# Mission Ready COTS

*A Framework for the Evaluation of COTS, Rugged COTS and Mission Critical Requirements.*

SKY COMPUTERS
A SUBSIDIARY OF ANALOGIC CORPORATION

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# Mission Ready COTS: The Guide



SKY Computers dedicates this book, which will help streamline the development of military and security systems, to the heroes of September 11, 2001. The people of SKY Computers would like to express our deepest sympathies to those who experienced a tremendous loss as a result of the attacks. We commend the rescue workers in New York and Washington for their tireless efforts. Our heartfelt thanks go to the U.S. armed services and our Allies who are risking their lives defending our freedoms here and around the world. Our spirit is unbroken and we are united in our resolve to protect our way of life.

## Introduction: Mission Ready COTS

Designing and integrating electronic systems for military applications presents developers with unique challenges. Fragile electronics, like a desktop computer, work well in a commercial environment, but generally can not survive the harsh environments found in aircraft or armored vehicles. In the early days of computing technology, electronic equipment was designed from scratch for each military application. This approach was both expensive and time consuming. In the early 1990's, the U.S. government mandated that all military electronics systems had to be procured as Commercial Off The Shelf (COTS) modules to the greatest extent possible. Ten years into the commercial off the shelf initiative, the COTS industry is sufficiently developed that, if a system can be configured with COTS modules, it generally is. The advantages to the systems integrator in QAI (quick application implementation), as well as reduced costs and risk are being realized in across the military establishments, all over the world.

The use of COTS electronics allows the system integrator to procure hardware, a software development toolkit, and an operating system off the shelf. Thus the integrator can focus their time and effort on writing the mission applications software and building defense/weapons systems, rather than designing and debugging infrastructure software such as O/S's, device drivers, and debuggers. Continuous development, upgrade, and maintenance of the COTS products by the COTS vendor relieves the integrator of these tasks over the life of the system.

The initial success of adapting COTS in the military has spurred program offices and prime contractors to explore how to extend COTS to work in platforms where there is either an extreme environmental challenge or a specialized form factor challenge that goes beyond off-the-shelf solutions. How can COTS electronics be exploited for very harsh environments such as an armored vehicle, for avionics, or for deployment into space? How can a COTS product be reformatted to fit an existing space on a legacy platform? And finally, how can suppliers be leveraged to extend the affordability, flexibility and upgradability benefits of COTS for mission critical programs? The Mission Ready COTS Guide will address these and other critical issues facing system integrators and prime contractors.

With more than 20 years of defense/military experience, SKY Computers sees the next wave of COTS going well beyond just supplying a simple point product. A complete life cycle approach, what SKY calls Mission Ready COTS, only begins with the off-the-shelf development system -- it extends to packaging the fundamental COTS design specifically for the application.

COTS today is a range of solutions that begins with development systems for benign environments, migrates to rugged systems for deployment, and extends to co-development or licensing solutions designed to fit the specific mission application. Mission Ready COTS is more than just rugged products, it is a business philosophy and model that embraces life cycle costing methods, manages technology insertion, and guarantees software portability from generation to generation.  There are very few electronics companies who have the experience and flexibility to provide this depth and breadth of support across the program life cycle; and who are willing to put it into the public domain.

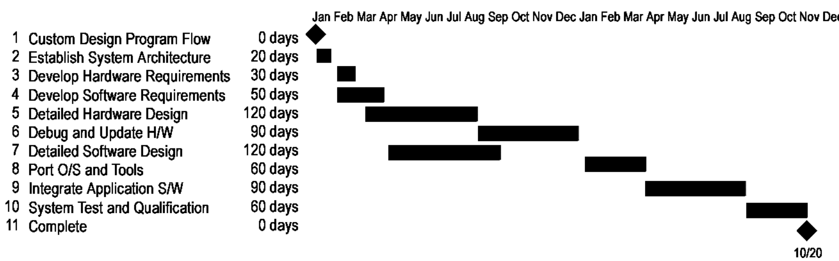



Figure 1 Shows the length of the development cycle for a custom designed system.

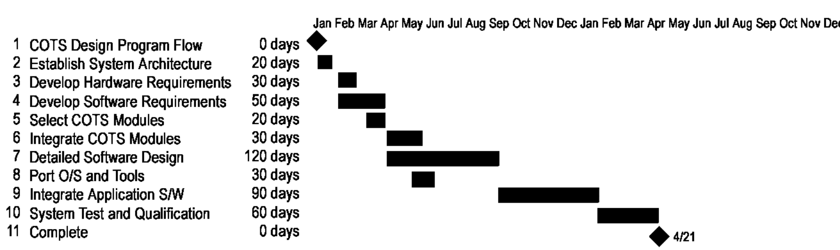



Figure 2 shows the same program using a COTS repackaging initiative.  This approach saves 25% of the development time, finishing a full 6 months ahead of the custom design.

The following chapters of the Mission Ready COTS Guide will overview the product, technology, and life cycle evaluations of COTS, rugged COTS and extreme COTS necessary when applying these technologies to legacy and new platforms whose requirements in form, fit, and function go beyond standard COTS.

The Mission Ready COTS Workbook, the companion book to this one, is a step by step evaluation tool that covers the COTS landscape. Once the groundwork has been introduced in the Guide, the workbook steps through the actual evaluation process. To receive a copy of the workbook, contact SKY Computers at 1 978 250 1920 or see www.skycomputers.com.

## Beyond Simple COTS to Deployment Programs

Most military programs have deployment requirements beyond those of commercially packaged products and commercial business practices. While standard COTS is appropriate for benign environments, military vehicles and platforms present a special challenge to the system integrator. Prior to the widespread adoption of COTS, the typical approach to designing and deploying complex electronic systems in military vehicles was to develop proprietary designs that met stringent military standards. These components were fully exercised through detailed environmental qualification testing procedures that complied to MIL standards.

MIL-SPEC's are a complex array of standards developed and maintained by the U.S. Government which were the normal design, test and qualification procedures that an equipment designer followed to ensure that the design would work in the intended environment. Historically all development and procurement contracts specified that the supplier comply with the referenced MIL-SPEC's.

The MIL-SPEC approach has been much maligned as a cumbersome and bureaucratic way for the services to procure equipment. However, the MIL-SPEC approach was effective when the equipment was being designed from the ground up specifically for a military application. This was demonstrated in the 1970's and 1980's, with the MIL-STD-1750A microprocessor for airborne computers and the AN/UYK-44 series of naval computers. At the time these systems were conceived, there was no comparable commercial technology available, and in many ways these systems led the wave of technology development.

During the 1980's, commercial computing capabilities, and the available range of applications, grew at an exponential rate. By the late 1980's, commercial computer resources far exceeded their military counterparts in performance, complexity, diversity, and were lower cost. While entire industries, fueled by growth in consumer and telecommunications systems demand, were funding the development of personal computers, operating systems, communications switch gear, display technology, and others, the military industry was still building systems from the ground up using standard military practice.

Massive growth in commercial electronics also led to growth in the semiconductor manufacturing industry. During the ‘70’s and ‘80’s, these companies derived significant profits from making “MIL-SPEC” semiconductor devices, designed and built specifically for use in rugged military applications. As was common at the time, most companies built one line of devices for commercial applications, while another division concentrated on military chips.

By the late 1980’s it became clear to every semiconductor maker that the market for their products in commercial applications exceeded the demand for military parts by orders of magnitude. Given the rapid growth in the commercial markets, and stable demand in military devices, semiconductor makers exited the military chip business. By 1995, most large semiconductor suppliers had shut down their military chip supply business.

