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INTEGRATING TECHNOLOGY OBSOLESCENCE CONSIDERATIONS INTO PRODUCT DESIGN PLANNING

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ABSTRACT
Technology life cycles affect a product manager's ability to sustain systems through their manufacturing and field lives. The lack of availability of critical parts and technologies poses a challenge not only to the acquisition community, but to customers of products that must be maintained for long periods of time. Technology obsolescence has an especially serious impact on systems that have significant electronics content because electronic parts are quickly obsoleted in favor of newer, higher performance components. In this study, market availability data was analyzed for operational amplifiers, a technology integral to most electronic products, and for flash memory devices. Procurement lifetimes are shown to have shrunk since operational amplifiers emerged on the market. Algorithms for forecasting electronic part obsolescence are proposed and the ramifications of electronic part obsolescence on product design planning are discussed.

Keywords: obsolescence, forecasting, operational amplifier, flash memory, DMSMS.

1   INTRODUCTION
Traditional design schemas have not extended the integrated engineering design process to include sustainment activities.[1] As it ages, a system designed for long-term sustainment, such as aircraft avionics or the 911 communications systems used by cities, will not continue to have access to the original components and technologies used in its manufacturing. Repair of failures and system expansion will require the procurement of obsolete components. Design refreshes may be used to update the original design, substituting, for example, a newer integrated circuit in the place of an older, obsolete integrated circuit that is no longer available. The refresh or update, however, will result in repeating a portion of the design process and in potentially expensive qualification testing to ensure that the replacement technologies do not compromise the reliability or performance of the system.

Design refreshes and life cycle management may or may not be part of the outcomes that matter to the original equipment manufacturer (OEM), depending on the product acquisition and contractual specifications. For sustainment-dominated systems, the OEM is being increasingly forced to manage both the manufacturing and the long-term sustainment of the product through concepts such as Performance Based Logistics (PBL). Although PBL implies many things, at its core it is essentially a shift from purchasing systems and then separately purchasing their support, to purchasing the availability of systems; simply put, performance-based strategies buy outcomes, not products. PBL and other shifting procurement and logistics practices are thus altering the engineering design landscape to extend product management from relatively short manufacturing lives to include longer life cycle considerations.

2   TECHNOLOGY TRENDS
Trends in technology lifetimes are important to product managers who must consider the long-term view of their products and to planners who determine the product development process in which time to market is critical. The electronics industry is a complex, dynamic sector of the global economy, rich in innovation and evolution. The remarkable ascent of computers gave rise to the electronics industry as a major force in market capitalization. "Computer technology is unique in being based on underlying devices whose performance has increased at a rate and over a range achieved by no other technology" (Gaines 1991). This speed of change has posed challenges to industry sectors that must utilize electronics in long support life, highly costly applications.

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[1] In this context sustainment refers to technology sustainment, i.e., the activities necessary to: a) keep an existing system operational (able to successfully complete its intended purpose); b) continue to manufacture and field versions of the system that satisfy the original requirements; and c) manufacture and field revised versions of the system that satisfy evolving requirements, (Sandborn and Myers, 2007).

Decision making for the advanced technology oriented product development process must balance the possible shrinkage in procurement life of required component technologies against the need for thoroughness, quality, market share retention, and many other factors. Ameri and Dutta (2005) note that products with long development processes will likely become obsolete more quickly than anticipated "given the high rate of introduction of new products to the market as well as the speed of change in customer needs." The shortening of procurement lifetimes poses a particularly difficult challenge to organizations facing changing environmental regulations and increased foreign competition.

The shrinkage in product procurement lifetimes may also have implications for the first mover advantage associated with being the earliest entrant into the market for a given product. Agarwal and Gort (2001) found a "decline in the duration over time" between the introduction of a new product and the emergence of a competitor, linked to a variety of factors including the effects of market globalization and greater workforce mobility. These global factors may be responsible for greater diffusion of technical knowledge via various media.

