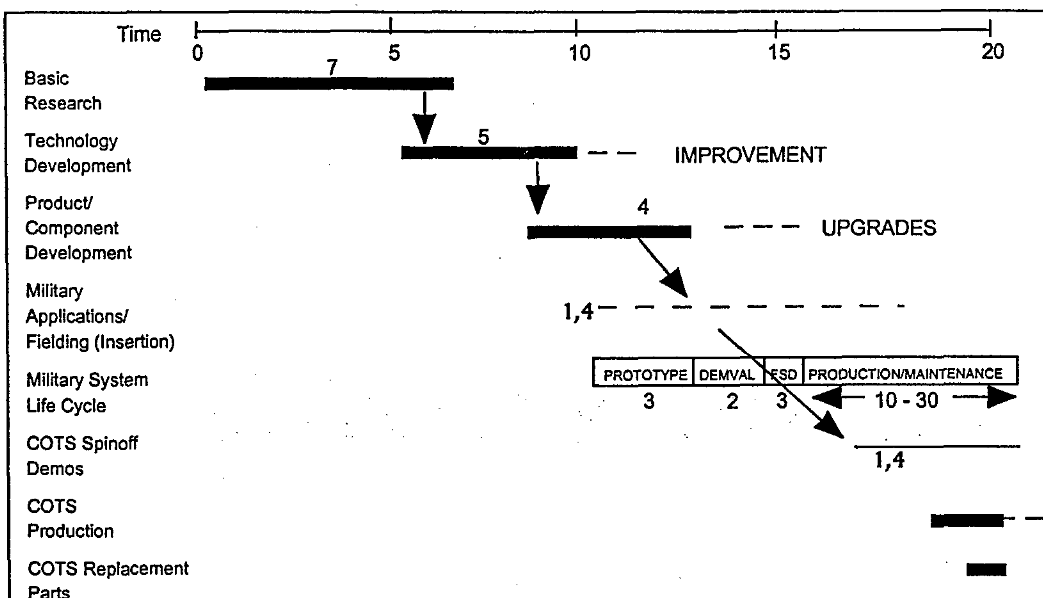
an efficient U.S. Defense posture. But the larger question of "How to Maintain Defense Superiority" leads to a different answer:

COTS alone is insufficient for superiority.

Although COTS usage will continue to expand, the need for military-unique electronic components to maintain superiority will not disappear. This rationale is firmly based on unique military sensor performance as well as the demands of unique mobile platforms and missions. To understand this important conclusion, refer to Table 1 (Military Unique Electronics Technologies) and Figure 1 (Electronics Technology Timeline).

Table 1. Military-Unique Electronics Components Technologies – 2000 to 2020

Examples
• High performance, high frequency microwave electronics (2 to 200 GHz)
• High bandwidth analog-to-digital converters (0.5 to 20 Gsps)
• Devices and components for operation at very high temperatures
• Electro-optic IR imaging arrays, EO components for missiles, and related components
• UV/IR Detectors
• Radiation-hardened integrated circuits for space
• High power RF sources - solid-state and vacuum (5 to 100 GHz, 1 to 1000 Watts)
• MEMS for miniature UAV
• Electronically steered antenna arrays for multiple agile beam forming.
• High performance, highly integrated packaging and interconnect MCM technologies



NOTES:
1. COTS is the fallout, not the driver, for military-unique technology
2. COTS can often provide replacement parts for fielded systems
3. Unique high leverage military-unique technology requires DoD funding until COTS spinoff occurs in 12 to 15 years
4. Defense systems superiority most often traces to important military-unique electronics technologies

Figure 1. Electronics Technology Timeline (Typical) – Military Use First

Without an enhanced continued U.S./DoD S&T investment in these types of military-unique technologies, the military superiority the U.S. has enjoyed in the latter part of the 20th century will gradually disappear in the 21st century, simply because superiority translates to time lead. This 5 to 10 year time lead must be provided by unique technology that is not available to potential U.S. adversaries, and difficult to reverse engineer in a short period of time.

During the 1990s, the DoD S&T investment in military-unique electronics technologies has eroded more than 50%. It now appears to be insufficient to provide decisive military time-advantage leverage for systems of the early 21st century.

The System Industry Panel recommends:

- ⇒ **A clear U.S. and DoD long-term policy of support for robust military electronics science and technology investment, traceable to military superiority needs should be established by the DDR&E with Service concurrence by October 1, 1999 traceable to military superiority needs.**
- ⇒ **Definitization of such technologies and funding levels**
- ⇒ **Responsibility assigned within DoD, with coordination and contributions from other government agencies (NASA, DoE, DoC)**

B. MAJOR PERSPECTIVE #2

- **A new defense system acquisition process/paradigm is needed for efficiently expanding COTS cost savings while providing and maintaining superior defense systems.**

The critical elements of the new COTS Process/Paradigm are as follows:

1. <u>FLEXIBLE SYSTEM/MISSION TOP LEVEL SPECIFICATION PROCESS</u>
   This incorporates cost as fixed independent requirement and system performance/features as a dependent variable requirement.

   <u>Benefits</u>:
   1) Contractors will be allowed the freedom to architect, design, and develop a total system approach of known cost and be allowed to tradeoff expensive performance and features for cost savings.
   2) Final configurations will be agreed upon with full participation by the DoD Program Manager.
   3) Intelligent decisions can be made concerning appropriate levels of incorporation of COTS and military-unique technologies to achieve the best balance between cost and performance.
   4) Provision/strategy for life cycle maintenance and upgrade must and will be included and planned for in advance.

Features:
1) System Engineering Process for incorporation of COTS hardware and software.
2) Elimination of unnecessary over specification of subsystem requirements and military standards.
3) Development and implementation of new system program processes and milestone standards which encourage and enforce the new paradigm, driven by the system contractor and SPO.
4) Incorporation of a pre-planned life cycle strategy with built-in milestones and "hooks" for system/subsystem/COTS component upgrades.

2. COTS SYSTEM ENGINEERING AND DEVELOPMENT PROCESS

Industry/DoD can develop a rapid turnaround, highly analytical/CAD intensive system engineering discipline for COTS incorporation and tradeoff at all levels (component/board/unit), both hardware and software.

Benefits:
1) Reduced system development cost and schedule.
2) Required dissemination of the system CAD tools that are funded by DoD.
3) Robust virtual system and hardware simulation, which reliably predicts cost and performance over a full 20 to 30 year life cycle, including planned upgrades.