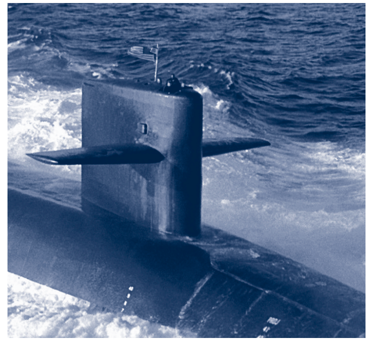
The combination of accelerated development and complexity in commercial systems, and the demise of the military integrated circuit industry led to a squeeze on the developers of military electronics systems. The military challenge now is how to deliver comparable capabilities to the commercial industry when so much more development money is available to commercial developers? How can the industry continue to deliver systems built to military standards when crucial semiconductor technology is no longer available?

One answer to these questions lies in leveraging commercial modules and technologies into military applications. This is how the COTS industry was born. Today mezzanine cards, general purpose and specialty boards and subsystems, are all available off the shelf for integration into demanding military programs.

## The Range of Environments Expands

Many military/defense programs use commercial components with commercial-level cooling, operating temperatures, and shock and vibration ranges. Ground-based radar systems, receiving sonar systems, and some airborne applications all utilize standard COTS.

One of the first rugged applications to embrace COTS was Naval below decks and submarine C3I systems. While a commercial workstation may not survive these moderate shock levels, the temperature range and random vibration demands are typically moderate. The most significant challenge in Naval applications is surviving the shock produced by under water explosions. The test environment is characterized in a well known MIL-SPEC, MIL-S-901, which outlines the test method using a hammer on a pendulum to simulate the effect on the ship. Designers must consider the hammer test in detail prior to finalizing the packaging arrangement for electronic systems.


Naval below decks and submarine systems were early COTS adopters.

System integrators have successfully deployed systems in these environments by shock mounting the electronics using readily available shock isolators. COTS rack suppliers now routinely provide shock isolated and EMI sealed chassis and racking systems which allow the use of standard VMEbus and Compact PCI board level products in these types of environments. Similarly, ground based applications can also benefit from the use of standard COTS modules where random vibration levels are moderate. Suitable environments include C3I systems mounted in rubber tire vehicles that do not need to operate in the absence of environmental controls provided for the occupants.

Another class of rugged COTS environments is characterized by extremes of temperature. These include ground fixed systems that are exposed to weather. In some cases, the equipment exposed to the outdoors for prolonged periods of time must survive temperature extremes but has no other extreme requirements. In these cases, temperatures of $-40^{o}$C are common in many places across the globe, and solar heating effects can raise operating air temperatures to over $70^{o}$C.

The use of COTS in these applications requires that the modules be ‘ruggedized’ to operate over the required temperature range. In the past, system designers chose components which were designed by the supplier to work over wide temperature ranges, and which were guaranteed by an environmental test standard such as MIL-STD-883. As the commercial semiconductor industry has focused more on the desk top and telecommunications markets over the past ten years, the number of suppliers who provide components characterized over wide temperature ranges has declined markedly. Even if a designer wanted certified components, it is doubtful that such components could be procured at any price.

Fortunately, using components in operating environments beyond their guaranteed limits is now an established approach. COTS vendors have a variety of techniques to ensure reliable operation under temperature extremes, including design derating, vendor selection, and qualification testing. While most COTS suppliers do not routinely design their products to operate over wide temperature ranges, many have qualification processes in place that extend their reliable operation. Conformal coating is also provided by vendors who test to temperature extremes, as this type of environment nearly always includes wide humidity variations.

At the more demanding end of the spectrum of ruggedization are environments such as armored vehicles and tactical aircraft. In most cases, the environment in these vehicles requires survivability under extremes of temperature, shock, and random vibration. Traditional means of building electronic systems for these applications were conduction-cooled designs based upon the Standard Electronic Module (SEM) or a proprietary form factor. Throughout the 1970's and 1980's, most tactical aircraft were designed to employ SEM form factor electronic modules housed in ATR style chassis. The SEM form factor provides an excellent combination of mechanical rigidity, conduction cooling, and high density.

SEM modules are still in wide use, primarily because the aircraft that use them continue in service. Aircraft such as the F-14, F-15, F-18, and others are predominantly equipped with SEM-E form factor custom designed electronics modules. Leveraging COTS in these aircraft is problematic because of the lack of an electrical and software standard in SEM-E modules, which prevents the COTS industry from designing standard SEM's off the shelf.

Conduction cooling provides very stiff physical boards with very high resonant frequencies that are immune to the effects of high shock and vibration. The technique gives the added benefit of "Zero Air Flow" which allows the modules to be used in cases where air is a scarce resource, such as high altitudes, or where it may be contaminated, such as a ground vehicle. Conduction cooling with SEM modules still represents a common approach, but results in long design cycles. The single biggest disadvantage of custom built SEM or proprietary modules for addressing the very harsh environment is the short shelf life of the design coupled with the long life of the development project. In cases where development and qualification times can be several years, many purpose-built rugged designs never survive the obsolescence of their constituent components to be deployed in volume.

The COTS industry has embraced commercial hardware standards such as the VMEbus and Compact PCI, which allow truly standard modules to be developed. To address shock and vibration, some COTS vendors provide stiffening bars or frames on their modules that increase the resonant frequency of the module significantly. In conjunction with shock isolated mounting, these types of ruggedized modules can now be used in many applications that historically demanded conduction cooled SEM designs. Recent systems have been tested recently use rugged COTS air-cooled modules in both armored and tactical aircraft.

As the life cycle for components becomes shorter, repackaging standard COTS or fielding rugged COTS modules as a basis of the design makes sense. This is not because COTS modules are immune from component obsolescence, but because the COTS industry provides compatibility from generation to generation, allowing for insertion of the new technology into a development program midstream.

QinetiQ, a leading contractor in the UK in a research report entitled, “The management and cost implications of radar signal processing using COTS systems” has determined that the most cost effective approaches to technology insertion are those which upgrade technology continuously throughout the program's life. This is in contrast to delaying upgrades to a 'big bang' where updates are undertaken at 10 year intervals.[2]

## Software Complexity Increases

The increased complexity of module design, and the demise of the military components industry have contributed to the rise of COTS modules as the approach of choice in military applications. Another factor is the move towards increased software complexity. Early electronics systems had no software at all, or if they were programmable, the software was "hard coded", and rather straightforward. During the 1980's, it became clear that the true advantage of microprocessors was their ability to perform many different functions by simply adding software. At that point system designers began to spend more on the development of software than the hardware.

Spiraling software development costs and quality concerns led to the imposition of the Ada programming environment and associated software development MIL-SPEC's. For a time, the military electronics industry attempted to go its own way with a software development methodology unique to the industry. Once again, the commercial industry with its larger markets and larger development budgets produced operating systems, languages, and tools which were superior to those in the military. The availability of lower cost tools and availability of programmers skilled in their use has forced the military equipment industry to employ commercial software languages and methodologies for many newer systems.

One of the most insidious effects of the move away from Ada is that software maintenance and contending with continuous updates are a significant issue. Where software was once written, tested, and then frozen, this approach is no longer feasible with commercial software. Most operating systems and tools are updated on a regular basis, and this means following the commercial supplier's software maintenance cycle for the life of the system, as long as patches, bug updates, and system expansion are required. Incremental upgrades can increase the complexity of accurately recording/reporting the configuration of each platform in a fleet where continuous upgrades could result in differing revision levels on each platform.

Just as using COTS hardware offers lower development costs and expanded capabilities, COTS software offers similar advantages. Where the COTS hardware compromise lies in adapting or repackaging the hardware to survive a harsh environment, COTS software commands a maintenance methodology that adapts to continuous update of tools and the obsolescence of old ones.

## Defining Requirements

COTS modules are a logical and cost effective approach to building deployable, mission ready systems for harsh environments. The challenge of using COTS is ensuring that the system requirements can be met while using a set of off the shelf items either as is, or with a minimum of modifications. Unlike designing systems from the ground up, designing systems with COTS demands a different approach. The key requirement for success is a clear definition of the system requirements.

