GEB1: Diminishing Manufacturing Sources and Material Shortages (DMSMS) Management Practices

Henry Livingston
Vice-Chair, Government Electronics & Information Technology Association (GEIA)[i] G-12 Solid State Devices Committee
E-mail: Henry.Livingston@ieee.org; Internet: http://home.att.net/~cetoolbox/

INTRODUCTION

Diminishing Manufacturing Sources and Material Shortages (DMSMS) is an increasingly difficult problem for DoD weapon systems because the manufacturing lives of many critical items get shorter while the life cycles of military weapon systems keep increasing. Traditionally, efforts to mitigate the effects of DMSMS have been reactive; that is, the effects are addressed only when they are seen. This reactive approach to DMSMS solutions leads to decisions that put a premium on faster solution paths with attractive short-term gains in order to avoid system inoperability, while ignoring the long-term solution paths that would lead to generic families of solutions or larger-scale solutions with the capability of avoiding future DMSMS issues. In order to solve DMSMS issues with lower overall cost, DMSMS solutions must change from reactive to proactive. The building blocks of effective proactive management of DMSMS are established during the design and development of systems. If systems are designed with the inevitability of DMSMS in mind, early solution paths with large-scale solutions can be started at an appropriately early time to enable intelligent choices without the imminent threat of system inoperability. Such generic large-scale solutions and a consensus on where DMSMS threats are most prevalent can be better forecasted by the use of a standard set of DMSMS management practices used by the foremost members of industry.

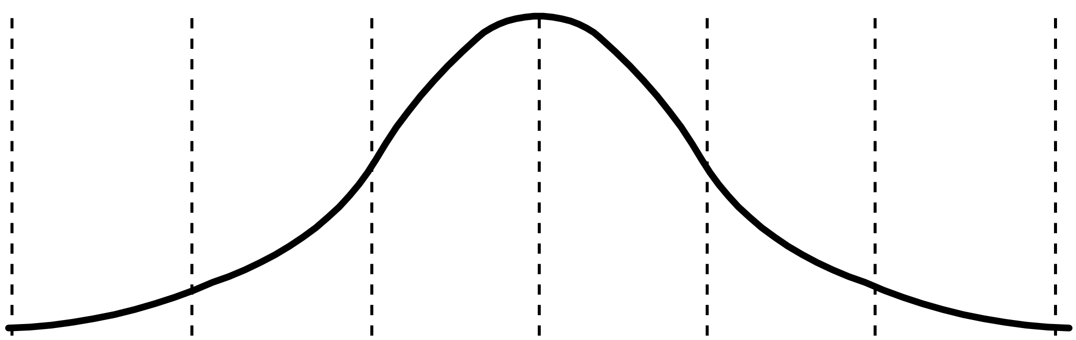
The Government Electronics and Information Technology Association (GEIA) G-12 Solid State Devices Committee developed a set of DMSMS management practices that can be used by original equipment manufacturers (OEMs) during the design and development of electronic systems to mitigate the effects of DMSMS. This paper provides an overview of EIA Engineering Bulletin *GEB1, Diminishing Manufacturing Sources and Material Shortages (DMSMS) Management Practices*.

MICROCIRCUIT LIFE CYCLES

Life cycle curves provide a basis for developing forecasts and planning for technology insertion and product update opportunities. GEB1 uses the definitions in *EIA-724, Product Life Cycle Data Model*, for the purpose of describing the life cycle of microelectronics. The figure below presents a summary of the characteristics associated with each life cycle stage.[1]

Not all devices conform to the six life cycle stages described in EIA-724.[2] Some devices undergo a false start and die out, or may be associated with a niche market. Some devices may be revitalized after the decline stage. Other possibilities can also arise due to various economic, social, and environmental occurrences. A false start typically suggests that a device starts out with a strong period of growth only to stall because of one or more of the following factors:

Product Life Cycle Model



	Stage 1 Introduction	Stage 2 Growth	Stage 3 Maturity	Stage 4 Saturation	Stage 5 Decline	Stage 6 Phase-Out
Sales	Slow increase	Increasing rapidly	Stable	Leveling out	Decreasing	Lifetime buys offered
Price	Highest	Declining	Stable	Stable	Rising	High
Usage	Low	Increasing	Stable	Stable	Decreasing	Decreasing
Part Modification	Frequent	Major	Periodic changes	Few	Few or none	None
Competitors	Few	High	Stable number	Decline begins	Declining	Declining
Manufacturer Profit	Low	Increasing	Stable	Stable	Reasonable for survivors	Reasonable for survivors (aftermarket)

[i] A Sector of The Electronic Industries Alliance

- Introduction of a superior competing part
- Improvement of a competing part
- Identification of a technical problem associated with the part
- Failure to reach the critical mass to allow economies of scale to be realized
- Lack of a unique and compelling application for the part

Historical data from industry studies shows that the average life span of total microcircuits across all quality ranges is around 10 years overall.[3] Military microcircuits average greater than 12.5 years while commercial microcircuits (including "mil-temp-only," industrial, and commercial temperature devices) average less than 8.5 years. Certain microcircuit families have different life spans; for example, certain linear devices average less than 14.5 years while some microprocessors and memories average less than 5 years. The following shows the average introduction rate for new generations of commercial integrated circuits:[4]

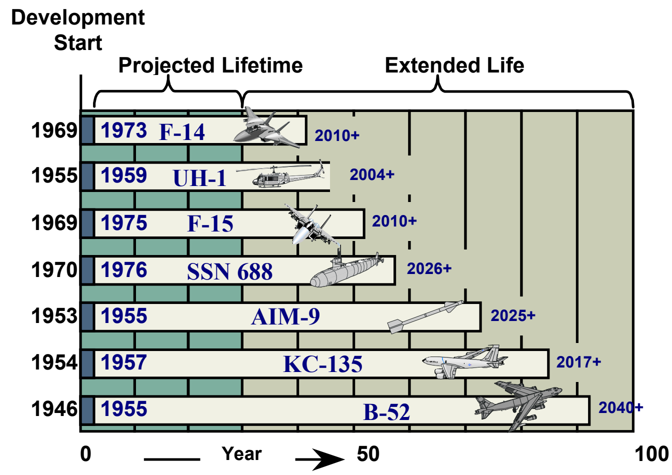
Device Category	Average Introduction Rate
Logic Families	6 years
Memory Families	9 months
Microprocessors	2 years
Digital Signal Processor (DSP)	3 years
Programmable Logic Device (PLD)	1 year
Linear Interfaces	8 years
Gate Arrays	2 years

Observations from various industry sources indicate that these average introduction rates have gotten shorter in more recent years.