Features:
1) New System Level/CAD "Open" Architecture Simulation Tools for major categories of defense subsystems – radar, EW, communications, imaging, fire control, etc., which permit rapid parameter performance/feature/cost tradeoffs.
2) Multilevel Macrocell Design Synthesis CAD Tools, which permit substitution of fixed COTS hardware and software library elements (all functional levels from component to board to box), in combination with variable elements, to conduct rapid iteration design. This will allow extrapolation of COTS usage to military environments with provisions of margin for life.
3) Cost Modeling CAD Tools and processes that provide full and accurate prediction of non-recurring engineering, manufacturing, and life cycle/upgrade costs. Both COTS and military-unique component cost elements, fabrication, assembly and test cost will be modeled.

C. MAJOR PERSPECTIVE #3

- **DoD/contractors should establish an industry-wide consortium-infrastructure and formal association to facilitate both COTS processes/database and military-unique technology policy, methods, and status.**

Benefits:
1) Clearly establishes DoD top level intent and policy for COTS component exploitation and simultaneously defines plans for military-unique S&T funding policy and expected output.
2) Reduces industry individual duplication of effort for all aspects of COTS infrastructure creation and maintenance – system suppliers and vendors.

3) Provides a means and forum to maintain COTS vendor interest to supply DoD, to reduce risk and uncertainties.
4) Exploits dual use.

Features:

1) A COTS vendor database would be maintained by a DoD information agency and shared by all contractors. It would include product specifications, test data and (on a nondisclosure basis) future product plans.
2) A national COTS Conference and Exhibit, driven by DoD, attended by DoD, system contractors, and COTS vendors, would be used to proliferate information about DoD policy, COTS CAD Tools/Processes, database sharing, and lessons learned. Multidisciplinary sessions, technical papers, panel discussions, vendor product exhibits, subcommittee sessions, and organizations would be established for continuing dissemination of information and discussion of COTS infrastructure issues such as IC CAD, Module CAD, System CAD, packaging, software standards, materials, obsolete part replacement methods, qualification and testing, and model year upgrade processes.

   Suggestions: a. Expansion of the DoD GOMAC conference.
   b. Establishment of an EIA division for self-administration by industry.

3) **A National Defense Electronics Science and Technology Conference – organized by DoD management with multiple agency participation. This would provide a forum for presenting DoD Electronics S&T policy, programs, long-term plans and results. It would allow a two-way discussion with industry.**

   Suggestion: Expansion of DARPA/NIST conference with participation of major DoD Laboratories and Reliance panels sponsored by the DDR&E.

D. MAJOR PERSPECTIVE #4

- **The balance between COTS exploitation and and military-unique electronics technology needs in the 21st century will vary with type of platform and segment of the weapon system (sensor-processor-network) being built.**

Components Suppliers Panel

Introduction:

Component suppliers are a distinct segment of the COTS community differentiated from the Government by a profit making business motive and differentiated from defense system companies as a piece part, mass production enterprise. Today, component suppliers do not generally furnish products exclusively for defense systems; rather, they find it cost effective to maintain a vigorous commercial business with military products supplied through a separate division or office or subsidiary. Most electronic component suppliers focus only on commercial business, driven by its much larger business base relative to that for satisfying defense needs.

Component suppliers to the defense community span a range from furnishing strictly commercial catalog parts to producing fully customized parts built to government military specifications. Intermediate between these extremes are firms which tailor commercial parts to meet augmented requirements. Some firms may tailor processes to produce higher quality military parts or may design a dual-use production process that serves both commercial and military needs. Common to all of these variants is the basic business profit motive; it will determine the approach each firm takes to serve the defense establishment.

This panel was invited to address the future components supply issue. **The ability of the Government to obtain current and new components and electron devices which meet system requirements is constrained by commercial business operations.** The purpose of the panel discussion was to explore the manner in which these constraints impact government procurement of suitable COTS parts and what the government R&D plans are for developing innovative new devices which ultimately will have to be produced in a cost effective manner.

The four panelists represented slightly different business segments as follows:

Mr. Joe V. Chapman	Military Products Division Government Relations/Facilities Manager of Semiconductor Group Texas Instruments
Mr. Brian D. Hagerty	Military and Commercial Parts Director; MSP Product Line Harris Corporation
Mr. Gerald E. Servais	Mainly Commercial Parts Manager, Parts Research & Test Development DELCO Electronics
Dr. John Vaughan	Military (mostly) and Commercial Vice President, Technology Marketing and Business Development M/A-COM

TI and Harris serve, in varying degrees, both commercial and military markets. DELCO is primarily an auto parts manufacturer supplying only COTS parts to the Government. M/A-COM has a military emphasis. The panel was organized to address the 3 questions shown in the Appendix on page 45. A lead panelist assigned to a particular question described the position of component suppliers for the general discussion. These discussions are summarized below. Findings have been extracted from them.

Discussion of Questions:

Q1. What is your definition of COTS components? What does the term COTS mean to commercial suppliers, military suppliers, and captive suppliers? (Hartwick)

Commercial suppliers do not generally distinguish a category of parts entitled COTS. Standard parts are typically identified by a number and a spec sheet. If a part is made on a QML production line, military part qualification is automatic. A part is no longer considered commercial if tailoring of the spec or the package is done to meet specific military requirements. There seemed to be little disagreement about the answers to these questions. Differences appeared to be more a matter of style than substance.

Q2-a. Can the DoD develop advanced systems without performing advanced component development and making use of these advanced components? (Servais)

Servais expressed the position that the quality of many automotive electronic parts is already adequate for military use. He cited the results for the Engine Control Module described in Figure 2. The point was made that auto makers are introducing a great deal of standardization into the specification of parts. Utilization of these parts eliminates costly development for new system designs. It was suggested that military buyers could avoid development of many new parts by understanding, in detail, the performance characteristics and specs of the >1000 automotive parts that are now available.

It was suggested that the DoD can influence commercial firms to build advanced components by making early investments during the R&D phase of a product's development cycle. However, firms can only be influenced to change their manufacturing processes to accommodate the needs of new military devices if they project a sufficiently large volume market. Investment of capital by industry has to be justified by return-on-investment (ROI) analysis.

Q2-b. Will it be possible for the DoD to gain information about advanced commercial component developments, and the products that will result, in sufficient detail to allow the design of systems that incorporate them as these products become available? (Hagerty)

The panel agreed that the answer to this question depends on projections of future DoD business. If the DoD were to invest in R&D for an advanced part and planned a large volume buy of this part, the answer would be "yes," provided that the company wished to retain military business. Extending R&D for an advanced part into qualification and production is expensive. The ability to sustain production processes is strongly dependent on the degree of synergism with high volume commercial part sales. "No" is the answer if non-standard technical data are required or if additional characterization data is necessary to model military system operation conditions such as radiation hardness levels or extended temperature performance. Suppliers will always supply standard data sheet information.