Unlike designing systems from scratch where elements such as the environmental concerns, supportability, and system function partitioning may be self evident, designing with COTS calls for insights into these variables. The first factor to consider when specifying COTS for a deployable system is the specification of environmental tolerances in a harsh, rugged environment. The second area for consideration is the functional partitioning of the system to best exploit the available COTS modules and minimize the impact of the evolution of the COTS modules over the life of the system. Where custom designs gave the systems engineer full control over the functional layout of an embedded system as well as full responsibility for the obsolescence management and maintenance, using COTS means passing some of these items off to the COTS supplier.

### Considering the Environment

Prior to selecting the right COTS modules, a clear definition of the program's specific environmental attributes is necessary to developing the right strategy. Considerations of air flow, humidity, shock and vibration levels, and operating and non-operating temperatures will determine what, if any, levels of ruggedization will be required for the platform under development.

For example, consideration must be given to the presence of salt fog or high humidity. If salt fog is an issue, conformal coating will be required.

The vibration environment, however minimal, must be defined when using COTS modules. In some cases, these modules are not equipped with positive retention mechanisms for components, or even lock washers on the fastening hardware. If not provided for, fasteners and parts can work loose over time.

Some applications demand environmental survivability that goes beyond commercial level modules. Beyond naval, wide bodied subsonic aircraft, and rubber tired vehicles, COTS for deployment is a much more complex problem. Supersonic aircraft, helicopters, and armored vehicles each present a unique set of challenges to COTS equipment: challenges that must be clearly defined by the integrator. For each of the environmental requirements (air flow, shock and vibration levels, and operating and non-operating temperatures) there is a continuum of solutions that range from standard COTS, to rugged COTS, to repackaged or extreme COTS that will achieve the program objectives.

Mission platforms such as attack helicopters present specialized packaging requirements for COTS systems.

The operating temperature range for a module is generally characterized by the COTS vendor, and in some cases, there is significant design margin beyond the standard specifications built into the product. COTS modules are generally verified as operating with a certain inlet air temperature at a certain barometric pressure. It is very likely that the platform being designed does not match these exact conditions, so an analysis of the cooling capacity available in the target platform must be performed. For modules that are air cooled, the overall cooling strategy becomes part of the analysis.

For some applications such as armored vehicles, the difficulty in supplying clean, cool, pressurized air for an electronic module is a critical issue.  Air-cooled modules and NBC (nuclear, biological, chemical) decontamination procedures do not mix, so either conduction cooling, or a sealed/filtered cooling air supply will be required. In any case, a clear definition of how cooling air will be supplied to the COTS module is required. In addition to mitigating the air flow issues, conduction cooled COTS modules are also inherently more resistant to shock and vibration than air cooled, since the modules tend to be stiffer and have higher natural resonant frequencies.

Shock and vibration are significant factors in very harsh environments. The standard most quoted by COTS vendors that supply rugged products is MIL-STD-810. This specification is invaluable in providing insights on test procedures and typical considerations, but is no replacement for precise definitions of the actual installed environmental characteristics. Those familiar with very rugged platforms know that proximity to engines and armaments can have a dramatic effect on the expected shock and vibration that will be seen by the equipment. Definition of the precise shock levels and duration, as well as the random vibration spectra will maximize the chances for successful qualification testing.

Where conduction cooled COTS modules are mandated, the shock and vibration tolerances of these modules are usually sufficient to survive the installation. In extreme cases, additional measures are required, but these are the exception. Air cooled modules, however, must consider shock and vibration requirements carefully. Commercial COTS modules are not designed to tolerate harsh mechanical environments. Integrators should evaluate COTS modules where the shock and vibration characteristics are well known, and preferably, have been qualified by a vendor who can supply test data. Particular attention should be paid to the frequency spectra used for testing versus the expected frequencies when installed in the equipment. COTS modules with very low resonant frequencies (Sub 100Hz) can expected to be problematic.

There are shock and vibration mounting techniques that can be used with great effect to shelter a COTS module from the environment on the platform, but only to an extent. Coil spring isolators and rubber dampening mounts will attenuate shock and vibration levels, as well as modify the incident frequency spectra to which the COTS module will be subjected. Ultimately, the weight and sway space required for isolating an equipment rack must be traded off against the cost of choosing a more rugged module, or modifying the COTS module to increase its resonant frequency.

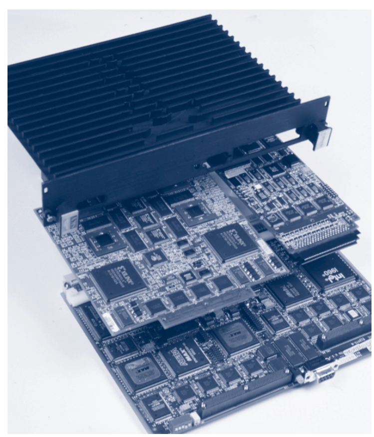
Increasing a circuit board or subassembly natural frequency is the single most effective weapon in the fight against shock and vibration. Some integrators will be comfortable in modifying a COTS product with stiffener and damping mechanisms, although procuring a module from a COTS vendor that has designed stiffness into an assembly is a lower risk approach.

COTS suppliers have different approaches to ruggedizing their products. Some vendors develop products exclusively for extremely harsh environments. The specialized technologies employed by these companies results in products that are expensive and typically do not keep pace with the industry standard price/performance ratio of performance increases of 2x every 18 months (Moore's Law). In cases where the environmental requirements are at the most extreme, the system designer must tradeoff environmental requirements with cost and performance.

Suppliers who specialize in high performance, high density computing have historically employed an iterative design approach to rugged COTS. Typically a supplier brings a COTS product to market and subsequently has it packaged and designed for harsh rugged environments.

Some COTS vendors have evolved their products to include standard levels of component and system ruggedization in their initial design. Stiffening schemes provide increased vibration tolerances and parts that withstand extremes of heat, cold, and humidity are all commercially available to electronic module vendors to build rugged versions at the component, board, and subsystem levels. The result is the availability of COTS for a benign environment; and rugged COTS for extended temperature, vibration, and humidity environments available from a single source, without long ruggedization development cycles. A single source for commercial-to-rugged technologies simplifies moving from development to deployment.

SKY Computers designs products with ruggedization and repackaging as a part of the overall mix, providing a family of products that uses common technology for each phase of the program development cycle. With its Xtreme™ product line SKY Computers has several levels of packaging for harsh environments, thereby providing the government and Defense contractors with a single source of multiprocessor technology. The table shows the range of environmental conditions each level of Xtreme ruggedization can meet. For environmental requirements beyond standard specifications SKY's Mission Ready COTS program evaluates repackaging, reformatting, and technology licensing.



SKY's Xtreme family of rugged products ensures easy transition from development to deployment.

| | Commercial | Xtreme1 | Xtreme2 |
|---|---|---|---|
| Board Temp: | | | |
| Operating Conditions | 0ºC to 40ºC inlet<br>3 cfm air flow | 0ºC to 55ºC inlet<br>3 cfm air flow | -40ºC to 71ºC inlet<br>5 cfm air flow |
| Storage | -40ºC to 85ºC | -40ºC to 85ºC | -55ºC to 85ºC |
| Humidity: (non-condensing) | | | |
| Operating | 5 to 95% | 0 to 95% | 0 to 95% |
| Storage | 5 to 95% | 0 to 100% | 0 to 1005% |
| Vibration: | | | |
| Sine | NA | 2G peak 15-2KHz | 10G peak 15-2KHz |
| Random | NA | .005 g2/Hz 15-2KHz | 0.04g2/Hz 15-2KHz |
| Stiffening Frame: | NO | NO | YES |
| Shock: | NA | 20g peak half sine<br>11 msec | 30 g peak half sine<br>11 msec |
| IC Temperature: | Commercial | Commercial/Industrial | Commercial/Industrial |
| Conformal Coating: | NO | YES | YES |

## Environmental Definition Check List:

The questions that need to be answered in this phase of the analysis include:

✓ Has the required environment been reduced to the minimum levels possible?