Weapon System Life Cycles

Obsolescence of subsystems is a risk driver for weapon systems because, as with many low-volume electronic systems, they are intended for use over extended time, leaving them vulnerable to obsolescence of the parts, subsystems, and technologies that comprise the system.[5] Resources have to be committed and combined engineering-business strategies need to be implemented to sustain supply of obsolete parts long enough to permit redesign and requalification.

With the collapse of the Soviet Union, very few new weapon systems are being built, and existing systems are expected to be the front line military defense far longer than planned. Many weapon systems can now expect to see a service life of 40 to 90 years. The B-52, for example, will be operational for more than 94 years. This is long enough to provide the potential for five generations of pilots from the same family to fly this aircraft. Technology obsolescence studies also note that the time period from the start of design to the beginning of production is increasing.[6] As the time from design to production stretches out, many technologies used during the design are obsolete before production starts.



Proactive DMSMS Mitigation Approaches

The following describes a variety of methods that can be applied during system design to minimize the impact of future component obsolescence issues.

System Architecture Approaches

The best known aspect of technology obsolescence is nonavailability of parts as vendors move on to newer technologies and products. A number of other factors contribute to the overall problem, including:

- Inadequate system partitioning, which often means that a specific part problem ripples out to affect a larger hardware ensemble, making the solution more expensive by increasing amount of hardware which must be redesigned.
- The use of commercial off the shelf (COTS) products, which is attractive as a way to use successive compatible generations of a product line but is complicated by the requirement to make such parts survivable in the military environment.
- Selective modifications, which are essential to deal with these problems but can create multiple configurations and thus add to the configuration management challenge.
- Although digital technology has the fastest rate of change, non-digital areas like RF hardware also present parts obsolescence problems, and finding suitable replacements is more complex because of the multiple parameters that must be matched.
- Software obsolescence affecting the operating system, the application programming interface (API), and the selected programming language. These are areas where military systems can enjoy savings through use of COTS products, but these too have finite market lifetimes.

Modular, open, integrated architecture has emerged as a key enabler of weapon systems that combine affordable cost with the ability to deal with rapidly changing technology and evolving system requirements. Key architectural attributes that minimize parts obsolescence problems include effective implementation of open systems principles and independence of specific implementing hardware.[7] The basic acquisition technique is to maintain technology-independent designs and implement any given hardware entity with the best products available at the time it is needed. Similarly, as software tools or other entities become unavailable or unsupportable, the open system structure allows selective replacement with new products.

Military electronic systems have traditionally been closed and largely platform-unique. Today, cost and supportability considerations motivate open systems that allow wider use of commercial technology and products, competitive sourcing, better software productivity and reuse, reduction in the number of unique configuration items, and selective modification and upgrading. Open systems are most often defined in terms of support for portability of applications software and implementation of widely supported standards. Equal or greater importance attaches to technology-independence and modular partitioning so that specific areas can be affordably upgraded, expanded, or replaced.

An open system design begins with rigorous functional decomposition of allocated requirements followed by allocation of functions to hardware and software components. The partitioning process continues down to the level of hardware and software modules. These modules become the "atomic" building blocks of the system and the basis for commonality across systems as well as facilitating selective replacement over the system's life. Careful system partitioning allows the effect of a hardware change to be localized to minimize the scope and cost of a system modification. Ultimately the key is comprehensive functional specifications that are truly independent of any particular implementing technologies or products, but retain the flexibility to consider subtleties like degraded operating modes that are closely tied to a specific design.

Technology Independence

Technology independence depends on defining all interfaces such that the individual modules can be redesigned with substitute or upgraded components without impacting their functional interfaces with other modules. This modular design approach can minimize system redesign impact. Economies of scale can be achieved if the modules are used across multiple equipment. Technology independence is especially relevant for modular systems, COTS assemblies, systems with a high probability of recurrent obsolescence, and components for specific applications.

Software interfaces must be implemented in such a fashion as to break hardware-software interdependencies, e.g., the use by applications programmers of unique features of a particular processor. Similarly, the modular partitioning and functional interface definitions must be independent of any specific implementing technology such as a particular semiconductor logic family or generation of analog signal processing components. Software must be implemented in widely supported higher order languages with excellent real-time support.

One powerful technique for achieving technology independence is to capture the design of a system in the form of executable simulation objects rather than, or in addition to, the traditional text and figures. Such an executable specification starts as a technology-independent behavioral model, which reproduces the activity of the module or other entity under any set of stimuli. It then evolves to a structural model when the entity must be instantiated in a given technology at a point in time. Modern languages like VHSIC Hardware Description Language (VHDL) support behavioral, structural, and mixed hardware modeling.

VHSIC Hardware Description Language (VHDL)

VHDL is a language used to describe digital electronic systems and is designed to fill a number of needs in the design process. First, it allows description of the structure of a design (i.e. how it is decomposed into sub-designs and how those sub-designs are interconnected). Second, it allows the specification of the function of the designs using familiar programming language forms. Third, as a result, it allows a design to be simulated before being manufactured, so that designers can quickly compare alternatives and test for correctness without the delay and expense of hardware prototyping. Through the use of Computer Aided Engineering (CAE) tools, it is possible to build detailed and accurate simulation models of electronic subsystems. The ability to define hardware in a descriptive model not only improves development efficiency, it also assists in migrating existing electronic subsystems to the next generation architecture.[8]

Many components designed today are for specific applications. Each of these high-density components is designed to perform unique functions specific to a single circuit board or application. When these devices become obsolete, frequently there are no direct replacements for them. This can cause two complicated DMSMS problems:

1. Since these devices are typically complex, those without appropriate documentation are very difficult and costly to reverse engineer.
2. If the functions are known, but not in vendor independent format, a considerable amount of engineering time and cost will be incurred developing a solution.

VHDL allows designs to be more cost-effectively transitioned to new technologies when the original components become obsolete. A paper published by the Air Force Materiel Command (AFMC) reported significant cost avoidance achieved when replacing discontinued technology.[9] For example, where VHDL was used to document F-22 ASIC designs, re-partitioning and redesign costs were approximately half the cost incurred by those who did not document ASIC designs in VHDL.