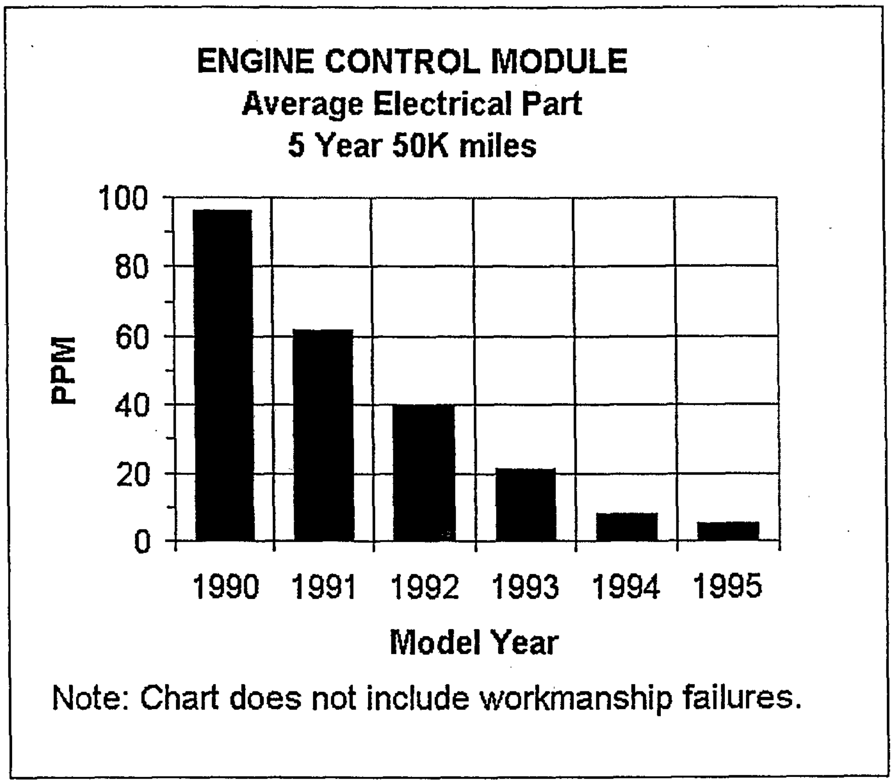


Figure 2. PPM Failure Rate vs. Model Year

Q2-c. Is it likely that commercial suppliers will develop any military unique components without direct funding support and guidance from the DoD? (Vaughan)

Unlikely! Generally the commercial ROI is poor, the customer base is small and the component suppliers are usually competing with system houses. Discussion of larger DoD single part orders for arsenals brought out the need for more analysis of the total logistics strategy for COTS; it was noted that regardless of the logistics strategy adopted, level of production still had to be sufficient to make the business viable for component suppliers. An important commercial phenomena called "churn", defined as buy a million....sell a (prime priced) thousand....sell the rest as surplus, has to be taken into account in developing a logistics strategy for COTS. It is also a consideration for venture capitalists exploring the possibility of transitioning a military R&D company into one addressing the commercial marketplace.

An alternative to direct government funding of component suppliers for development of needed unique parts was suggested. In the proposed scheme, system/component supplier consortia would be set up with DoD technology base funding provided to the system house members. A sharper focus might be achieved in this way that would result in reseeding the industry. Although not explicitly stated, the stronger system business base would have to be sufficient to entice and bolster the component business.

Q3. Will technology for COTS components continue to develop at an acceptable rate without continued investment by the DOD in the development of leading-edge electronics? What is the history of current COTS products and expectations for new COTS products that will emerge within the next decade? (Chapman)

It was pointed out that the QML component houses (TI, Harris, National, Analog Devices) supply the military with ICs and provide leading edge technology; new part introductions occur each year. However, the DoD buys only ~1% of the total electronic part output and, hence, does not have a significant influence on the business. Some suppliers will only take DoD investments if the product DoD desires will also have significant commercial sales. Some mention of consortia formation was made, but the continued pace of COTS component development is driven by the commercial market.

Findings:

1. Component suppliers of COTS and advanced/unique military parts are viable for support of DoD missions as long as the business is profitable to them.

This point came up over and over in the panel discussion in the context of the particular question under discussion and seems to apply regardless of the relative percentage of military and commercial business.

2. DoD logistics strategy needs to fully account for the business positions of Finding #1 in terms of volume buys of COTS or military unique parts.

3. DoD needs to support the development of advanced electronic parts unique to military systems and find a funding structure for sustaining the qualification and production of these parts through formation of consortia, flexible manufacturing, or other means that provide the necessary business incentive.

Government cannot otherwise gain the attention of commercial suppliers.

Science and Technology Perspective Panel

Introduction:

Defense sponsored research and development in electronics, over the last fifty years, has been the primary source of science and technology knowledge from which extraordinary advances in electronics technologies have sprung for both military and commercial purposes. The commercial application of electronics high technologies has formed the basis for great advances in almost every part of our society and has become the engine of the world economies. Defense, as is well known, also has gained very substantial rewards, in terms of its capabilities, from its S&T investment. At issue today is the appropriate level and application of Defense sponsored research and development in electronics in light of the significant application and capabilities of commercial electronics products in military systems. **The lack of investment by the commercial market place for all but mass market commodities ensures that such products will not only be available to us but also to our potential adversaries.** The Science and Technology Perspective Panel representing a cross-section of the performing community – industry, academia, and the DoD and its services – was well suited to address these issues.

The Panel first made opening remarks followed by a detailed discussion of "Questions for the S&T Perspective Panel", given in the Appendix on page 47. The Panel also interacted with the floor after each question. Highlights of the opening remarks are as follows. Professor Thomas McGill noted the great change in the conduct of science and technology that is now on-going between industry, academia, and government. He also commented on the important contributions made by the OXRs and DARPA in avoiding technology surprise and their large contribution to graduate research. Specifically, he commented upon the production of students, sponsored by the DoD and its services, who entered the work force and made, in aggregate, large contributions to national security. Noel MacDonald gave the DARPA-ETO perspective as one of finding means to achieve higher levels of integration of diverse functional components (e.g., MEMS and silicon ICs) to perform real time sensing functions over the entire frequency spectrum. Michael Andrews, representing the Army, pointed out the relatively small volume component buys made by the military and their diversity. Although the Army requires that its electronic systems function at an extraordinarily high level of reliability in a military environment, it must also weigh cost versus performance during the selection of components. Bobby Junker, representing the Navy, made several salient points. He noted that DoD systems requiring extremely high performance usually dictate requirements for DoD to drive the enabling technologies by supplying R&D funding. Often, spin-offs from these high performance component developments are later adapted by industry for commercial applications. He also pointed out the **reluctance of industry to lead the development of major paradigm shifts in electronics technologies. Industry**, he pointed out, **will not pursue long-term, high-risk R&D**. He also expressed concern about providing adequate logistic support for COTS components that rapidly become obsolete in the commercial market place. Michael Polcari, representing IBM, expanded upon Dr. Junker's logistics concerns by pointing out that, in the commercial computer and information technology hardware business, speed of integration (i.e., bringing new products quickly to market) is crucial to market success. He further commented that, in the high tech electronics business, making a profit is insufficient justification to invest new capital. Business growth must also be present. Dale Hutchinson, from Lockheed-Martin Federal Systems Group, reinforced earlier comments about logistics issues, specifically as they impact configuration control. In his view, prime contractors would have to maintain systems that depend heavily on COTS components throughout their life cycle. Tim Kemerley, representing the Air Force, noted that his Service was under great pressure to develop affordable electronic components. He felt that it is necessary for the services to not only learn how to apply COTS but also to develop "long lead items", for as yet undefined systems of the future, that industry will not pursue by itself. He noted that many of today's COTS components were developed as a result of prior DoD R&D investments. In closing, he commented that the Services need to maintain a core technology base to meet future military specific component needs and to develop dual use COTS components.