✓ Operating Temperature Range?

✓ Non-Operating Temperature Range?

✓ Ambient Humidity Range?

✓ Vibration Spectrum?

✓ Shock Duration/Intensity?

✓ Mounting Orientation to Shock and Vibration Input?

✓ Operating Altitude?

✓ Clean Air available?

✓ Space available for Shock/Vibration isolators?

## System Design with COTS

Embedded aerospace subsystems have certain commonalities in processing power, operating systems, and networking capabilities to the subsystems employed in commercial process control or telecommunications systems. In addition, aerospace systems normally include specialized military networking and interface standards, such as MIL-STD-1553B that are not readily supported in the COTS world. Once the environmental requirements presented by the target platform are defined, the available COTS options/vendors can be identified. In cases where the environment is manageable through packaging, many options exist, and it is likely that a complete COTS solution is a viable option. Where very rugged modules are mandated, the available COTS choices become somewhat limited. Where extreme ruggedization is required, the choices are further limited to vendors who offer re-packaging and technology licensing options.

The majority of deployable computing solutions will require some custom designed elements in order to fulfill the program requirements. Usually the requirement comes from a legacy I/O subsystem that continues to be supported on the platform. As legacy I/O devices are not available from a COTS vendor, this portion of the system will generally be custom designed. System partitioning becomes a critical issue.

### Partitioning the System - COTS Style

“Partitioning” describes how the various functions of the LRU (Line Replaceable Unit) will be assigned to the COTS modules that constitute the system. Whether the integrator plans to design the custom hardware internally, subcontract the work to a third party, or ask the COTS vendor to augment the capabilities of an existing design, the system partitioning decisions have long term consequences for the supportability costs of the deployed system.

For a system integrator used to designing systems with their own resources, the system partitioning may look logical, but the most logical looking approach can defeat the advantages of using COTS. Let’s consider an example of a system that requires a processor, standard COTS I/O, a COTS real time operating system, and a specialized legacy interface that is not readily available from a COTS vendor.

As shown in Figure 1, one way to accomplish the system goal is to start with a COTS CPU board which is equipped with the standard I/O. The integrator, or a third party, can then design a new hardware module that encompasses the legacy I/O. The new hardware is commonly a separate VMEbus or cPCI module, or a PMC that attaches to the system and memory maps to the CPU busses for communication.

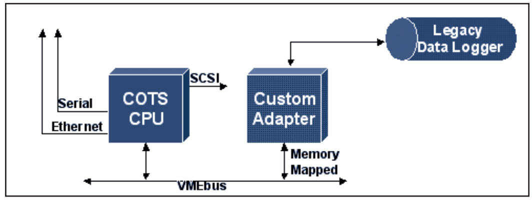


Figure 1. This approach requires writing, integrating, and maintaining a device driver.

While logical and straightforward, this approach means that the designer is required to write a device driver for the COTS operating system and integrate it with the COTS operating system. Many integrators are comfortable with this approach when they have significant software resources to dedicate to the task of porting the device driver. More importantly, in this case, the integrator is committed to maintaining the device driver through each of the regular maintenance updates that the COTS operating system will see through its life.This is an expensive approach.

An alternate partitioning strategy is shown in Figure 2. Here the custom designed hardware mimics the behavior of a COTS supported device. For instance, suppose that one of the legacy I/O devices was a data logger that included a solid state memory and a rudimentary file system for capturing data from a sensor suite. A potentially cost effective approach is to design the new interface as a standard SCSI interface, rather than a memory mapped I/O device that requires augmenting the shrink wrapped COTS software. The advantage to this approach is that the maintenance of the COTS software and the maintenance of the software driving the new I/O device are disconnected from each other. The integrator now has the option of swapping the COTS processor board and operating system without having any impact on the remainder of the system, or re-porting a new device driver. Rather

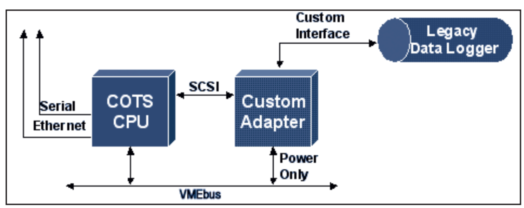


Figure 2. This approach simplifies development and maintenance of the software.

than memory mapping the new I/O, the partitioning strategy is to map it onto SCSI.

### COTS System Partitioning Checklist

The following questions need to be considered during the partitioning phase of the analysis and development.

✓ Does the proposed architecture maximize the use of COTS modules?

✓ Are all COTS modules independent of one another from a software support view point?

✓ Are all interfaces between modules standard and supported by the COTS software?

### Planning for Obsolescence

Perhaps the most significant event to impact the developers and maintainers of deployable electronics systems has been the demise of the long term supply for semiconductors. The exponential growth of semiconductors in the commercial world has relegated the military components market to near boutique status with the major semiconductor vendors.

The harsh reality is that the COTS board and subsystems vendors have no more control over the availability of parts for a ten or twenty year life cycle than the major defense contractors have. To support a hardware product for 20 years traditionally meant monitoring end of life status on components, and stockpiling parts. Component stockpiling as a strategy is an extension of the old model where the integrator designed, built, and maintained the products over the fielded life of the program. This was good business when parts were available, and funding was readily released. This strategy leaves the integrator with the responsibility for maintaining the system in the field, but they no longer have direct control over the constituent parts of the system. Consequently, obsolescence of a purchased item leaves the system maintainer high and dry. There is an option to perform end of life purchases of critical items, but this is an expensive approach that cannot always be funded by the end user.

Fortunately, there are strategies that can help mitigate the maintenance risks. The first of these is ensuring that the system partitioning allows for technology insertion.

Technology insertion is an approach whereby an obsolete product is replaced by a form, fit, and function similar item of a newer generation. This strategy was validated by the personal computer industry years ago by demonstrating that a new PC could be swapped into a system without requiring a rewrite of the applications software or replacement of the surrounding peripherals.

The same technique can be used to great effect with embedded rugged systems by strictly adhering to the principals of standards and open systems. Consider not only the standardization of the hardware interfaces to broadly supported specifications, but more importantly the software standardization as well. By sticking to common interfaces, the likelihood of finding next generation products 5 or 10 years down the road that can be phased into a system to solve an obsolescence problem is very good.

**System Maintenance Requirements Checklist**

✓ What is the expected life of the end system in service?

✓ Can all equipment including spares be procured at once to support maintenance?

✓ Can the COTS vendors guarantee repair and support for the modules?

✓ How long can the COTS Software vendors guarantee support for their products?

✓ Who will stockpile spares either at the part of module level?

✓ Who will perform reintegration where technology insertion is planned?

## Selecting COTS Products

Once the environmental requirements have been defined and the system partitioning is complete the systems integrator should have an array of possible COTS sources to fulfill the program's requirements. Selecting the final COTS modules and refining the systems architecture requires a detailed analysis of the options prior to finalizing a selection. When COTS supportability is designed into the COTS system architecture using accepted standards for both hardware and software it results in both lower system acquisition costs and life cycle costs. Because software maintenance costs are estimated to be 200% of the original project costs[1], a detailed consideration of the software approach should be performed first, followed by a thorough analysis of the hardware options.

### Software

Systems built with COTS modules are assembled either by the COTS vendor, or by the systems integrator, to provide a platform with the necessary characteristics, connectivity, and environmental tolerance for the application programs. The systems integrators main task is to write the complex application programs and provide content that will be integrated into the target platform.