Programmable Logic Devices (PLDs)

Programmable Logic Devices (PLDs) are general-purpose combinational or sequential digital components whose ultimate functions are determined by the designer. They leave the manufacturer in an unprogrammed state. The configurations of the internal switches are fixed after the particular logic function for the device has been prepared and checked using CAE tools. PLDs are manufactured in most digital technologies: fuses, antifuses, floating-gate, MOSFETs and RAM cells. Floating-gate devices can be erased and reprogrammed; RAM-based devices are reconfigured dynamically. Field Programmable Gate Arrays (FPGAs) combine the integration of an ASIC with the flexibility of user-programmed logic. FPGAs present the user with basic cells and interconnect resources, which serve as the building blocks for design implementation. Users specify their design with a schematic or hardware description language. This design is then converted to a vendor-specific format with the components of the design mapped onto the basic cells of the FPGA. Once the design has been successfully simulated, interconnect resources are programmed by the user. FPGAs are extremely useful in migrating existing designs to new hardware technology and are, therefore, an effective means to mitigate microelectronics obsolescence. Though specific FPGA families are discontinued as frequently as other integrated circuit technologies, they can be cost-effectively transitioned to new technologies using the hardware description from the original FPGA design.

Software Portability

Obsolescence of embedded computer systems occurs both in hardware and software. Hardware obsolescence arises as hardware components become outdated or are no longer manufactured. Software obsolescence arises since software is written for a particular platform (i.e. microprocessor or computer) and cannot easily be moved to a new platform without significant rework and cost. Often, only a part of the system is actually obsolete. Unfortunately, replacement of part of the system is usually as difficult (and expensive) as replacement of the entire system due to the system being developed as a single entity, with much interdependence between hardware and software.

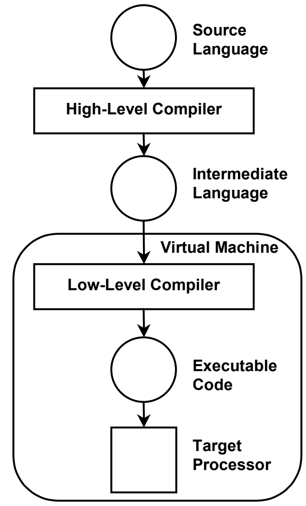
Software source code, such as Ada or C, is not directly executable by the processor in the target computer. It is turned into an executable code by a compiler. One problem with conventional compilation is that software is compiled with a specific target in mind. This ensures the obsolescence of the software as soon as the hardware needs to be replaced. Ideally, software should be compiled independent of the target. Portable code allows compiled software to be executed on any platform without change. This enables hardware to be replaced when it is obsolete, but software to be moved to the new hardware unchanged and, therefore, reducing the cost of obsolescence.[10] Portable code compilation is broken into two stages:

- *High-level compilation:* Translation of source code, written in a high-level language, into portable code, expressed in an intermediate language.
- *Low-level compilation:* Translation of portable code into executable code.

Low-level compilation translates the portable code, in the intermediate language, into an executable form. This compilation can occur in four main ways:

1. *Host:* The translation is performed from portable to executable code on the host. The executable code can then be loaded onto the target for direct execution.
2. *Target pre-run-time:* The portable code is translated into an executable by the target, prior to executing the code.
3. *Target interpretation by software:* The portable code is translated 'on-the-fly' into an executable form by the target. Often, this is done on a line-by-line level-i.e. only when a portable code statement is needed is it translated.
4. *Target interpretation by hardware:* The portable code is translated 'on-the-fly' by hardware into an executable form.

Methods 1 and 2 reflect conventional compilation. Methods 3 and 4, involving interpretation, offer more freedom from obsolescence. Here the portable code (i.e. intermediate language statements) can be viewed as being directly executed by the target, or at least by a 'thin' layer of software or hardware directly above the processor. This is commonly known as the virtual machine approach. The virtual-machine layer effectively incorporates the low-level compiler. The virtual machine interprets the software for the particular target processor. Essentially, the underlying hardware is transparent to the portable code, high-level source code and the programmer. To move the portable code to a different platform requires that the new platform implement the same virtual machine (i.e. low-level compiler).



There are a number of technical problems in the reuse of source code on a different platform. This is largely a software engineering issue, requiring the elimination of all non-portable aspects of system design and implementation. Typically, source code was originally designed and implemented with a particular target platform in mind. Thus, the task of porting the code is complex and costly. Often, the end result is a system that behaves differently from the original system, creating a host of other problems.

While it is probable that some software cannot be made entirely portable, typical problems and potential solutions for porting existing software source code include:

Problems vs. Potential Solutions for Porting Software

Problem:	Solution:
Hardware specific references: The software contains references to specific hardware functions, such as memory locations or interfaces.	Write the software such that all hardware specific references are made via a look-up table (either internal or external to the actual software) that can easily be modified, or are made via the operating system, which provides a hardware independent abstraction over all the devices.
Operating system references: The software contains calls to specific operating system features, which may not be supported on other operating systems, or later versions of the same operating system.	Use an operating system that has a standard interface layer, such as POSIX, so that calls to the operating systems are always the same. While providing a standard interface, this is not a complete solution because the actual behavior of the system may change.
Architectural assumption: Assumptions regarding the underlying architecture are made such as the precision and/or representation of data. For example, an integer is stored as a 32 bit word (i.e. 4 bytes) in the order of most significant bit (i.e. the one that represents the largest value) is first.	Data structures are created so that data types (such as integer) are always of a specific size. Then data is always manipulated in a way that makes no assumptions about the way in which data is stored, i.e. direct memory accesses are avoided.
Timing assumption: Assumptions regarding the timing behavior of the system are built into the software, e.g. a loop that effects a specific delay on a particular processor.	Software should be structured so that timing properties are handled by the operating system, e.g. provision of a delay call, or the use of scheduling for concurrent software.

Technology Roadmapping

Technology roadmapping is a specific technique for technology planning which fits within a more general set of planning activities. It identifies critical product needs that will drive technology selection and development decisions, determines the technology alternatives that can satisfy those needs, helps select the appropriate technology alternatives, and helps generate and implement a plan to develop and deploy those technologies. *ANSI/AIAA-R100-1996, Parts Management*, describes the use of technology roadmaps to minimize risk of obsolescence and to develop a strategy for technology insertion during the entire life cycle.