3 TECHNOLOGY OBSOLESCENCE

Obsolescence is defined as the loss or impending loss of original manufacturers of items or suppliers of items or raw materials. Brigadier General Eugene Payne of the 4th Marine Logistics Group estimated that the annual cost to the U.S. Department of Defense of reactively managing and mitigating electronic part obsolescence is $10 billion (Payne, 2006). Technology obsolescence is a significant problem for product managers that stems from a mismatch between the life cycles of products and the technologies they incorporate. The fast pace of the electronics industry has resulted in rapid technological development. Older generations of electronic parts are phased out as the consumer electronic products sector drives the introduction of smaller, cheaper, and faster technologies. Product sectors including aircraft, ships, industrial and medical equipment, and computer networks for air traffic control and power grids struggle to adapt to technological changes. The challenge is particularly severe for aircraft and military systems whose extended field lives are much longer than their original electronics content is procurable. These sectors must cope with identifying, integrating, supporting, and verifying the suitability of substitute electronic technologies (integrated circuits and discrete passive components).

The end of the Cold War witnessed a shift in defense acquisitions that replaced "Mil-Spec" electronic parts with their commercial counterparts, subjecting long-lived military systems to the shorter life cycles and different performance requirements dictated by the consumer-products sphere. Systems with long sustainment lives are dependent on a supply chain with business plans that place a premium on introducing new products as quickly as possible; as observed by Bill Gates, "the only big companies that succeed will be those that obsolete their own products before someone else does" (see Dreuil, Anderson, *et al.*, 2003). The fundamental disparities in life cycle needs and business objectives impose inevitable obsolescence challenges.

The lifetimes of Apple's iPod™ products are deliberately chosen, highly calibrated to the market, and are revealing of Apple's product line strategy and goals. In contrast, military aircraft are acquired and supported for decades of use: the Joint Strike Fighter is a forty-year program including seven years of test flights and anticipated expenditures of as much as $1 trillion for production, sustainment, and follow-on development (Shannon 2006, Harvey 2006). Time-to-market is generally less significant for military and avionics systems; instead, technology obsolescence dates (the date on which a part or technology is no longer procurable from its original source) are important inputs during life cycle planning for long-field life, sustainment-dominated systems.

Design for product variety and quick turnover of product offerings within a product line often effectively sidestep the obsolescence problem for market segments that accept high product turnover rates – consumers expect to buy a new PC every 3 years. However, for product segments such as commercial airplanes, managing obsolescence via quickly turning over the product design is impractical. For airplanes, the product design is fixed for long periods of time (e.g., 20+ years). The timespan of a generation for aircraft is far longer than the part procurement lives, whereas generations of iPods may not be substantially longer than the part procurement lives.

Obsolescence becomes a problem when it is forced upon an organization; in response, that organization must <u>involuntarily</u> make a change to the product that it manufactures, supports or uses.[2] There are generally three types of involuntary obsolescence:

1. *Logistical* – Loss of the ability to procure the parts, materials, manufacturing or software necessary to manufacture and/or support a product.

2. *Functional* – The product or subsystem still operates as intended and can still be manufactured and supported, but the specific requirements for the product have changed, and as a result, have obsoleted the product's current function, performance or reliability. For consumer products, functional obsolescence is the customer's problem; for more complex systems (e.g., avionics) it is both the manufacturer's and the customer's problem. For complex systems, functional obsolescence of a subsystem is often caused by changes made to other parts of the system.

3. *Technological* – More technologically advanced components have become available. This may mean that you still have or can get the older parts to use to manufacture and support the product, but it becomes a technological obsolescence problem when the supplier of those older parts no longer supports them.

These three types of obsolescence are referred to as DMSMS (Diminishing Manufacturing Sources and Material Shortages).

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[2] The type of obsolescence addressed here is caused by the unavailability of technologies (parts) that are needed to manufacture or sustain a product. A different type of obsolescence, addressed in inventory modeling, called "sudden obsolescence" or "inventory obsolescence" refers to the opposite problem in which inventories of parts become obsolete because the system they were being saved for changes so that the inventories are no longer required.

Note, obsolescence of the kind discussed above can strike hardware, software, and intellectual property.

4 ELECTRONIC PARTS: PROCUREMENT LIFE CYCLE EXAMPLES

Previous studies (Bayus, 1998, Bayus and Putsis, 1999) examined shrinking lifetimes for personal computers (PCs), leveraging data from the 1980s to conclude that while the lifetimes of PCs were not shrinking, the lifetimes of their component technologies were. More recent market data for electronic parts suggests that the problem is being compounded as the procurement lives of electronic parts have grown shorter in the last two decades, exacerbating in the commercial sector the life cycle mismatch that beleaguers the military and other long field life products ranging from aircraft to traffic lights.