Historically systems integrators built their own hardware, and wrote their own software from the ground up using a commercially supplied compiler, linker, and debugger. Integrators still use commercial tools, but the complexity of the "foundation software" that isolates the programmer from the hardware details has increased dramatically. The principal driver for the increased complexity is the growth in services supplied by the operating system. Ten years ago, the operating system provided a multitasking kernel or executive designed to manage memory allocation, simple I/O, and not much more. Modern operating systems like Linux, Solaris, and VxWorks provide extensive support for a variety of communications protocol stacks like TCP/IP, USB, and others. The communications stacks talk directly to the hardware support devices on the COTS modules. This software, along with a commercial operating system like VxWorks, is provided by the COTS hardware vendors.

In order to properly exploit the advantages of COTS, integrators should make maximum use of the underlying software provided by the COTS vendors. This approach relieves the applications programmers from the need to become intimate with the inner workings of the hardware, and more importantly, preserves the key advantage of COTS:  managing obsolescence through technology insertion.

The costs associated with solving a hardware obsolescence problem for a COTS board level module can be daunting. A closer look usually reveals that the major cost factors are associated with rehosting and requalifying a complex application software load onto the replacement hardware platform. Applying the example of the PC market, the costs can be greatly reduced if the software environment that the application was written under is still supported, even in legacy mode, by the COTS operating systems, libraries, APIs, and device drivers. For example, there are still DOS based programs in wide use on PC's many generations after the last version of DOS was fielded.

The implication in selecting COTS products for supportability is that the COTS hardware interfaces and software environment must be judged to have staying power. Factors to consider when selecting COTS hardware and software include:

✓ Does the COTS vendor have a history of producing successive generations of products with backwards compatibility?

✓ Are the chosen I/O interfaces sufficiently standard that one side can be changed without changing the other?

✓ Are the software device drivers designed to allow for user maintenance?

✓ Do the software tools used for maintenance change with every generation of product?

✓ Is the selected operating system likely to be in general use in ten years?

✓ Does the software suite allow a simple "compile and run" or is a major rewrite or conversion required from generation to generation?

Partitioning a requirement down to established standards at the hardware level is straightforward. Applying the same principles to the partitioning of the software can simplify programming the application and greatly reduce maintenance costs over the life of the system.

For most systems engineers, changing COTS hardware to add new capabilities is not an option since it defeats the cost saving benefits of using COTS in the first place. What is less obvious is that the same issues apply to changing COTS software. It is true that for some systems, there are no choices but to modify the COTS software load to suit the new application. The systems engineer must nevertheless consider the software partitioning the same way that hardware partitioning is considered to reap the full benefits of COTS.

In most cases, the most cost effective solutions are those which have been partitioned to leverage the advantages of the available COTS modules without modification, combined with custom designed portions of the system, interfaced to the COTS modules through standard interconnects.

Over the course of a program's life cycle, there could be numerous technology refresh and technology insertion points. Many of these upgrades, driven by changing application requirements, demand flexible and powerful technologies that far exceed the capabilities of the original design. In addition to considering the impact of hardware changes to a program upgrade, the impact of software migration and supportability costs cannot be understated across a program's life cycle. Software development can represent a multimillion dollar multigenerational investment with software maintenance typically significantly exceeding the initial development. Choosing a COTS supplier with a standard API and tools for quick application implementation can reduce the program's overall software development and optimization effort by as much as 30-50%. This savings provides "quick program turns" to support military preparedness/readiness.

To keep the software life cycle costs in check, the management of upgrade costs, through the use of portable software is another key element in COTS supplier selection. COTS suppliers under consideration must focus on methods for containing upgrade costs and providing a path for continuous performance upgrades and cost reductions over the program life cycle.

There are two key considerations: code portability and code optimization. Companies such as SKY Computers who provide open architectures and standard APIs can support a technology upgrade with tools that easily port software from one product generation to the next and from other vendor's platforms to SKY.

With just a few instructions, the code is ported to the new target platform. SKY refers to this as “compile and run” and ensures code compatibility from generation to generation. As importantly, the code is migrated to the new platform fully retaining its optimization. No additional time-consuming hand-coding and performance tweaking is required. Given the range of technology insertions and improvements that may occur over the program life-cycle and the critical need to move legacy code forward, advanced software capabilities, become essential to program success. In addition, by providing tools to easily port other vendors code to SKY systems, developers and integrators currently utilizing competitive systems can ensure that they are not locked into a single vendor’s technology or support.

### Hardware

The previous chapters described the exercise of determining the functional requirements for the platform and will have yielded a potential COTS architecture that meets the processing, I/O, and environmental requirements for the COTS modules. Selecting the specific modules for use should be based on consideration of the established requirements.

For environments where commercial grade modules are suitable, a wide range of choices are available. Most deployable systems, however, have environmental requirements which cannot be met by a standard commercial module. Some COTS vendors offer a wide range of ruggedization grades, ranging from commercial practice up to very rugged. To maintain maximum choice and lowest cost, the least rugged modules that can meet the requirements should be selected.

In some applications, integrators have chosen an approach called “cocooning” where COTS or rugged COTS electronics are built into environments with interfaces or enclosures designed to give the COTS solution greater tolerance to the environment. Cocooning is most effective where the environment is essentially benign, save for some particular aspect. Typical candidates for cocooning include:

**Naval Applications:** In most naval applications, the only ruggedization required is tolerance to salt fog and and MIL-S-901 shock. In most cases, electronic modules can survive salt fog or other airborne contaminants with conformal coating performed either by the COTS vendor or the integrator. Acrylic resin is the most common although urethane and silicone types are also used. The shock requirements can normally be met with coil spring isolators on a 19”rack arrangement, although others are possible.

**Wide Bodied Aircraft:** These environments tend to be similar to those of a commercial jet liner, although electronic equipment is normally mounted to the air frame for stability. Here there is a problem with low levels of random vibration from the jet engines, or the fundamental plus harmonic components of sinusoidal vibration from propellers. Depending upon the expected levels, these can often be mitigated with vibration dampeners fitted between the chassis and the mounting points.

**Ground Fixed Installations:** These may include remotely mounted surveillance sites or monitoring stations which are not provided with environmental controls. These types of installations are usually only subject to the changes in ambient temperature with the changes of seasons. While wide temperature range modules may be considered for this type of installation, an environmental control unit for the electronics modules may be a cheaper solution in the long run, given the life of the equipment, and the restricted choices available for extended temperature range COTS modules.

Some systems simply cannot use COTS or rugged COTS modules. Requirements that include any of the following criteria usually mean that rugged COTS modules are not an option:

✓ Retrofit of an existing chassis that uses a proprietary card format

✓ Application unique interfaces not supported by COTS industry

✓ Specialized cooling techniques

✓ Confined spaces such as pylon/pod mounting on aircraft

✓ Unique assembly or quality assurance requirements

✓ Exceptional shock or vibration environment

In these cases, a COTS solution is typically disqualified, and a custom design appears to be the only remaining option. However, a reformatted or repackaged COTS or rugged COTS product could provide the solution. In the next section, we will explore those options.

### Hardware Selection Checklist

✓ Has the system been partitioned to use standard modules to the greatest extent?

✓ Have custom elements of the system been isolated to one or maybe two unique modules

✓ Are all interconnects with custom modules from COTS modules standard COTS supported interfaces?

✓ Has the minimum ruggedization level possible been specified?

✓ To what extent is chassis level cocooning used to mitigate environmental concerns?

✓ Are COTS suppliers under consideration offering technology insertion options in out years?

## Extended COTS Options

Most aircraft in service today were designed in the 1970's and 1980's. Some, such as the venerable B-52 are now fifty year old designs. The developments in air frames and engine technology have continued at a slower pace than the fast paced improvements in electronics. The mismatch in development of new technology has led to a situation where military planners are interested in upgrading aircraft with new electronics much more often than they are in replacing them with new aircraft.

Recent history shows that aircraft upgrade and retrofit work is the most common form of capability enhancement. While an appropriate approach from the customer viewpoint, older aircraft that were designed in the "custom" era do not readily lend themselves to accepting COTS modules. Typical U.S. and European systems were built around the SEM-E or some custom derivative form factor, and need to preserve this format. This requirement is driven by the fact that equipment bays on the aircraft cannot easily be changed; there are few places to add a new box to an airframe like an F-15.