The main benefit of technology roadmapping is that it provides information to help make better technology investment decisions. It does this first by identifying critical technologies or technology gaps that must be filled to meet product performance targets. Second, it identifies ways to leverage R&D investments through coordinating research activities either within a single company or among alliance members. Some companies do technology roadmapping internally as one aspect of their technology planning. At an industry level, technology roadmapping involves multiple companies focusing on common needs.

The following table provides an overview of the three phases in the technology roadmapping process. [11]

The Technology Roadmapping Process

Phase I: Preliminary Activity
1. Satisfy essential conditions
2. Provide leadership/sponsorship
3. Define the scope and boundaries for technology roadmap
Phase II: Development of the Technology Roadmap
1. Identify the "product" that will be the focus of the roadmap
2. Identify the critical system requirements and their targets
3. Specify the major technology areas
4. Specify the technology drivers and their targets
5. Identify technology alternatives and their time lines
6. Recommend the technology alternatives that should be pursued
7. Create the technology roadmap report
Phase III: Follow-Up Activity
1. Critique and validate the roadmap
2. Develop an implementation plan

Technology roadmaps are developed from market survey data. In addition to its use for keeping abreast of technology advances, changes and trends, market survey data can also be useful for anticipating product life cycles to assist in upgrade and technology insertion planning. Market survey data can be collected through researching trade publications and technical societies, vendor product and technology briefings, and other means. Technology roadmaps should be updated regularly to sustain their effectiveness. This is especially important for memory devices, microprocessors, and other components with shorter life cycles or limited sources of supply.

Microelectronics technology roadmaps provide the visibility necessary to maintain a strategy that aligns product life cycles to take advantage of technology insertion and product update opportunities. Examples of resources available to support technology roadmapping activity include:

International Technology Roadmap for Semiconductors (ITRS), published by International SEMATECH, provides excellent top level information for use in obsolescence management and product update planning activities.

1998 Technology Roadmap for Integrated Circuits Used in Critical Applications (SAND98-1914) published by Sandia Laboratories provides guidance when developing and applying IC's in critical applications and documents major technical trends impacting critical ICs and the major technical needs.

Integrated Circuit Engineering (ICE) Corporation market research analysis and technical publications provide information about semiconductors, semiconductor manufacturing and capital equipment.

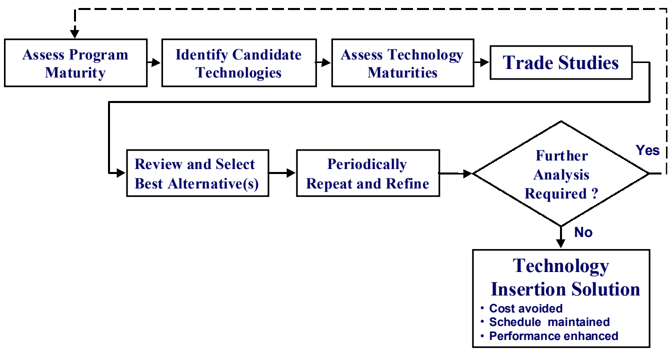
Further insight into future product offerings and technology is often needed for more effective planning. Some companies establish nondisclosure agreements with device manufacturers to gain this insight. Used in conjunction with component obsolescence forecasts, technology roadmaps can be an effective tool for design review activity.

Some OEMs hold technology interchange sessions with semiconductor industry representatives to exchange information concerning forecasted equipment application requirements and semiconductor industry technology roadmaps. Such technology exchanges are common in the commercial semiconductor industry and are becoming increasing popular in the military and aerospace industries. Government organizations occasionally host symposia such as "Industry Days" that provide OEMs opportunity to hear from the services and government agencies what the perceived technology needs are going to be several years into the future. Extending these Government hosted symposia to include semiconductor industry representatives might stimulate more interest in supporting the military and aerospace market, increase willingness to consider alternatives for supplying parts to these markets, and encourage suggestions for improvement to the user community through a true "need versus capability" discussion.

Technology Insertion

Technology Insertion is a means of dealing with the rapidly growing problems posed by DMSMS. Technology Insertion refers to “The introduction of new technology into a given design, manufacturing, marketing or maintenance process in order to effect measured change in the performance of that process”. If conducted effectively, Technology Insertion provides a principal means of proactively dealing with obsolescence. [12]

To properly integrate Technology Insertion activities into the System Engineering process, DMSMS must become an element for consideration, analysis and planning beginning with the program concept phase. It must play a significant role in the entire Integrated Product and Process Development (IPPD) effort. It must be addressed in market surveys and trade studies and in the formation and activities of IPTs. DMSMS must be considered in developing design guidelines and rules, management and manufacturing plans, and risk management methodologies. It should be incorporated in Request for Proposals (RFPs), contract Statements of Work (SOWs), incentive and award fee elements plus entrance and exit criteria in program reviews (particularly design reviews).



The Technology Insertion process should be tailored, as necessary, to accommodate the particular driver(s) confronting a program. While the process would be of most benefit to new programs, it can also be employed to advantage by programs already well into the acquisition cycle. At each stage of the process, appropriate sources of knowledge (e.g., funding profile, tolerance limits, candidate technology performance improvements) are considered. Of particular interest within the System Engineering area, is a focus on development of design techniques that capitalize on advances in modeling and simulation tools to facilitate rapid prototyping to achieve faster, cheaper part replacement or component redesign to incorporate new technology prior to actual design freeze.

Planned System Upgrades

System upgrades should be planned at defined intervals so microelectronics obsolescence can be dealt with at the same time. This involves predetermining points during the equipment life at which the design of all or parts of the system will be brought up to date and obsolete items replaced. This approach is particularly effective when phases of research, development and use take place in parallel. A limitation of this approach is that these modifications can be so large that they require weapon systems to be unavailable for operational service for a significant period while being upgraded. Between the planned upgrades, other options, such as bridge-buys, may be necessary as interim means to mitigate microelectronics obsolescence for on-going equipment manufacturing while upgrade development proceeds. Planned system upgrades should be considered for new electronic systems, when the time scale for obsolescence can be predicted accurately, under circumstances of rapid technological development, or when a lifetime buy is inappropriate (e.g. shelf life constraints).