Discussion of Questions:

Q1. What areas of S&T will the commercial marketplace dominate? What areas will commercial suppliers make significant investments in over the next 10 years? How can DoD best access this knowledge base for its purposes?

The Panel stated that **information technology will be an electronics technology area dominated by the commercial marketplace**. The range of technologies spanned by commercial developments will range from communication products to enabling integrated circuits. Industry will make significant investments in these areas. **However, "high end" RF technologies, of great importance to the DoD, will not be driven by industry. DoD must pay for necessary improvements in this technology area.** COTS mainstream areas in which significant spin-on to military needs can be expected include: Silicon IC Technology; CAD tools, languages, and environments; networks and protocols; semiconductor processing equipment and starting materials; measurement and test equipment; packaging technology; optical fiber technology; and flat panel displays. There is an inevitable slowing coming in the ability to scale CMOS ICs because of device physics and optical lithography limitations. **DoD should remain active in silicon research to ensure the availability of a national industrial base.** DoD can best access this commercial knowledge base in two ways. The first is by establishing strategic relationships with suppliers. The second is by early involvement (i.e., government investment) in key emerging technology efforts that allow steering these efforts toward meeting defense needs. The Panel also noted the **pull back in corporate sponsored long-term research** (greater than five years).

Q2. What areas of S&T will be the ones that the commercial marketplace will not dominate? What areas, likely to be of considerable importance to the DoD, will commercial sources not make significant investments in? What approach is best for the DoD to pursue in order to perform necessary R&D in areas of crucial importance that the private sector is not motivated to pursue: Use of Government laboratories? Contract R&D with Academia? Contract R&D with Academic-Industrial Consortiums? Contract R&D with defense industry contractors? Other methods?

In general, the industrial sector is very averse toward taking economic risks and toward making investments that are not likely to provide an immediate return. As a

consequence, **it will not make the necessary R&D investments in high risk technologies without substantial government financial support.** DoD historically has held a dominant position in providing funding for basic research in the physical sciences, particularly electronics research. The results of this long term funding has led to many situations in which DoD has been the first and largest user of a new technology. Its applications are often eventually followed by commercial spin-offs. This point is shown pictorially in Figure 3.