Faced with a fixed form factor requirement to upgrade an old SEM-E form factor module, some systems integrators automatically redesign from scratch, as in the past. Today, COTS modules can be used as the foundation of these upgrades.

### Option 1: Form Factor Repackaging

Some systems integrators have recognized that the fundamental value of COTS is in avoiding the custom design of a new module, given that the supportable life of that module is likely to be short. As previously described, the benefits of COTS are not only in the design of the hardware, but in the support software around the module. Given an available COTS module that meets the functional requirements for an upgrade or retrofit program, why not simply reformat the existing COTS module onto the new form factor?

Reformatting has been used with great success in programs where a COTS module meets the program functional requirements, except for the physical form factor of the module. By using the schematic of the COTS module as a starting point and relaying out the circuitry to suit the space available, all of the COTS software can be used essentially as is, and the task is greatly simplified.

When a COTS electronics module is reformatted, there are significant advantages in affordability, flexibility, and upgradability over launching a development initiative. Reformatted solutions can often be integrated much more rapidly and cost effectively than a custom design, and the software infrastructure for the module is preserved. Thus there is a simple migration of application software from the development environment to the deployment environment. A reformatting initiative is preferred due to the following factors:

✓ The COTS module offers a proven reference design for the hardware that greatly reduces development time, cost and risk. In most cases, the COTS hardware design can be used essentially as is with new partitioning and printed circuit layouts.

✓ Parallel development efforts can be initiated by using the standard COTS modules to develop new application software while the Reference Design is being repackaged. Schedules can be reduced by having software and hardware design proceed in parallel.

✓ Wide deployment of COTS development tools means that less time will be spent developing a software infrastructure and debugging the environment, while more time will be focused on critical mission applications software development.

✓ As most COTS modules are periodically updated and maintained by the COTS vendor, maintenance of the reformatted design is simplified by leveraging design updates for software patches or component obsolescence initiated by the COTS vendor. Technology insertion and maintenance costs are reduced.

✓ Applications software designed for the COTS module can be ported, with minimal effort, to the repackaged hardware platform. Software for the COTS module is preserved including device drivers and board support packages.

Once a suitable COTS product with the necessary functional characteristics is identified, the simplest option is to have the COTS vendor redesign the hardware into a suitable form factor, while preserving the application programming interface. If the COTS vendor possesses the necessary expertise in rugged hardware design, and is prepared to support the effort, this option is most efficient as the COTS vendor is in the ideal position to redesign one of their own existing products with a minimum of effort and risk.

**Form Factor Repackaging Considerations**

✓ Does the COTS Vendor possess the expertise to adapt their design to a new form factor?

✓ Has the planned design of the new module affected the ability of the underlying COTS software and development tools to support the module?

✓ What are the risk factors in the underlying design not working in the target environment?

✓ Is the COTS vendor prepared to support the module with software upgrades and maintenance?

**Option 2: Technology Licensing**

Repackaging an existing product is considerably easier than designing a new one from scratch, but it is not always practical. Even the most experienced COTS suppliers can run afoul of other program considerations or technologies when considering such an option. Some of the common pitfalls of form factor repackaging are:

✓ The COTS vendor cannot commit the necessary resources to perform the work, or the potential return to the COTS vendor does not justify the perceived level of effort. This case is common during very busy periods, or where the system integrator needs to build just one of two modules for a proof of concept phase.

✓ The program may have extraordinary security requirements. A number of "Black Programs" carry security ratings that preclude releasing critical application and operating data from the systems integrator to the COTS supplier. While these considerations can sometimes be overcome, there are circumstances where they cannot.

✓ The physical form factor requires the use of technologies that the COTS vendor is unfamiliar with, like liquid core cooling, or multi-chip level repackaging into radiation tolerant silicon-on-sapphire packages. Where the COTS vendor may need to learn too much about a packaging technology to do the work cost effectively, the proposition makes little sense.

When the COTS vendor is unwilling or unable to perform the redesign work, or where the application demands specialized processes or security measures, the integrator can perform the repackaging with their own resources. In this case, licensing the design from the COTS vendor minimizes schedule and risk factors.

Technology licensing combines the advantages of COTS with the necessity of a custom design for some applications. When electing to license an existing COTS design, the integrator should consider the risk factors in performing the repackaging. Things to consider will include:

✓ Is the basic design robust enough to work in the rugged environment? Has the basic design ever been qualified to work over the necessary temperature ranges in the past?

✓ Will it be possible to select functionally compatible wide temperature range components that meet the environmental requirements?

✓ Will the COTS vendor support the effort with their expertise and software source code? Can the COTS vendor verify compatibility with existing software?

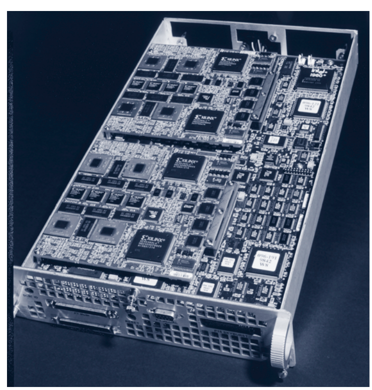
✓ Can the existing COTS vendor test processes and software be integrated into the new module's manufacturing flow?

Not all COTS designs can be successfully or economically be repackaged in a custom form factor. The integrator should examine the characteristics of the design carefully prior to committing resources to the effort.

**SKY Computers Repackages SKYstation for Submarine Detection and Classification**

SKY was chosen by ORINCON Corporation to supply the computer engine for the DARPA SAST (Situationally Adaptive Sonar Tracking) Program. SAST is a sonar signal processing system for the detection and classification of submarines.

SKY repackaged its COTS SKYstation to fit the mission application space, and included self-hosting capability and battery power. Software compatibility was maintained from the laboratory to deployment providing easy upgrade and savings in software porting costs and time.



## Evaluating Vendors for Repackaging

There are many COTS electronics vendors, some of whom offer standard levels of ruggedization. However, there are only a couple of vendors willing to repackage beyond their standard form factors, or who are willing to share their intellectual property. An important element in vendor selection is choosing the supplier(s) who do this as their standard of doing business, as SKY Computers does, not just as an exception. Whether the COTS vendor does the design work, or the design is licensed by the integrator, form factor repackaging demands multi-disciplinary strengths in engineering. In the make/buy evaluation, the following check list of packaging capabilities identifies the critical competencies that must be present either with the COTS vendor or with the integrator undertaking the work.

### ✓ Component Selection

When the semiconductor industry made military temperature range components, component selection was easy. Today, without those parts, selecting wide temperature range components will help, but ultimately, the hardware designer is faced with selecting components that are purely commercial, but are either known to work over a wide temperature range, or can be qualified to do so. Making the right choice requires the focus and expertise of people who understand the tradeoffs.

### ✓ Thermal Management

Successful qualification testing depends on paying close attention to the management of heat and cold extremes. Where a PC can use a microfan to cool the microprocessor, operation at 50,000 feet usually means conduction cooling, pressurization, or even spray cooling. Design for optimum thermal management is a science that requires extensive knowledge of the ultimate platform requirements and of each component of the system.

### ✓ Component Placement

Extreme shock and vibration levels can sometimes be managed at the rack and chassis level, as is commonly done as a hybrid implementation in naval applications. In most cases however, the ultimate limiting factor in survival is the resonant frequency of the printed circuit assemblies, and the consequent movement of the boards under vibration loads. Experienced designers maintain maximum stiffness and minimum weight, while carefully deciding where to put fragile BGA packages.

### ✓ Component Retention

In commercial designs, there is usually little consideration given to the effects of random vibration. Experienced designers know that the reliability of an electronic module is partly influenced by the reliability of the solder joints and the plated through holes in the printed circuit. These are in turn influenced by their mechanical topology, but ultimately, how much the solder joints are flexed by vibration, as well as thermal cycling.  Experts focused on these considerations determine the survivability of the modules.