Life Cycle Analysis and DMSMS Monitoring

The foundation for effective life cycle obsolescence management resides in careful integration of DMSMS program elements with system / equipment configuration control activities. Maintenance of accurate configuration data to the piece part level is essential in support of DMSMS impact assessments and associated resolution analyses. At the same time, this information will also support visibility of potential out-year DMSMS problem areas and provide the basis for proactive resolution efforts. Accordingly, an effective life cycle DMSMS management program will involve components from each of the following areas:

Configuration Item Identification / Analysis: Development and maintenance of current configuration item listings to the piece part level are essential to effective DMSMS program management. Moreover, as system parts listed are defined, line items should be subject to periodic technology / risk screening to identify existing and potential out year DMSMS problems.

Parts List Review / Prioritization: Once general DMSMS risk factors have been assigned to system parts lists, a prioritized set of targets for both reactive and proactive DMSMS analyses may be developed. All current and near term problems should be slated for immediate investigation, with remaining line items categorized by projected out year availability. It may be desirable to further refine rankings to reflect general engineering judgment, specific item / source risk elements as identified during case analysis, or individual item characteristics deemed appropriate (e.g., criticality, number of applications, demand volume).

Periodic Market Assessment: Although DMSMS screening has the potential to assist in statistical problem prediction, the accuracy of such forecasting for individual line items cannot be guaranteed. Direct manufacturer coordination is often the only accurate means to evaluate DMSMS vulnerability for specific items. Selected item manufacturers, other industrial organizations and government agencies should be contacted to maximize early identification of DMSMS issues. *JESD48, Product Discontinuance*, establishes the requirements for device manufacturers concerning timely customer notification of planned product discontinuance, which will assist customers in managing end-of-life supply, or to transition on-going requirements to substitute products.

A number of industry and government sponsored resources are available to support life cycle analysis and DMSMS monitoring …

Computer Aided DMSMS Management Tools, such as those provided by TACTech Inc. (i2 Technologies, Inc.) and Manufacturing Technology Inc. (MTI), provide means to automate research and notification, component selection, and changing availability. Parts lists are loaded into a database that provides automatic DMS event notification and presents analysis concerning the risk of microelectronics obsolescence associated with a specific design. Many sources of parts, indenture and other related information exist which are invaluable for DMSMS case analysis. DoD CD-ROM products are available which provide supply, maintenance, procurement, design, engineering, and other logistics data on items purchased / used by the government. The AFMC DMSMS Case Resolution Procedures Guide and NAVSEA DMSMS Case Resolution Procedures Guide include comprehensive listings of these resources.

The Government Industry Data Exchange Program (GIDEP) maintains DoD's centralized database for DMSMS and provides a number of services to support DMSMS Management.[13] GIDEP issues DMSMS Notices when notified by a part manufacturer or GIDEP participant that a part or production line will be discontinued. GIDEP promulgates notice to representatives at subscriber activities in DoD, and to member organizations in private industry. These notices normally contain data such as the last date of part manufacture, last date for order processing, and minimum order quantity or buy value. GIDEP DMSMS notices are available to registered GIDEP participants via the GIDEP WWW Database Access. Member organizations can submit parts lists through the automated parts matching service and they will be run against the GIDEP database to determine if there are any non-conforming or obsolescent parts reported against it. A report is then returned to the member showing any DMSMS information against their parts list. GIDEP also provides for exchange of information relative to part manufacturing, testing, operation, and characteristic data among industry and government agencies, and may also be used as a primary source of information for identifying substitute parts and redesign criteria.

The DoD DMSMS Teaming Group is a formalized group of representatives from DoD programs and industry that work together to share solutions to common component obsolescence problems.[14] The Teaming Group maintains a database of current information on component obsolescence and, whenever possible, explores resolutions that will work for all programs experiencing the obsolescence problem, often reducing the cost. For example, if a specific component used by more than one program is no longer offered by either the original device manufacturer or from an aftermarket supplier, each affected program may determine that emulation is the best resolution. Each affected program could then share the nonrecurring engineering costs equally.

Part Selection Guidelines

When selecting components for use in new equipment designs, the life cycle of the components should be considered in order to minimize the negative impact of obsolescence during product development and subsequent product support. New design activity should focus on selecting devices that are in the early stages of their product life cycle. When selecting device manufacturers, consideration should be given to those manufacturers who have established agreements with aftermarket sources for product life cycle extension.

Examples of industry guidelines that include consideration for component life cycles when selecting components are *ANSI/AIAA-R100-1996 Parts Management, IEC CA-AWG/1/DC Component Management Plans,* and *CENELEC ES 59010 Electronic Component Policy and Management Programme.*

SD-18, Defense Standardization Program Guide for Part Requirements and Application, provides part acquisition guidelines for Program Managers (PMs)/System Program Offices (SPOs) and original equipment manufacturers (OEMs). The database contains guidance that enables OEMs to use military and commercially specified parts for military equipment. It provides guidance on how the DOD and its contractors can cooperatively select devices, which will result in the lowest cost of ownership for the DOD.

Part Documentation

A process should be in place to collect, store, and retrieve component data needed to address DMSMS issues that will arise in the future. For example, in cases where engineering drawings (e.g. SCDs) were used in conjunction with design disclosure packages, these drawings would be used in conjunction with evaluating candidate replacement parts. Component data to be considered may include the original device manufacturer's data sheet, application data, qualification data, etc. For complex devices, functional and behavioral level models (e.g. VHDL) should be included to allow designs to be cost-effectively transitioned to new technologies.

EXECUTIVE AGENT FOR DOD MICROELECTRONICS DMSMS

The Defense Microelectronics Activity (DMEA) has been designated the Executive Agent for DoD Microelectronics DMSMS. As such, DMEA develops and coordinates solutions to DoD's obsolescence problems and is responsible for issues relating to IC microelectronics DMSMS. These responsibilities include:

- Develop partnerships with the military services, other DoD and non-DoD organizations, the Semiconductor Industry, and Electronics Manufacturing Industry to foster cooperation and achieve a joint resolution to current and/or potential DMSMS issues that affect the DoD.
- Advocate and develop cost-effective technical solutions to the DoD's IC Microelectronics DMSMS problems.
- Implement an "IC Clearinghouse" for IC problems and solutions in order to provide a vehicle to talk about common DMSMS problems, and share in the solutions.
- Develop guidelines and strategies in conjunction with the military services and DLA that will help weapon system program managers effectively manage and mitigate microelectronics obsolescence and related issues.
- Provide design recommendations for mitigating microelectronics obsolescence throughout the life cycle of a weapon system.