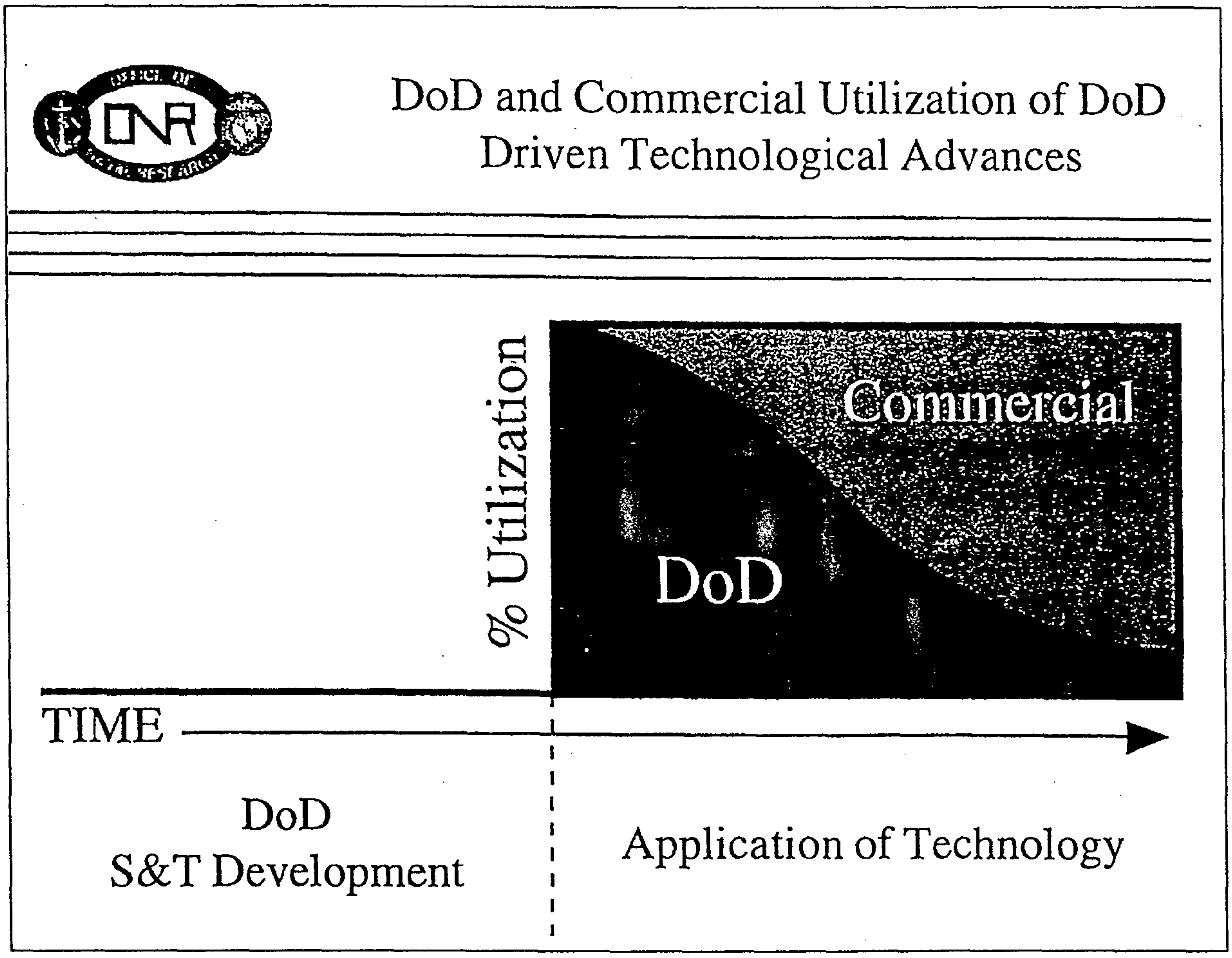


Figure 3. DoD and Commercial Utilization of DoD Driven Technological Advances

The commercial market place will not meet DoD needs for highly integrated, high performance sensors. Specific component technologies that DoD must support include: high power microwave solid state and vacuum electronics; high speed and high resolution analog-to-digital and digital-to-analog converters; very high speed signal processors; high frequency components-millimeter waves; high temperature devices and components; multi-octave frequency bandwidth components; UV/IR detectors and focal plane arrays; E-O sources; mixed signal digital/microwave/electro-optic ICs; phased array antennas; and highly integrated packaging and interconnect MCM technologies. It was also pointed out that technology development must include plans for transitioning results to manufacturing in order to avoid shelf life obsolescence. The plans for the transition to manufacturing must also take into account the timing and magnitude of potential markets. Total life cycle cost reduction through the early use of R&D most also be an important consideration for investment.

Q3. Are the current DoD designations for RDT&E (i.e., Category 6) still relevant today and is the implied model of those designations still valid (i.e., serial transition of knowledge, new capability, and results from basic research to fielded demonstrations)? If not, what alternatives might be more attractive (e.g., S&T investments grouped by time to achieve results)?

The Army RDT&E process was described. It includes Strategic Research Objectives for 6.1 programs and Strategic Technology Objectives for 6.2 and 6.3 programs. The Panel had no opinion as to the continued applicability of the Category 6 designations.

Q4. What are the implications for defense electronics R&D in light of defense industry consolidation?

Several concerns were presented that have implications for deliberations concerning the appropriate use of COTS components. The industrial point of view is that the DoD must continue to supply significant R&D funding to the large consolidated industrial military manufacturers. This is seen as necessary because stockholders of these companies expect double digit returns on their investments. **The fact that government funds are being saved through consolidation also means that these companies' use of their internal R&D funds, also declining because of declining DoD procurement in general, will be tightly focused on programs that are perceived to have immediate impact on the growth of the company. This will limit future strategic investment making DoD funding in this category imperative.** A DoD concern is that the lack of competition for DoD business, resulting from consolidation, will lead to a decline in companies' internal funding for innovative work, a loss of access to independent validation of new concepts and technologies, and a loss of innovation in new systems. Since DoD S&T funding is also declining, it is likely that a major decline of internal R&D by industrial defense contractors may also occur. This will further inhibit innovation and force a COTS solution by default. **Industrial response to this concern, expressed at the STAR, was that, in order to grow their business and gain a larger market share, industry must pursue tightly focused efforts. This strategy may not be in the best long-term interests of the DoD.**

Q5. How is the international S&T environment for electronics R&D likely to evolve over the next ten years? What nations/geographical centers will serve as resources for R&D capability? How can the DoD best exploit these capabilities? Are international S&T activities a threat or concern of any kind?

The DoD must sponsor or participate in international R&D, not as buyers of products resulting from the S&T knowledge base of others but as partners that become technically smart as well. In this way, full value to the DoD can be achieved for the investment it makes in sponsoring some foreign R&D.

Insertion Lessons Learned Presentations

The final set of panelists at the COTS STAR were program managers from the Army, Navy, Air Force and DARPA who shared their experiences of using COTS components in the systems that they were associated with. Panelists included Mr. Kevin Richardson, a fire control radar systems engineer from the LONGBOW program office, Mr. J. J. Lacamera, Deputy Program Manager, Undersea Weapons Program Office (PMS 404B) who spoke about the ADCAP torpedo, Mr. Don Hartman of the Air Force's C-17 SPO, and Major Don Lacey of DARPA's HAE UAV program office who spoke about DARKSTAR. A summary of their comments follows.

LONGBOW

Experiences encountered in attempting to use COTS for the Longbow Fire Control Radar were mixed.

A positive experience was encountered during development of the Longbow radar frequency interferometer:

- COTS technology was used.
- An estimated savings of $12M accrued.
- There was a significant performance improvement.

Negative experiences were, unfortunately, also encountered. Some of these were:

- Inability to purchase various COTS parts as system production progressed because they were discontinued by their manufacturers. Each time this problem occurred it was necessary to redesign the printed wiring board.
- Similar problems with the MIL-SPEC parts used in the Longbow Ka-band transmitter. During EMD, a vendor notified the prime contractor that key MIL-SPEC parts would no longer be manufactured. This necessitated redesign. MMIC technology was inserted; available COTS parts were not suitable.

General recommendations concerning COTS use are as follows:

- **Open architecture should be utilized for designs.**
- **Continuous monitoring of the number of sources for a given part (DMS issue) should be made a risk element during milestone reviews; funds should be provided to ameliorate this type of risk.**
- **COTS technology should be considered at the beginning of a system development project.**
- **Performance requirements that hinder the use of COTS should be carefully reviewed to see if they are essential.**
- **Parts interchangeability is an important consideration.**

ADCAP (Torpedoes)

Mr. Lacamera divided torpedo designs into four sub-areas: propulsion energy subsystems, sensors, signal processors and high powered computing subsystems. For propulsion energy subsystems, which have very high power densities, use of COTS is not possible. There are also no suitable commercially available sensors. However, there are some COTS signal processors that are worthy of consideration and use of COTS is planned for the high-powered computing subsystems. Mr. Lacamera offered the general observation that as one moves down the signal path away from the sensor, use of COTS becomes more viable.

Current efforts related to the use of COTS in torpedoes include the following:

- An attempt to standardize architecture across product lines
- Use of common processors
- Use of common software

However, **the Navy torpedo design team has observed that "(use of) COTS isn't as easy as advertised."** Some difficulties encountered were as follows:

- The impact of "simple" parts substitution did not become apparent until the torpedo under development was undergoing "in-water proofing" testing:

  ⇒ In water, there were problems with noise on all channels; these did not occur during preliminary testing

  ⇒ Documentation showed that a given (COTS) part was a one-for-one replacement for a similar part used previously – it was not! This caused major torpedo performance problems and necessitated rework

- Use of COTS replacement parts can also cause problems for equipment users.

  ⇒ For example, updated models of meters and instruments were procured. The new models had different knobs and dials which, in turn, required changes in fleet maintenance and torpedo building procedures. The problem was discovered after the new equipment reached a point where it was ready for deployment.