The dominant paradigm for the commercial success of technologies such as computer processors and semiconductor memory is a correlation to an impetus or 'driver,' exerting force within the marketplace to offer improvements in a single area. Market trends for these technologies may be isolated to a single driver or to a combination of factors, including faster speed, smaller footprint, larger memory capacity, and higher resolution. Products such as the Canon Powershot[TM] and the Motorola RAZR[TM] reflect consumer demand for a hybrid of technological drivers (small size, plenty of storage, etc.). By contrast, there are other key electronic components that do not enjoy the visibility of higher-level technologies. These parts have no clear "driver" but their obsolescence attributes are just as detrimental to system sustainment as memory and microprocessors.

Analysis of flash memory devices (Sandborn, *et al.* 2005) reveals that their sales performance is strongly differentiated by memory capacity, the dominant (driving) characteristic of the product. Figure 1 shows sales data for flash memory as a function of memory capacity.
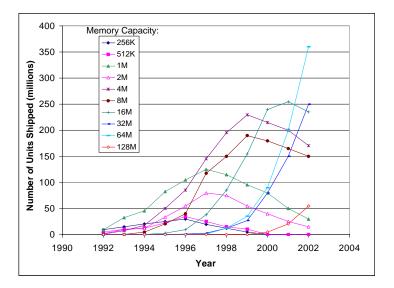

Figure 1. Flash memory units shipped between 1992 and 2002 (from Matas and de Suberbasaux (1997), supplemented with newer data)

The analysis of sales data for a decade's worth of flash memory units revealed that storage capacity strongly correlated to the number of units shipped. Sales of larger sizes soared towards the end of the period from 1992 to 2002 as consumer's storage needs grew. For flash memory, windows of obsolescence were computed based on Gaussian form-fitting of the sales data (such as that shown in Figure 1) for each memory capacity. The mean and standard deviation from the curve fits can themselves be plotted and fit to generate equations allowing the prediction of the sales curves for future flash memory with capacities larger than those shown on Figure 1. To determine the window of obsolescence for a particular part, the actual obsolescence dates of all parts in a database of obsolete flash memory was mapped to the number of standard deviations after the mean for the memory's particular capacity. The results were sorted by vendor and plotted as histograms from which vendor-specific obsolescence forecasting algorithms can be developed. For example (Sandborn, *et al.* 2005), the obsolescence dates of Atmel (ATM) flash memory are given by,

$$\text{Obsolescence date} = \underbrace{1.5663\ln(M)+1997.2}_{\text{Peak sales date}} + \underbrace{[0.88 \pm 0.72x]}_{\substack{\text{Number of standard deviations past}\\ \text{the peak for ATM Flash}}}\underbrace{(-0.0281\ln(M)+2.2479)}_{\substack{\text{Standard deviation}\\ \text{in sales data}}} \quad (1)$$

where M is the memory capacity in megabits, and x denotes the desired confidence level (x = 1 represents a 68% confidence of obtaining the range that accurately predicts the obsolescence event, x = 2 represents 95% confidence). Obsolescence forecasting algorithms for other types of parts with clear driving characteristics have also been developed; see Solomon *et al.* (2000) and Sandborn *et al.* (2005).

Next, we considered a key electronic systems technology lacking a clear driving characteristic. Operational amplifiers ("op amps") have been a mainstay of electronic parts since their invention in the mid 1960s. Since the 1960s, op amp technology has diversified, grown more precise, and become widely incorporated into systems whose "designs call for higher speed and increased accuracy" (Jung 2005).

Op amps are an essential part of information systems and are available in a multitude of sizes, packaging styles, and configurations. For sustainment-dominated systems with substantial electronics content, the implications of op amp obsolescence trends are significant; key to the analysis of procurement lifetimes is the understanding of op amps as a component technology *within* a system. They are integral and indispensable elements yet they do not attract the marketplace spotlight; the product line strategies used for more prominent electronics may be applied differently. Marketing decisions that impact personal computer sales, such as the concern for the appearance of product line 'freshness' (see Bayus and Putsis, 1999) may be minimally in evidence or non-applicable in the case of op amps.

An analysis of procurement lifetimes for operational amplifiers was performed to determine whether forecasting of part unavailability was possible when there were no clear driving

characteristics. The objectives of this analysis were to: 1) predict the obsolescence date for a part from a specific manufacturer given a product introduction date, 2) identify drivers affecting op amp procurement lifetimes (if any), and 3) examine whether the trends were consistent with the popularly held notion that electronic part procurement lifetimes are shrinking.