DMEA's Flexible Foundry is being developed to support obsolete 5-volt semiconductors that the commercial industry has abandoned in the pursuit of newer lower voltage technologies. The program was implemented after the commercial semiconductor industry made the understandable and justifiable business decision to no longer produce parts for the low-volume, long-product-cycle military market. DMEA's Flexible Foundry solves this problem by licensing and fabricating proven industry microelectronics processes. This allows DoD to obtain its small volume requirements from DMEA's Flexible Foundry while large volume orders are supplied by industry. The flexible foundry provides a diverse mix of functions ranging from personalization of device and gate arrays to full custom fabrication of ASICs.

RESPONSE TO DMSMS EVENTS

Numerous resolution alternatives exist which may be used singularly or in combination. Industry experience shows that responses to DMSMS events fall within the following major categories and percent probabilities:[15]

DMSMS Response	% Probability
Replacement Part	67%
Life-of-Type-Buy	20%
Bridge Buy / Redesign	12%
Emulation	1%

The following presents common DMSMS problem resolution alternatives.[16] The potential may exist to combine resolution options to achieve cost, technical or schedule benefits. For example, modified LOT buys (called "bridge buys") may be made to provide sufficient stopgap materiel while longer term design-related alternatives are pursued. Therefore, throughout the case investigation process, the potential for integrating elements of different solution methodologies to support cost-effective resolutions should be considered.

Alternate Source

Use this option if part specifications and test, acceptance, and related technical data are complete and available. Aftermarket sources are firms that buy obsolete production lines and thereby maintain capabilities to reproduce selected DMSMS parts. Many original device manufacturers establish agreements with aftermarket sources for product life cycle extension. If such manufacturers were selected during equipment design, the aftermarket source provides a viable option when the original device manufacturer discontinues product.

When considering this alternative, manufacturer production capabilities, tooling, test programs, etc., should be evaluated to ensure ability to meet original item specification requirements. For some ground based systems and for space based systems in general, particular attention must be given to ensuring the alternative source for the device meets radiation requirements.

In addition to or in lieu of purchasing manufacturing capability, an aftermarket supplier may procure wafer or chip product from the original manufacturer. Some final manufacturing steps such as specialized packaging and testing are usually required to prepare the device for application.

It may be possible to make an extended buy from this supplier or to negotiate a long-term parts supply agreement. If the wafer or chip was produced on a QML, they may be acceptable without further testing; otherwise, a test and qualification program may be necessary.

Substitution

This alternative involves analyzing DMSMS item characteristics and attempting to locate a similar part with an acceptable degree of nonconformance. A detailed cross reference and comparison of original versus substitute part characteristics must be conducted, and an engineering deviation or waiver is generally required to support the change since it may require relaxing part specifications or performance parameters. It should be noted that cross-reference methodologies may differ for mechanical / materiel versus electronic items, in part due to the availability of MILSPEC/MILSTD/CID references. For example, for electronic items the process may generally be expedited through immediate analysis of lower quality parts, or by utilizing commercially available systems that cross-reference all parts.

Redefine Requirement to Accept Commercial Item

Working through the appropriate engineering support activities, redefine the requirement to accept a commercial item. This could lead to the emergence of additional sources. The process is similar to the substitution alternative, except you are redefining the item to accept a commercial item already available, instead of finding an item that is similar to the DMSMS item.

It is important to remember when selecting commercial-off-the-shelf (COTS) items that the spectrum of those items in quality and technical specifications is broad. The design limits, environmental profiles, and life cycles vary. General categories of commercial items include consumer, industrial, automotive, and specialty items. The characteristics of these items must be understood and evaluated carefully to ensure that the selected COTS part meets the needs of the application. For some severe application environments (e.g. airborne uninhabited, space applications), COTS items may not be a viable solution due to reliability considerations.

The Government Electronics & Information Technology Association (GEIA) G-12 Solid State Device Committee developed guidelines for assessing the suitability of plastic encapsulated microcircuits and semiconductors for use in military, aerospace and other rugged applications. EIA Engineering Bulletin *SSB-1, Guidelines for Using Plastic Encapsulated Microcircuits and Semiconductors in Military, Aerospace and Other Rugged Applications* provides:[17]

- Methods for selecting the most suitable device for the application from both an equipment performance and economic perspective
- Means to emulate commercial buying practices by drawing upon qualification and reliability evaluation methods applied by the microelectronics design and manufacturing industry

Emulation

Emulation is the process of developing replacements for obsolete microcircuits using state of the art materiel, design and processing techniques. For unavailable components; however, a risk does exist that emulated parts may fail to meet certain unspecified performance characteristics of the original item and thus, suitability for all applications may not be guaranteed. As with aftermarket manufacturers, price per unit for emulated items is likely to be extremely sensitive to order quantities and this fact should be considered when developing a procurement strategy for this alternative. At the same time, the emulation process involves creation of a design library supporting wafer fabrication; therefore, if the DMSMS item is a common or previously emulated design, preliminary engineering costs may be greatly reduced. The emulation process may be conducted at the IC, circuit card, or other designated system indenture level, and is therefore often considered a subset of redesign initiatives as discussed.

Life-of-Type (LOT) Buy

This alternative involves purchasing a supply of DMSMS items to support total demands for the projected service life of the impacted systems / equipment. It should be noted that LOT purchases are not necessarily limited to DMSMS items. For example, in the case of microcircuits, the only available option may be the purchase of LOT quantities of die, which would require additional fabrication steps prior to use. Similarly, the LOT buy option may involve purchase of items or materiel essential to continued production or repair of the DMSMS item. LOT buys have traditionally been a common resolution alternative, but accurately predicting lifetime demand requirements can be difficult. Other issues to consider when evaluating this option include long term storage, periodic verification of lead solderability, etc.

Redesign / Design Modifications

This alternative involves designing out DMSMS items via engineering changes at various system indenture levels, with goals of enhancing system performance and improving reliability and maintainability. As in previous alternatives, redesigns at the component or assembly may involve significant risk and extensive system integration testing if the item in question has multiple different applications. Moreover, depending on the scope and level of the redesign effort, substantial nonrecurring engineering and life cycle logistics costs may accrue. Redesigns may be most appropriate when a fairly large percentage of current or potential DMSMS parts are resident within a particular component, equipment or end-item.