General observations were as follows:

- Acquisition reform and COTS insertion can provide reductions of system development time and costs
- However, no change is ever "too minor" until proven to be so
- The design and production teams must fully understand the impact of all changes on the overall system

- Testing approaches must be tailored to identify the impact of component changes on system performance early in the production process
- "It hasn't worked until it works"

C-17

Mr. Don Hartman stated that COTS was used for the C-17 mission computer and for the wireless intercom system. Problems were encountered with the latter. The intercom system was found to be susceptible to electromagnetic interference (EMI) during full testing at Patuxent River. It also operated at frequencies with restrictions on their use outside of the United States. Its battery charger was not compatible with the airplane. Mr. Hartman concluded that using **COTS "as is" doesn't work well for military applications, but work-arounds are sometimes possible.**

DARKSTAR

Major Lacey gave a brief introduction of the factors driving DARKSTAR design. An upper limit of $10 million (in FY 94 dollars) was set for the total cost of each DARKSTAR. Mostly commercial practices and standards were used. Substantial amounts of COTS were used in the Synthetic Aperture Radar (72%) and the Integrated Sensors Systems (61%).

APPENDICES

TECHNOLOGY NEEDS AND TRENDS (1998-2020)
STAR AGENDA
TERMS OF REFERENCE
QUESTIONS FOR PANELISTS

Technology Needs and Trends (1998 – 2020)

1. Digital Technology (logic, memory, processors, controllers)
   a. Commercial
      - Amazing and rapid commercial progress will continue through year 2010, with a 50x performance/cost improvement expected.
      - A rapid product obsolescence cycle of 18 months will continue through 2005, but will slow to 36 months by 2010.
      - Custom ICs will migrate from gate arrays to standard cells (including macrocells and supercells) and FPGAs.
      - Fewer custom ICs will be needed.
      - Design/CAD/software complexity will dominate DSP core development; use of embedded processors will increase.

   b. Military
      - **Military Space Rad-Hard/Rad-Tolerant digital ICs will continue to be needed and used as unique technology. However, usage of rad-tolerant (COTS process, unique cell library) chips will increase particularly for spares. The cost and performance gap between rad-hard and rad-tolerant/COTS will increase. This will promote development of design methods and a COTS infrastructure for rad-tolerant chips. Continued DoD S&T investment will be required for both.**
      - **High Speed/Low Power Logic - will require unique material and device technologies tailored for specific military applications. 1 to 20 Gbps clock rates will be required.**
      - Use of digital COTS components will increase from 80% (1997) to 100% (2010) on all military platforms, with a few exceptions as noted above. Digital COTS usage will increasingly also encompass module and board levels although at less than a 100% level by 2010.

2. Analog/Multifunction Technology (dc - 500 MHz)
   a. Commercial
      - Analog IC technology (baseband linear, nonlinear, power function) progress will advance by 10X by 2010, limited by fundamental noise and power density factors. CMOS will dominate over bipolar devices, except where maximum precision is required.
      - A Multifunction ("commercial system on a chip") trend will emerge and increase, dominated by consumer applications. It will provide a process and design capability which combines analog, digital, and some RF functions (<1 GHz) on the same chip. Library techniques will be established for users.

   b. Military
      - **Some rad-hard analog IC military-unique technology applications will continue, primarily for nuclear missiles. However, it will be problematic to find sources for dielectrically isolated analog ICs. Instead CMOS SOI**

will be increasingly used, with a common fabrication process for rad-hard digital ICs.

- **Analog-to-Digital Converters. Wideband (≥0.5 Gsps) ADCs will continue as a unique-military technology to be implemented with compound semiconductors (GaAs, InP, and other materials). High leverage applications for these are wideband EW and Space Communications. They will also serve as enablers for all digital battlefield reconnaissance systems.**

3. Microwave Technology (0.5 to 200 GHz)
   a. Commercial (0.1 to 5 GHz)
   - COTS use in wireless telecommunications will dominate and provide technology for military use. The exception will be high power, solid-state amplifiers.

   b. Military and Space (5 to 200 GHz)
   - **The progress rate for monolithic ICs will continue only if DoD sponsors an S&T program, to include 6.1, 6.2, 6.3 and MANTECH efforts, of significant size. This program must include efforts to transfer promising R&D results to robust manufacturing processes and systems-ready products. In recent years there have been huge funding cuts in this technology area.**
   - **This microwave technology area is probably one of the three most important electronics enablers for DoD in the early 21st century. Phased array radar, wideband space communications, smart weapon seekers, covert sensors and many new applications for electronic warfare are enabled by this technology.**
   - **With a robust DoD technology program, the rate of progress enjoyed in the 1980s can be extended to higher frequencies, higher integration levels and higher performance levels (power/range, sensitivity, etc.).**

Platform Needs and Trends (21st Century)

Military platforms of smallest size and highest mobility will benefit the most from electronics using unique-military electronics components. These platforms include:

- Manned and unmanned aircraft
- Missiles and smart munition weapons
- UAVs and micro UAVs
- Spacecraft and microsatellites
- 21st century warrior.

Commercial Off-The-Shelf (COTS) Electronic Components
Special Technology Area Review
AGENDA

Thursday, 4 December 1997

PLENARY SESSION

0830-0835	Welcome	CAPT B. Buckley
0835-0900	Overview of STAR Issues and Objectives	W. Howard
0900-0945	DoD Perspective	J. Gansler
0945-1030	Balancing COTS and Security Issues	R. VanAtta
1030-1115	Congressional Perspective	J. Young
1115-1145	Industrial Perspective (R&D Coalition/EIA)	J. Hartman
1145-1215	Just In Time Electronics Systems-DSRC Study Results	T. McGill
1215-1300	LUNCH	

PANELS

1300-1430	Acquisition & SPO Perspective	
	Panel Moderator – R. Bierig	
	Army – ADO	Col. C. Fornecker
	Navy – AEGIS	CDR D. Stevenson
	Air Force – F-22	R. Gibler
	Fleet Logistics Office	N. Riegle
	Joint Strike Fighter	A. Rivera
1445-1630	Defense Systems Industry	
	Panel Moderator – B. Dunbridge	
	Sanders	J. Kreick
	Raytheon	R. Smith
	Boeing	D. Mayfield
	TRW	M. Bever
	Northrop Grumman	W. Eikenberg
	ITT Defense	E. Hammer

Friday, 5 December 1997

0830-1000	Components Suppliers (Military and Commercial)	
	Panel Moderator – T. Hartwick	
	Texas Instruments Military Products	J. Chapman
	Harris Semiconductor	B. Hagerty
	M/A-COM	J. Vaughan
	DELCO	G. Servais
1000-1130	S&T Perspective	
	Panel Moderator – G. M. Borsuk	
	Army	M. Andrews
	Navy	B. Junker
	Air Force	H. Hellwig
	DARPA	N. MacDonald
	California Institute of Technology	T. McGill
	IBM Watson Research Center	M. Polcari
	Lockheed Martin	D. Hutchinson
1130-1230	COTS Insertion Examples – Lessons Learned	
	Army – LONGBOW Radar	K. Richardson
	Navy – ADCAP Torpedo	J. LaCamera
	Air Force – C-17	D. Hartman
	DARPA – Dark Star	D. Lacey