Historical data furnished by PartMiner Information Systems, Inc. containing detailed product information from eight major manufacturers was used. The products' sales availability was contrasted to their market introduction dates to assess trends in op amp procurement lifetimes. The original dataset consisted of over 21,200 op amp part entries from: Analog Devices, Fairchild, Intersil, Linear, National Semiconductor, ON Semiconductor, Philips, and Texas Instruments. Each entry contained the last order date (the effective obsolescence date of the part), the introduction date, and numerous attributes and performance specifications. Parts that are not yet obsolete as well as entries with inconsistent or missing last order and/or introduction dates were removed from the dataset. Parts whose procurement life was less than one year were considered anomalies and removed from the dataset. These parts reflect changes in corporate ownership or early removal from the market due to defects or because of unusual circumstances. The majority of ON Semiconductor entries were excluded from the analysis because of truncated market introduction dates reflecting a corporate divesture from Motorola. The final dataset for analysis has approximately 2,400 entries from seven manufacturers.
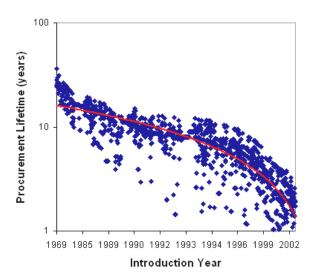

Figure 2. Procurement Lifetime (length of time the part can be procured from its original manufacturer) versus Introduction Year for Operational Amplifiers

The procurement lifetime was calculated as the difference between the last order and the introduction dates for the remaining entries. The procurement lifetime was compared to the introduction date for the parts to examine trends over the 30 year spread of the data. Figure 2 depicts the relationship between the procurement lives and the introduction year for the 2,400 operational amplifiers studied. Linear regression equations were used to construct algorithms for predicting the procurement

lifetime of a part from one of the seven manufacturers given a user-defined introduction date using (2),

$$\hat{y} = a + bx = \left(\frac{n\sum xy - \sum x \sum y}{n\sum (x^2) - (\sum x)^2} \right) \left(x + \frac{\sum y - b\sum x}{n} \right)$$

(2)

where
y = procurement lifetime
$\hat{y}$ = the expected value of y for a given x
x = the introduction date
b = the change in y with respect to each change in x
a = procurement lifetime at market introduction
n = the number of paired observations of market introduction years and procurement lifetimes in the sample.

Computing the standard error of estimate as

$$s_{y,x} = \sqrt{\frac{\sum (y^2) - a\sum (y) - b\sum (xy)}{n-2}}$$

(3)

and the estimated standard error value as

$$s_b = \frac{s_{y,x}}{\sqrt{\sum (x^2) - (\sum x)^2 / n}}$$

(4)

the test statistic for the t-test is calculated as

$$t = b / s_b.$$

(5)

The prediction interval for the expected procurement lifetime of an op amp part introduced on a particular date x_g is given by

$$\hat{y} \pm t_{\alpha/2} \left[s_{y,x} \sqrt{1 + \frac{1}{n} + \frac{(x_g - \bar{x})^2}{\sum (x^2) - (\sum x)^2 / n}} \right]$$

(6)

where
$t_{\alpha/2}$ = the appropriate t table value for a given confidence level with n-2 degrees of freedom
α = level of significance (halved for a two-tailed prediction interval)
$\hat{y}$ = point estimate of y computed with the regression equation for a given x_g
$\bar{x}$ = average of original x values.

For a given introduction date, 95% prediction intervals around the regression were constructed using (6).

The historical relationship between product introduction and procurement lives for operational amplifiers is well characterized by a piecewise function decreasing linearly following the technology's introduction and then reaching a plateau in the contemporary market. This 'bottoming out' around the one-year mark may reflect the balance of new product

introductions, time-to-market, and many other corporate product line factors within a highly competitive industry.