### ✓ Thermal Coefficients

Some commercial hardware designers are surprised to learn that a design can be overstressed with the power off simply by cycling temperatures between the extreme low and high that the module will experience in storage. When a COTS supplier is building a module for a mission application consideration must be given to the effect of differences in thermal coefficient of expansion for dissimilar materials that are bonded together.

### ✓ Connectors/Cabling

Commercial cabling solutions suffer from mechanical fragility as well as a lack of resistance to corrosive atmosphere and fluid contamination. Systems designed for exposure to high levels of random vibration or NBC decontamination procedures must consider the connector selection and cabling solution as critical points of failure in testing.

### ✓ Test Procedures

Some vendors will use Highly Accelerated Life Testing (HALT) or Highly Accelerated Stress Screening (HASS) techniques as part of the design verification cycle. Few will subject a design to test procedures intended to verify operation of the system well outside of its intended operating environment, or perform 100% testing over temperature and vibration as a military supplier would.

### ✓ Derating

A classic approach to maximizing the first pass success rates for a new hardware design is to derate the timing parameters and fanout values. Rather than using the commercial semiconductor vendor specifications for a part, the designer will ensure that a design can tolerate a component operating outside of its minimum/maximum timing parameter ranges.

### ✓ Engineering and Re-engineering Focus

Beyond these critical skills, COTS and rugged COTS suppliers, like SKY Computers, can provide maximum focus to engineer the repackaged solution. By assembling a team of full-time, high-level experts in packaging technologies, physics, computer design, system analysis, production engineering and instrumentation the advantages of COTS can be realized for the most demanding mission application requirements.

**SKY Computers Licenses COTS Technology for Firefinder Radar**

Grumman selected SKY Computers computer engine for the electronics upgrade to the U.S. Army's Firefinder counterbattery radar system. The SKY board was used to improve Firefinder's detection probabilities, false location rate and projectile classification rate.

Through a technology transfer effort with Radstone, Grumman upgraded radar installations in the U.S. and with some U.S. allies.

## Test and Qualification of COTS Systems

At the outset of a development program, the test strategies to be employed in qualifying a system for deployment seem straightforward. As with any custom design, the finished unit will be subjected to environmental testing in accordance with MIL-STD-810, and tailored to the specific application at hand. This strategy has worked well for many years in an environment where the underlying electronics modules that constitute the system have been designed at the outset to meet the guidelines.

Employing COTS introduces risks into this strategy because the typical COTS modules are designed for commercial environments, or for rugged environments that do not exactly match the target environment. To maximize the chances of a COTS based system passing qualification testing, other strategies can be considered.

The familiar approach of designing with military temperature range components, employing military grade processes, and selecting parts that have established reliability has been described as “Guaranteed By Design”. This approach has worked when the designer has full control over all constituent items. As we have discussed, however, military grade parts are no longer generally available. Even if they were, many printed circuit materials and soldering processes used in military electronics systems are not in general use by COTS electronics companies.

Since the Guaranteed By Design strategy cannot be employed cost effectively, it has given rise to an alternative referred to as “Guaranteed By Test”. In this approach, the modules that make up the system are not necessarily designed to withstand the target environment, but can be individually qualified to meet it through a sequence of tests. Robustly designed commercial electronics modules can be successfully qualified to run over much wider temperature ranges than specified. While not generally advertised by the semiconductor industry, many vendors qualify their parts over a wide temperature range; wider than that required for commercial or industrial temperature ranges. Through careful selection of components, a military systems integrator can exploit this fact to build reliable systems from commercial and industrial temperature range parts.

## Establishing the Test Strategy

The testing strategy will depend on whether or not the end hardware system can be procured from a single COTS source. If all modules can be procured from a single source, then the integrator can place the onus on the COTS vendor to demonstrate, through an acceptance test procedure, that the delivered hardware meets a predefined procurement specification.

Most COTS vendors will not be able to demonstrate through a Guaranteed by Design analysis that the modules are guaranteed to work. However, operation can be demonstrated through a combination of qualification testing on first articles, followed by Environmental Stress Screening (ESS) procedures on delivered production units.

The test standards used can be established by the systems integrator from the target environment specification. Generally, most COTS vendors with rugged products are capable of performing this type of testing.

Unfortunately, in the majority of cases, the system configuration will result in modules provided by multiple COTS vendors, sometimes in concert with custom designed elements. The obvious approach to testing the system is for the systems integrator to perform qualification testing on the completed unit. The likelihood of this strategy resulting in success is dependent upon the quality of each module in the system.

When a COTS module fails in a system during qualification testing it can be very difficult to determine the nature of the failure, and pinpoint a solution. Careful partitioning of the qualification test software suite can improve the odds of isolating a test failure to a specific module, along with providing enough information to suggest a fix. Alternatively, the integrator can require each COTS vendor to perform qualification testing on each module independently prior to integration. This strategy is more expensive initially, but where risks of failing qualification are significant, isolating failures is clearly much simpler. The systems integrator must be prepared to specify the test conditions for each system module that mimic the environment which the module will experience in operation. Reducing a system environment to a module environment will require a clear understanding by the integrator or chassis vendor of the air flow characteristics as well as the mechanical transmissibility characteristics for shock and vibration.

Some COTS vendors, such as SKY Computers, have performed module level testing to establish the performance of the COTS hardware as part of the design process. Where possible, pre-existing qualification data should be reviewed by the integrator prior to selection of COTS modules for use in the system. Modules which have been used in harsh environments in the past have a much lower risk of inducing failures in the system during qualification testing.

**Test Strategy Checklist**

✓ Is test data available for all COTS Modules?

✓ Are the local environments for each module known?

✓ Are individual tests required for certain modules?

✓ Has the system test software strategy been defined?

✓ Can qualification test failures be isolated to individual modules?

## Integration Options

Unlike designing systems entirely in house, working with COTS means extending part of the design responsibility to a third party. The preceding sections have dealt with the technical aspects of using individual COTS modules with an eye towards narrowing the field of available options down to those which meet the program technical requirements. Beyond the capabilities of the individual product, vendor selection includes an evaluation of using a COTS vendor to perform initial system integration versus doing it from an array of COTS modules. Other considerations, which will be discussed in future chapters, include an evaluation of the vendor's life cycle approach, as well as the design practices used by the vendor.

Following the partitioning of the system requirements, and the selection of a suite of candidate COTS modules that can be used as building blocks, the integrator is faced with selecting specific vendors from the available COTS market. There will be a range of possible options, with some vendors offering strong elements in some functions, while others offer compelling options for other functions.

Regardless of the breadth of available options, a fundamental decision is to perform board/subsystem integration yourself, or to purchase a turnkey pre-configured system from a COTS vendor. Many COTS vendors offer system integration services that relieve the systems engineer of having to put together a kit of modules prior to commencing application software testing.

The advantages of selecting a pre-configured solution from a COTS vendor can be substantial. Most systems integrators possess the necessary skills to complete board level integration, but few can afford the time or the resources to do infrastructure work. Precious software engineering talent is generally better allocated to solving applications problems rather than the mundane tasks of ensuring interoperability of a diverse range of COTS modules.

Selecting a COTS supplier who can provide complete subsystems saves valuable program development time.

To avoid the lost time and uncertainty of integrating dissimilar COTS modules, selecting an integrated solution from one vendor is a low risk approach. The module selection process should be constrained to those vendors who will do the integration as a primary function of configuring the overall system. Selecting board level products that can be cost effectively integrated by the COTS provider becomes part of the decision matrix. In some cases, the best overall solution may be the one that can be integrated most easily, or provides life cycle cost benefits, rather than the one that offers the lowest entry-level price.