CLOSED SESSION

1230-1315	LUNCH	
1315-1630	Summary, Analysis, Preliminary Findings and Recommendations	COTS STAR PANEL

TERMS OF REFERENCE

COMMERCIAL-OFF-THE-SHELF (COTS) ELECTRONIC COMPONENTS STAR

PRIMARY OBJECTIVE:

The objective of this STAR is to provide information which will allow the Advisory Group on Electron Devices (AGED) to assist the Department of Defense (DoD) in identifying and distinguishing three classes of electronic components for use in DoD systems: (1) those which are available as COTS products and can be effectively used without further R&D investment or logistics support, (2) those components in which modest DoD R&D investment can extend the performance and/or military robustness (i.e. COTS adapted for military purposes), and (3) those custom electronic and electro-optic components which have performance or environmental characteristics that will result in clear advantages for DoD war fighting systems compared to those of our potential adversaries. The components in the latter category are ones that may require DoD R&D investment to allow them to meet the performance challenges of DoD systems required by military mission statements.

The STAR will also examine those factors necessary to create new COTS components, needed by DoD, available in the longer term. The STAR will identify technologies likely to create new COTS in the time period from one to five years in the future as a result of new tools, processes, etc. that are funded as a result of current DoD S&T investment and/or by other sources.

SUPPORTING OBJECTIVES:

1. To establish a concise definition of COTS components.

2. To identify areas where COTS modules and sub-systems can be used without impairing DoD system effectiveness. This set should be updated periodically.

3. To identify areas where use of custom products is essential and a COTS alternative is not expected in the near future.

4. To identify areas where use of modified COTS hardware is most appropriate. For example, enhancing the radiation hardness of commercially available gate arrays, memories, and/or microprocessors.

5. To identify the degree to which battlefield and/or space qualified components and processes differ from commercial sector application components and processes and ascertain the impact of these findings on military parts procurement.

6. To catalog lessons learned from system program managers' prior experience with use of COTS hardware.

7. To assess the impact of COTS use on such issues as logistics, parts replacement, component obsolescence, system maintainability over its lifespan, technology up-dating, packaging technology, performance requirements, power consumption, heat dissipation, environmental constraints, EMP immunity and electrical emissions.

TENTATIVE DEFINITION OF COTS COMPONENTS:

COTS components are those which are either readily available from one or more sources of commercial supply or ones that can be produced using existing design, processes and fabrication capabilities without requiring additional DoD research and development investment.

National Semiconductor has offered four criteria for an IC to be termed "commercial". This includes "military grade" IC's. A commercial IC must meet these criteria:

1. It must be included in a manufacturer's price book or catalog, offered to any potential customer or application

2. A part number that all users recognize must identify it

3. It must be fabricated with a process common to a family of products and assembled and tested using standard methods and equipment

4. It must be interchangeable with all other devices bearing the same part number and (where various grades of product are offered) be downward compatible with all lesser grades of product

QUESTIONS AND ISSUES TO BE ADDRESSED AT THE STAR:

1. What types of electronic functions in DoD systems can make effective use of COTS parts? What are their characteristics and what are the environments in which they operate?

2. How will the use of COTS components affect system reliability and system design? Will commercial (0° - 70°C) and industrial (-40° - +85°C) grade components function reliably in a military (-55° - +125°C) environment? What testing and screening precautions should be taken? Can custom packaging of COTS parts provide electronic components capable of reliable operation under the stress of military environments? Are there new design/manufacturing strategies which can be invoked to make COTS based sub-systems operationally compatible with military functional requirements? What (if any) aspect of the battlefield/space qualified component-development requires specific action by the DoD (including funding support) to assure the availability of these components for DoD weapon system use?

3. Can components/parts meeting very aggressive specifications needed for DoD systems be made in small to moderate volumes with very high yield in facilities which are fundamentally designed and operated to provide very high yield to nominal performance specifications at high rates of throughput? For example, what are the limitations for COTS versions of the following

types of components and how do their specifications compare with DoD system needs? What are the projected cost savings of using COTS components in identified specific application examples as opposed to using custom components or a mix of COTS and custom components? How will the use of COTS impact system life cycle costs?

a) Stable sources (frequency ranges of operation, modulation ranges, short term and long term stability)

b) Microwave and millimeter wave power boosters (amplifiers)--both vacuum tube and solid state types (power levels, operating frequencies, bandwidth transmitter noise characteristics)

c) Receiver/detector (RF and EO) components capable of reliable operation in the presence of jamming and other countermeasures.

d) A/D and D/A converters

e) Components of all types requiring a high degree of radiation hardness

f) Components requiring electromagnetic pulse (EMP) immunity

g) Non-volatile memories

h) Flat panel displays

i) Components intended for use in space

j) Flight qualified system components

4. What techniques can be implemented to achieve extended performance ranges and enhanced reliability characteristics for COTS parts? Would such parts still fit the criteria and be considered COTS?

5. Will the use of COTS hasten the trend toward diminishing manufacturing sources (for military specific components)?

6. How will the use of COTS components affect DoD system logistics? For example, how should anticipated spare parts requirements be addressed? What changes need to be implemented within the present logistics procedures to make the most effective use of COTS?

7. What methods for providing sourcing information about COTS parts to DoD system developers and SPOs are likely to insure parts availability over the operational lifespan of their systems and also provide the anticipated benefits of COTS use such as reduced cost, reduced development time, and enhanced performance?

8. Are there examples of documented savings resulting from the use of COTS components/parts? What were the factors that resulted in those savings? Are they applicable to wider ranges of systems and situations? What was the level of savings achieved? What were the drawbacks of COTS use in those situations, if any?

9. Are models of COTS components adequate to support design of military hardware?

10. How will the use of COTS impact DoD system life cycle costs? If it is necessary to depend upon the use of COTS components in future weapon systems, how will system costs be impacted? Will sufficient component documentation be available to insure maintainability?

11. What will be the impact of the COTS strategy on the technical superiority objectives of the War Fighter Strategy?

12. Is DoD support necessary to assure the continued evolvement of COTS parts for long term technical superiority?

13. What will be the performance consequences for DoD systems should the DoD not be able to fund the development of needed non-COTS components, for next generation systems or system upgrades?

PARTICIPATION:

It is expected that the STAR will provide a forum for discussions between DoD and industrial system program managers, component designers and OEM suppliers. It would be particularly valuable for military technology planners, who define warfighting capabilities, to participate as well as agencies responsible for procurement of major weapons systems and their required logistics support.

ANTICIPATED OUTCOME:

1. A detailed report that describes AGED's recommendations on the use of COTS components in military systems and enumerates both expected benefits and anticipated limitations.