- *Redesign / Design Modifications:* This alternative involves designing out DMSMS items via engineering changes at various system indenture levels, with goals of enhancing system performance and improving reliability and maintainability. As in previous alternatives, redesigns at the component or assembly may involve significant risk and extensive system integration testing if the item in question has multiple different applications. Moreover, depending on the scope and level of the redesign effort, substantial nonrecurring engineering and life cycle logistics costs may accrue. Redesigns may be most appropriate when a fairly large percentage of current or potential DMSMS parts are resident within a particular component, equipment or end-item.
- *Redesign the Entire System:* Replacing an obsolete or discontinued item often can extend the life of a next-higher-assembly (NHA) and / or result in enhanced performance. In addition, it may be more economical to replace the item or the NHA than to use another method to resolve the problem. Replacement with newer technology or replacement of a higher assembly are two common replacement options. Note: Replacement of a higher assembly is not limited to the next higher assembly. For example, an entire radar unit may be replaced with a newer, more enhanced one rather than continuing to replace board or part level discontinued items on the original radar unit.
- *Redesign or Modify the Next Higher Assembly:* As indicated in the previous alternative, this option is touched upon within the context of other alternatives such as substitution. In cases where replacing the DMSMS item itself is cost, time or design prohibitive, consider the replacement of the next higher assembly as an alternative. For example, replacement at the board level many be a better option than replacement of an individual chip.
- *Replacement with Newer Technology:* With the continual improvement of technology, many serviceable technologies become obsolete rather than nonfunctional. They may rapidly go out of production in favor of the newer, enhanced technology. Replacing these items with the newer counterpart if it meets form, fit, function and interface requirements may be an easy and cost effective solution. A review of the specifications should be done to ensure obstacles to use of the new technology are not artificial (i.e. created by the limits of technology available at the time). Enhanced performance may be achievable through exercising this alternative. When evaluating this option, design analysis may be necessary to ensure the newer technology does not introduce functional performance problems (i.e. using a higher speed device may result in timing problems, a lower voltage device may be susceptible to noise in supply voltage, etc.).

DMSMS Case Resolution History File

The DMSMS solution should be documented for the purpose of capturing lessons learned, use by other programs confronted with the same DMSMS case, to support cost estimating efforts for DMSMS resolution activity and to support technology trend analysis. The history files should contain all data collected or developed during the case resolution process. The files should be maintained to support follow-on analyses and to assist others in conducting related DMSMS investigation efforts. As a corollary action, procedures should be established for tracking prospective sources, technologies or other DMSMS risk areas identified during case investigations. For example, conversations with manufacturers may indicate emerging DMSMS problems or broader supplier financial or technical circumstances that may affect continued production operations. Alternately, a predominance of DMSMS cases involving similar part types or technologies may suggest general obsolescence trends. Any such source / technology trends should be monitored in support of life cycle DMSMS management efforts.

Nonrecurring Engineering Cost Factors

To minimize the impact of DMSMS, DoD activities and original equipment manufacturers (OEMs) must be able to incorporate the most timely and cost-effective resolutions. The following nonrecurring engineering cost factors were developed to allow DoD programs to uniformly report DMSMS cost avoidance associated with implementing the best resolution in line with program requirements and cost constraints.[18] Original equipment manufacturers (OEMs) can also use these cost factors to perform an economic evaluation of solutions to DMSMS events.

Resolution	Low	Average	High
Existing Stock	$0	$0	$0
Reclamation	$629	$1,884	$3,249
Alternate	$2,750	$6,384	$16,500
Substitute	$5,000	$18,111	$50,276
Aftermarket	$15,390	$47,360	$114,882
Emulation	$17,000	$68,012	$150,000
Redesign— Minor	$22,400	$111,034	$250,000
Redesign— Major	$200,000	$410,152	$770,000
Life of Type Buy	*	*	*

* The LOT buy resolution is program-specific and should be calculated by individual programs

These cost factors were determined for nonrecurring engineering (NRE) in constant fiscal year 1999 dollars. NRE cost factors do not include procurement and administrative labor hours (e.g. time to identify sources of supply) and do not include costs associated with developing new microcircuits using state-of-the-art technologies (e.g. ASIC replacement for several discrete devices).

The following should be considered when using these cost factors:

- New source qualification could add cost; however, no standard value could be obtained because the cost could be amortized as part of recurring cost.
- If radiation hardening testing is required, the cost factors presented in the table could increase from $5,000 (dose rate only) to $52,000 (dose rate, total dose, and single-event upset) and possibly as much as $82,000 for microprocessors.
- If additional testing is required, each cost factor could increase from $600 (acoustic microscopy only) to $47,340 (full qualification of a 100-piece lot).

An Economic Method for Evaluating Electronic Component Obsolescence Solutions

This section of GEB1 describes a quantitative approach to developing a solution for component obsolescence. It is important to have tools that will allow the engineering team to understand the economic factors involved in the determination of the optimum year for planning a redesign. Detailed models can be developed that consider anticipated production life of all components within a subassembly. When using this methodology, the engineering team must assure that they have accounted for all potential obsolescence events that can be projected for the production and support lifetime of the product in question. The details of this methodology were derived from *"An Economic Method for Evaluating Electronic Component Obsolescence Solutions"* by G. Zell Porter, Boeing Company (May 1998).

Acknowledgments

Members of Task Group G9906 of the GEIA G-12 Solid State Devices Committee developed GEB1. While the members of the Task Group and principal contributors are shown below, it is not possible to include all of those who assisted in the evolution of this Bulletin. To each of them, the members of the GEIA G-12 Solid State Devices Committee extend their gratitude…

Olin Bray	Sandia Labs
Doug Casanova	Defense Microelectronics Activity
Joe Chapman	Chapman Enterprises
Justine Corboy	Sarnoff Corporation
Frances Crull	Northrop Grumman, ESSD
Tom Dean	Boeing Company
Don Gagnon	ITT Industries
Scott Hatch	BAE SYSTEMS
Wes Hubbell	Raytheon
Mike Jones	Defense Supply Center Columbus
Paul Kelley	Litton Aero Products
Henry Livingston	BAE SYSTEMS
Lee Mathiesen	Lansdale Semiconductor
Keith Meyer	NWSC DMS Technology Center
Charlie Minter	Best Manufacturing Practices Center of Excellence
John Nirschl	Rockwell Collins
G. Zell Porter	Boeing Company
Bill Pumford	GIDEP Operations Center
Kevin Rankin	Defense Microelectronics Activity
David Robinson	Defense Supply Center Columbus
Ron Shimazu	Defense Microelectronics Activity
Vernon Singleton	Lockheed Martin Systems Integration
Jack Tarsa	General Dynamics Defense Systems
Bahig Tawfellos	Honeywell
Walter Tomczykowski	ARINC Incorporated