**SKY Computers Builds Supercomputer for the Air Force Research Laboratory (AFRL)**

AFRL, Rome Research site selected SKY Computers to design a 384 processor computer system which is used by the DoD-wide community of signal/image processing researchers. It is used as a real-time signal and image processor for the development and testing of embedded parallel algorithms supporting major defense command and control projects. The system is a resource shared among the U.S. Air Force, the U.S. Army and the U.S. Navy.

## Understanding the COTS Life Cycle Challenges

The initial goals set for COTS including cost reduction, performance improvement, and accelerated development cycles have, to some degree, been realized. However, in electronic systems and large-scale weapon development the utilization of COTS has created as much complexity as it has simplified. Across a program's life, developers contend with shorter product life cycles from the COTS vendors that in turn introduces technology refresh, insertion, and obsolescence management issues.

The number of organizations involved in each procurement provides additional complexity. A typical program involves the procuring government agency, the defense contractor/integrator, and numerous commercial suppliers. Each of these organizations has differing views on program and product life cycles and differing business models. The typical COTS suppliers' product life cycle is 2-3 years. The typical defense contractors' program life cycle is 7-15 years. The typical government program life cycle and sustainable platform life is 25-40 years. These disparities have the defense contractors and COTS suppliers looking closely at the costs of technology refresh, insertion, and obsolescence management.

The P-3 Orion entered service in 1962 and is still in use and being upgraded.

The U.S. DoD has realized that the program life cycle (which can have a platform life of 40+ years) needs to be revised to build in shorter design/insertion cycles. Successive refinements, rather than a series of point-designs, is the approach that best fits the COTS model. Low startup costs and the need for continuity between generations of a product design were historically the reasons for the success of COTS programs. As COTS has been adopted it is rapid prototyping, accelerated implementation, and reduction of complexity that are now regarded as the real benefits of COTS.

## Evaluating the COTS Supplier's Life cycle Approach

In a typical program life, Defense contractors incur 60-70% of their costs after initial platform deployment in the form of ongoing maintainability, reliability, and supportability programs. Defense contractors have always considered these life cycle issues when choosing COTS suppliers. Conversely, most COTS suppliers are not familiar enough with life cycle costing and programmatics to provide more than initial product and maintenance pricing.

Further, while hardware costs across the life cycle are easily quantified, the majority of "hidden" costs are software-related. The selection criteria of COTS suppliers needs to extend beyond hardware evaluation to the evaluation of software tools that can provide quick application implementation and a standard API that enables application code to easily migrate to new technology without expensive recoding and re-optimization.

government agencies and defense contractors cooperate in the selection of the COTS supplier for any given project or program. The U.S. government has established standard cost criteria that includes the following costing elements in the selection of COTS suppliers. This information provides a realistic life cycle cost model, which provides the government and military with solid insights into projected cost behavior and estimates cost of ownership. Life-cycle costs include:

### Hardware Related Costs

| | |
|---|---|
| Initial Product Price (development) | Initial price of commercially packaged COTS product |
| Initial Product Price (deployment) | Initial price of deployable/rugged COTS product |
| Installation Costs | Initial cost to install and test equipment |
| Maintenance Costs | Costs for system installation and MTB unit repair |
| Training Costs | Cost of operator(s) learning to operate including training manuals, installation, service manuals |
| Operational Costs | Cost of reliability over the life of product including projected cost of replacement product |

| | |
|---|---|
| Fault Isolation/Redundancy Costs | Costs associated with fault isolation and fault redundancy (continuous performance) |
| Support Costs | Costs associated with integrated logistics support, program for sparing, test & repair, and documentation |
| Disposal | Cost of displacement |

## Software Related Costs

| | |
|---|---|
| Cost of Software Tools | Initial cost of supporting software tools, GUI, libraries, optimizers |
| Software Integration Costs | Costs of integrating new software with existing systems. Application development and optimization |

## Technology Refresh and Insertion Costs

| | |
|---|---|
| Planned Product Improvement and Life cycle Installation | Costs associated with planned product improvements during the program life-cycle |
| Interchangeability of Hardware/Software | Costs associated with portability of architecture, form fit, function, replacement and expandability of capabilities |
| Software Change/ Upgrade Costs | Costs of porting and re-optimization of software as new technologies are inserted and new technologies emerge |

## Supplier Performance Risks

| | |
|---|---|
| Past Performance | Supplier reputation for meeting or exceeding product performance claims. Ability to a provide clear technology upgrade path to match program life-cycle |
| Risk Mitigation | Vendor history of providing open systems architecture and tools to support technology refresh and technology insertions |
| Avoid Vendor Lock | Maintain a viable position for alternative sources. Understand both vendor's technology roadmaps |
| Supplier Longevity and Financial Stability | Can this supplier meet the complete life cycle needs? |

Defense contractors use a similar set of evaluation criteria to that of the government. However, profit motive and competitive pressures distinguish the supplier model from the government model. The long-range upgrade plan for technology insertion, including the utilization of the latest hardware, software development, and maintenance costs have the most impact on the potential profit that can be realized. Developing these costing elements makes the COTS supplier much more valuable to the defense contractor and builds long-term relationships between the two organizations that continues through out the program life.

Surprisingly, most COTS suppliers are not able to provide life cycle statistics, some lack any experience in military deployment/production. Many companies are able to offer defense contractors initial pricing models but are unable to get realistic predictions of both product and cost performance over the program life cycle. In today's highly competitive electronics market place, only a few companies including DY4 and SKY Computers have made a commitment to life cycle planning and analysis for the defense community.

### The Successful COTS Vendor's Approach

Successful COTS companies focused on the needs of the defense and military, have built their business to reflect the requirements of the government and the defense contractor base. By maintaining flexibility in their working relationship with the defense contractors and striving to understand the divergent needs of different programs through consistent communication with program managers and industry sources, these COTS suppliers will net long-term customer relationships.

## Conclusion

At SKY Computers we see that the next wave of COTS goes beyond just supplying a point product. A complete life cycle approach starts with the off-the-shelf development system and extends to packaging the fundamental COTS design to meet the specifics of the target program. An effective COTS partner needs to include co-development of form factors designed to fit the mission application, and licensing the COTS supplier's intellectual property as part of the total life cycle solution. There are very few electronics companies who have the experience and willingness to explore the mission application to this level of cooperation.

Not every program is a candidate for the COTS approach to systems integration. And there are few COTS companies who have the experience and willingness to explore the mission application needs, beyond the point product approach.

However, with attention to the process of system partitioning and procurement, COTS can be used with great success. Unlike the tradeoffs associated with designing a system from scratch, the benefits of COTS can best be realized by ensuring that the selection of available modules consider the operating and integration environment carefully.

### One Approach to Extreme COTS

"Extended COTS" is SKY Computers' reformatting/repackaging and technology transfer program. Extended COTS includes a thorough evaluation of the program requirements including operational objectives, upgrade and retrofit plans, and supportability goals across the life of the platform. Once the designs are approved, manufacturing can begin, either in our state-of-the-art facilities, or the designs can be licensed for outside manufacturing. Simultaneously, application software development can begin using standard COTS subsystems. This concurrent engineering process allows quick turns to meet accelerated program cycles. Ongoing upgrades and support programs are built into the original design, ensuring complete application flexibility, upgradability and cost minimization.

After 20 years of experience with COTS, at SKY Computers we believe that the most effective utilization of COTS includes co-development of the platform solution. This means COTS modules/systems designed to fit the mission application, at the commercial, rugged or extended ranges. For requirements beyond this level, repackaging/reformatting or licensing SKY intellectual property is available. Today's active military and defense integrator needs this degree of flexibility and must demand it from their selected COTS providers to be successful.

This COTS Guidebook is a starting point in the selection and use of COTS. When you are ready for a complete evaluation of your program's requirements, contact SKY Computers or your local account manager for a copy of the Mission Ready COTS Handbook, a workbook on how to apply these fundamentals to your Mission critical program.

## References

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