2. A list of DoD needed electronic component types and/or subsystems not amenable to a COTS approach and therefore requiring a DoD investment consideration.

3. Anticipated affordability of non-COTS components.

4. Recommendations on DoD R&D investments in electronics necessary to provide continued military leadership in an international environment dominated by COTS parts in military systems.

QUESTIONS FOR ACQUISITION AND SPO PERSPECTIVES PANEL
COTS STAR
DECEMBER 4-5, 1997
NAVAL RESEARCH LABORATORY
WASHINGTON, DC

1. What is your programs/agency's policy regarding the use of COTS electronic components in military electronic systems upgrades, defense system development procurements and parts acquisition for existing systems?

2. What is your definition of COTS components?

3. What electronic system functions cannot (or should not) be implemented using COTS components?

4. Who makes the "COTS versus Custom" decision, and what are the decision criteria?

5. What are the general lessons learned that are related to COTS component usage from past experience in your agency?

For example in:

- logistics
- parts replacement
- component obsolescence - metrics for forecasting availability?
- system maintainability
- technology upgrading
- packaging
- performance tradeoffs (including power requirements and heat generation)
- environmental tradeoffs if any

QUESTIONS FOR DEFENSE SYSTEMS INDUSTRY PANEL
COTS STAR
DECEMBER 4-5, 1997
NAVAL RESEARCH LABORATORY
WASHINGTON, DC

1. What factors and parameters are taken into consideration in selecting components (either COTS or custom) for systems that you build for DoD? As a contractor, what are the tradeoffs (i.e., risks and rewards) that you assess in deciding between use of COTS and custom components?

2. Which specific systems are ones for which your organization has considered the use of COTS vs. custom component parts? If the systems have been subsequently built, which electronic functions were implemented using COTS and which using custom components? Did system performance meet requirements? If not, what were the causes of the performance shortfalls?

3. In your opinion, is DoD support necessary to assure the continued evolution of COTS parts for long term technical superiority? In your opinion, what will be the performance consequences for DoD systems should the DoD not be able to fund the development of needed non-COTS components, for next generation systems or system upgrades?

4. Which electronic functions in the system(s) your organization has built or is considering building are ones for which COTS parts are considered suitable for implementing? What are the required performance parameters; what environments must the system(s) operate in?

5. Have cost savings through the use of COTS components been documented? If so, will you share information about the magnitude of these savings? What is the anticipated impact of the use of COTS on system life cycle costs?

6. What impact is the use of COTS having on your logistics planning? What approach will your organization adopt to assure that replacement parts will be available for this system 5-20 years in the future?

7. If system(s) built by your organization that use COTS components have already accumulated sufficient field use, is reliability data available. If so, what portions of the system(s) were responsible for generating observed failures, if any?

8. How did the use of COTS electronic components affect system reliability and system design? Did the commercial (0° - 70°C) and industrial (-40° - +85°C) grade components function reliably in a military (-55° - +125°C) environment? Were any special testing and screening precautions taken for any of the components used? Was custom packaging used in an effort to enhance reliability? Were any new design/manufacturing strategies invoked to make COTS based sub-systems operationally compatible with military functional requirements?

9. Are models of COTS components adequate to support design of military hardware? Will sufficient component documentation be available to insure maintainability?

10. In your opinion, what (if any) aspect of the battlefield/space qualified component development requires specific action by the DoD (including funding support) to assure the availability of suitable components for DoD weapon system use?

QUESTIONS FOR COMPONENTS SUPPLIERS PANEL
COTS STAR
DECEMBER 4-5, 1997
NAVAL RESEARCH LABORATORY
WASHINGTON, DC

1. What is your definition of COTS components? What does the term COTS mean to commercial suppliers, military suppliers, and captive suppliers?

2. a. Can the Department of Defense (DoD) develop advanced systems without performing advanced component development and making use of these advanced components?
   b. Will it be possible for the DoD to gain information about advanced commercial component developments, and the products that will result, in sufficient detail to allow the design of systems that incorporate them as these products become available?
   c. Is it likely that commercial suppliers will develop any military unique components without direct funding support and guidance from the DoD?

3. Will technology for COTS components continue to develop at an acceptable rate without continued investment by the DoD in the development of "leading-edge" electronics. What is the history of current COTS products and the expectations for new COTS products that will emerge within the next decade?

QUESTIONS FOR S&T PERSPECTIVE PANEL
COTS STAR
DECEMBER 4-5, 1997
NAVAL RESEARCH LABORATORY
WASHINGTON, DC

1. What areas of S&T will the commercial marketplace dominate? What areas will commercial suppliers make significant investments in over the next 10 years? How can DoD best access this knowledge base for its purposes?

2. What areas of S&T will be the ones that the commercial marketplace will not dominate? What areas, likely to be of considerable importance to the DoD, will commercial sources not make significant investments in? What approach is best for the DoD to pursue in order to perform necessary R&D in areas of crucial importance that the private sector is not motivated to pursue: Use of Government laboratories? Contract R&D with Academia? Contract R&D with Academic-Industrial Consortiums? Contract R&D with defense industry contractors? Other methods?

3. Are the current DoD designations for RDT&E (i.e., Category 6) still relevant today and is the implied model of those designations still valid (i.e., serial transition of knowledge, new capability, and results from basic research to fielded demonstrations)? If not, what alternatives might be more attractive (e.g., S&T investments grouped by time to achieve results)?

4. What are the implications for defense electronics R&D in light of defense industry consolidation?

5. How is the international S&T environment for electronics R&D likely to evolve over the next ten years? What nations/geographical centers will serve as resources for R&D capability? How can the DoD best exploit these capabilities? Are international S&T activities a threat or concern of any kind?

QUESTIONS FOR COTS INSERTION LESSONS LEARNED PANEL
COTS STAR
DECEMBER 4-5, 1997
NAVAL RESEARCH LABORATORY
WASHINGTON, DC

Provide examples of successful and unsuccessful attempts to incorporate COTS components into Department of Defense (DoD) electronics systems? Have there been situations where COTS usage initially looked attractive but turned out to be unfeasible? Why? Are there reverse situations?

Are there system implementation situations (or component areas), that can be identified as general cases, where the use of COTS is the best approach? What are these situations (e.g., computers)?

Are there classes of devices/components that can be identified as being most or least amenable to being as COTS in DoD systems?

In your experience, how often was it possible to make use of COTS components without their modification to meet DoD requirements? If modifications were necessary, how extensive were they?

For systems in which the COTS approach was used, would you recommend its usage now, after the fact? Why or why not?

In retrospect, can you cite examples of systems developed by your organization where a COTS solution should have been used in place of the use of custom components? Are there examples of systems where custom components should have been used rather than COTS?