With few exceptions, plotting procurement lifetimes against introduction dates yielded linear correlations of a negative slope with coefficients of determination (R^2 values) exceeding 0.70, indicating that the linear regression fitted the majority of the data. The coefficients of determination were likely weakened by the multiplicity of data points with the same last order dates. The regression equation based on the filtered dataset is $\hat{y}$ = -0.7722(x) + 1547.3 with associated 95% prediction interval bounds on $\hat{y}$ of

$$\pm -0.9305(x_g) - 1863.2 - 1.645(0.856)\sqrt{1 + \frac{1}{2400} + \frac{(x_g - 1992.621)^2}{\left(2.406\text{x}10^9 - \frac{1.208\text{x}10^6}{2400}\right)}}$$
(7)

As an example, consider a National Semiconductor bipolar, 8 pin, 1 Amp metallic op amp is introduced at the end of April, 1981. Its expected procurement life is computed as -0.7722(1981.32) + 1547.3 = 17 years and 4 months with a 95% two-tailed prediction interval of $\pm$ 4.22 years and an 80% prediction interval of $\pm$ 2.76 years. The actual last order date for this part was April 1995 (a 14 year procurement life).

Several manufacturers were found to have multiple distinct clusters of data, similar in slope but differing in y-intercept on the procurement lifetime versus introduction date plots. The repetition of last order dates was found to account for the appearance of multiple trend lines within a manufacturer's dataset. This repetition reflects the business practice of withdrawing parts in batches rather than continuously, often segmenting data from a manufacturer into sizeable groups (e.g., almost 10% of parts from Linear Corp. were withdrawn in July 1994 as shown in Figure 3). The appearance of multiple trend lines reflects an industry reality and suggests that a range of forecasted obsolescence dates is possible depending on which withdrawal "batch" a part falls into. The regression equations and prediction intervals for forecasting the procurement life employ an average the withdrawals and are not sensitive to batching or to a particular company's policies.
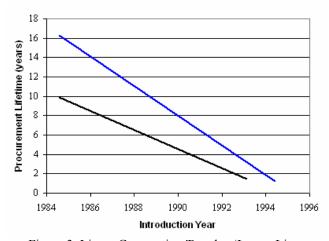

Figure 3. Linear Corporation Trends. (Lower Line: Parts Withdrawn July 1994, Upper: Withdrawn on Other Dates)

5   MANAGING TECHNOLOGY OBSOLESCENCE

For products that are sensitive to technology obsolescence, avoiding obsolescence is generally regarded as nothing more than putting off the inevitable. Designing an electronics-rich system that can be supported for 20 or more years so that none of its constituent parts will become obsolete is not considered a practical endeavor. Therefore, design for involuntary obsolescence becomes an exercise in making the problem manageable (or minimizing the life cycle cost of sustaining the system). Figure 4 shows a summary of the hierarchy of design activities that can be undertaken to make involuntary obsolescence manageable.

Commercial tools exist that focus on tracking the availability of electronic parts and identifying alternative parts, e.g., Q-Star™, TACTRAC™, and Total Parts Plus. These tools also employ life cycle models based on a part's technical and logistical attributes to provide, ordinal scale based obsolescence risk forecasts without addressing uncertainties in the forecasts. The absence of the insider perspective from the manufacturer or knowledge of the corporate decision-making that guides product withdrawals limits the predictive accuracy of forecasting models (whether quantitative or qualitative). The op amp dataset from Linear Corporation considered in this study reflected this: knowledge of the corporate product roadmaps dictates the discontinuance of whole groups of parts. Furthermore, forecasters may find that rhythms of electronic part life cycles within the global supply chain are impacted by shifts in economic activity or by sweeping environmental legislation such as the Restriction of Hazardous Substances (RoHS) compliance regulations in Europe, which restrict the use of tin-lead solder in electronic parts.
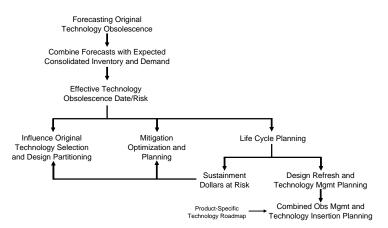

Figure 4. Hierarchy of design for involuntary obsolescence activities. A complete taxonomy of activities associated with electronic part obsolescence management is available in Sandborn, *et al.* 2007.

Even firms that lack the resources for extensive data forecasting or software-based tools probably incorporate some knowledge of obsolescence of their component technologies into their product planning and development. Certain manufacturers announce their intended obsolescence dates for their products (or in some cases advise that the part should not be used in new designs). While obsolescence forecasting can

be performed without commercial tools, these products are potentially more efficient data aggregators and do offer their information as a service (on a BOM by BOM basis) as well as larger scale subscriptions.