Henry Livingston has over twenty years of engineering and engineering management experience in the Aerospace Electronics industry. He presently manages Component Engineering at BAE SYSTEMS Information and Electronic Warfare Systems. Henry is Vice-Chairman of the Government Electronics & Information Technology Association (GEIA) G-12 Solid State Device. The G-12 Committee develops solutions to technical problems in the application, standardization, and reliability of solid state devices. Henry received the Electronics Industries Association Engineering Department Distinguished Contribution Award for exemplary leadership and outstanding contributions to the defense electronics industry, to the Defense Department and the Electronics Industries Association in the field of solid state devices. Henry is the third recipient of the GEIA E. J. Nucci Memorial Excellence Award for Engineering Excellence to Henry Livingston for his many years of dedicated service to G12 and the high reliability solid state devices industry. Henry is a member of the IEEE Components, Packaging, and Manufacturing Technology Society, the IEEE Electron Devices Society and IEEE Reliability Society.

References

The GEIA G-12 Solid State Devices Committee would like to thank the following authors and organizations for significant contributions through their published works that provided the foundation for EIA Engineering Bulletin GEB1, Diminishing Manufacturing Sources and Material Shortages (DMSMS) Management Practices…

[1] Onkvisit, S.; Shaw, J. "Product Life Cycles and Product Management," Quorum Books, New York, New York, 1989.

[2] Pecht, M.G.; Das D. "Electronic Part Life Cycle," IEEE Transactions on Components and Packaging Technologies, Volume 23 Issue 1, March 2000, pp.190-192.

[3] Bick, E. (TACTech Inc.). "New & Improved Life Cycle Codes Updates - Response To AIM Users Regarding The New & Improved LCCs." ebick@tactech.com (20 Jul. 1999).

[4] TACTech Inc. "Obsolescence Management In the Year 2000." 28 Oct. 1998. ftp://tactech.com/pub/overview.exe (23 Oct. 2000).

[5] Dasgupta, A.; Magrab, E.B.; Anand, D.K.; Eisinger, K.; McLeish, J.G.; Torres, M.A.; Lall, P.; Dishongh, T.J. "Perspectives To Understand Risks In The Electronic Industry," IEEE Transactions on Components, Packaging, and Manufacturing Technology, Part A, Volume 20 Issue 4, Dec. 1997, pp.542-547.

[6] Hitt, E.F.; Schmidt, J. "Technology Obsolescence (TO) Impact On Future Costs," Proceedings of the 17th Digital Avionics Systems Conference (DASC), 1998, AIAA/IEEE/SAE, Volume 1, pp.A33-1 - A33-7.

[7] Borky, J.M.; Lachenmaier, R.N.; Messing, J.P.; Frink, A. "Architectures for Next Generation Military Avionics Systems," IEEE 1998 Aerospace Conference, 1998 Volume 1, pp.265-281.

[8] Houston, J.A.; Concha, L.; Bohannan, R. "VHDL Design Environment For Legacy Electronics (VDELE)," Proceedings of the VHDL International Users' Forum, 1997, IEEE, pp.162-169; and…
Fitzhugh, G.L. "Rapid Retargeting - A Solution To Electronic Systems Obsolescence," Proceedings of the IEEE 1998 National Aerospace and Electronics Conference (NAECON 1998), pp.169-176.

[9] Barker, D. "Why Are People Always Talking About VHDL?" 16 Aug. 1999.

http://www.ml.afrl.af.mil/ib/dpdsp/AFMC_VHDL_Article.PDF (23 Oct. 2000).

[10] Audsley, N.; Bate, I.; Grigg, A. "Portable Code: Reducing the Cost of Obsolescence In Embedded Systems," Computing & Control Engineering Journal, Volume: 10 Issue: 3, June 1999, pp.98-104.

[11] Bray, O.H.; Garcia, M.L. "Technology Roadmapping: The Integration of Strategic and Technology Planning for Competitiveness," Innovation in Technology Management - The Key to Global Leadership. PICMET '97: Portland International Conference on Management and Technology, 1997, IEEE, pp.25-28.

[12] Minter, C. (Best Manufacturing Practices Center of Excellence). "Diminishing Manufacturing Sources and Material Shortages (DMSMS) in the Systems Engineering Process." Proceedings of DMSMS Conference 1999.

[13] Government Industry Data Exchange Program (GIDEP)." http://www.gidep.corona.navy.mil/ (23 Oct. 2000).

[14] Martinez, J.G.; McDermott, J.T. "DMSMS Teaming Group Process." 1998. http://www.gidep.org/dmsms/initiatives/teamgroup.htm (23 Oct. 2000).

[15] Porter, G.Z. (Boeing Commercial Aircraft Company) "Strategies for Obsolescence Management in the New Millennium." Proceedings of DMSMS Conference 1999.

[16] US Naval Sea Systems Command (NAVSEA). "DMSMS Case Resolution Procedures Guide." 2 Aug. 1999. http://www.logtools.navsea.navy.mil/SuplySup/DMSMS/dmstable.htm (23 Oct. 2000); and…
US Air Force Materiel Command (AFMC). "DMSMS Case Resolution Procedures Guide." 15 Jul. 1998. http://www.ml.afrl.af.mil/ib/dpdsp/crgv10.pdf (23 Oct. 2000); and…
US Army Materiel Command (AMC). "DMSMS Program Case Resolution Guide." 13 May 1999. http://smaplab.ri.uah.edu/dmsms98/papers/dmsms.pdf (23 Oct. 2000).

[17] Livingston, H. "SSB-1: Guidelines for Using Plastic Encapsulated Microcircuits and Semiconductors in Military, Aerospace and Other Rugged Applications." Proceedings of DMSMS Conference 2000.

[18] "Resolution Cost Factors for Diminishing Manufacturing Sources and Material Shortages." Prepared for Defense Microelectronics Activity (DMEA), McClellan Air Force Base, California, by ARINC Incorporated. Revised May 1999. http://www.dmea.osd.mil/dms_contrb.html (23 Oct. 2000).