Most organizations use obsolescence forecasting to audit their Bill of Materials (BOM) in order to avoid selecting parts that are too close to obsolescence; however, when parts become obsolete various mitigation approaches can be employed (Stogdill, 1999). Replacement of parts with non-obsolete substitute or alternative parts can be done as long as the burden of system re-qualification is not unreasonable. A lifetime buy of parts, i.e., buying and storing a sufficient number of parts to last through a system's remaining manufacturing and sustainment life when it goes obsolete, is another approach (Feng *et al*. 2007). There are also a plethora of aftermarket electronic part sources ranging from original manufacturer authorized aftermarket sources that fill part needs with a mixture of stored devices (manufactured by the original manufacturer) and new fabrication in original manufacturer qualified facilities (e.g., Rochester Electronics and Lansdale Semiconductor) to brokers and even eBay. David Sarnoff Laboratories operates GEM and AME (Johnson, 2000), which are electronic part emulation foundries that fabricate obsolete parts that meet original part qualification standards using newer technologies (e.g., BiCMOS gate arrays). Thermal uprating of commercial parts to meet the extended temperature range requirements of an obsolete Mil-Spec part is also a possible obsolescence mitigation approach for some parts (Pecht and Humprhey, 2006).

If obsolescence forecasts are available during a system's design phase or during its sustainment, then more strategic approaches that enable the estimation of lifetime sustainment costs are possible. In these situations, even with data that is incomplete and/or uncertain, the opportunity for sustainment cost savings is potentially significant with the application of the appropriate decision making methods.

Two types of strategic planning approaches have been used to manage technology obsolescence: material risk indices and design refresh planning. Material Risk Index (MRI) approaches analyze a product's bill of materials and scores a supplier-specific part within the context of the enterprise using the part, e.g., (Robbins, 2003). MRIs are used to combine the risk prediction from obsolescence forecasting with organization-specific usage and supply chain knowledge in order to estimate the magnitude of sustainment dollars put at risk within a customer's organization by the selection of the part and the part's eventual obsolescence.

Because of the long manufacturing and field lives associated with sustainment-dominated systems, they are usually refreshed or redesigned[3] one or more times during their lives to update

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functionality and manage obsolescence. Unlike high-volume commercial products in which redesign is driven by improvements in manufacturing, equipment or technology; for sustainment-dominated systems, design refresh is often driven by technology obsolescence that would otherwise render the product un-producible and/or un-sustainable. The goal of design refresh planning is to determine when to design refresh (dates) and what obsolete system parts should be replaced at a specific design refresh (versus managing with an alternative obsolescence mitigation strategy).

The simplest model for performing life cycle planning associated with technology obsolescence (explicitly electronic part obsolescence) was developed by Porter, 1998. Porter's approach focuses on calculating the Net Present Value (NPV) of bridge buys and design refreshes as a function of future date. A bridge buy approach involves purchasing and storing enough parts before obsolescence occurs to last until a scheduled future refresh date. As a design refresh is delayed, its NPV decreases and the quantity (and thereby cost) of parts that must be purchased in the bridge buy required to sustain the system until the design refresh takes place increases. Alternatively, if design refresh is scheduled relatively early, then the bridge buy cost is lower, but the NPV of the design refresh is higher. The Porter model performs its tradeoff of bridge buy costs and design refresh costs on a part-by-part basis. In order to treat multiple refreshes in a product's lifetime, Porter's analysis can be reapplied after a design refresh to predict the next design refresh, effectively optimizing each individual design refresh, but the coupled effects of multiple design refreshes (coupling of decisions about multiple parts and coupling of multiple refreshes) in the lifetime of a product are not accounted for.

A more complete optimization approach to refresh planning called MOCA (Mitigation of Obsolescence Cost Analysis) has been developed that concurrently optimizes multiple refreshes and multiple obsolescence mitigation approaches (the Porter model only considers last-time buys), Singh and Sandborn, 2006. Using a detailed cost analysis model, the MOCA methodology determines the optimum design refresh plan during the field-support-life of the product. The design refresh plan consists of the number of design refresh activities, their content, and respective calendar dates that minimize the life cycle sustainment cost of the product.

In the example that follows, MOCA was used to perform design refresh planning on a Full Authority Digital Electronic Controller (FADEC) manufactured by Honeywell International, Inc. for the AS900 engine. The engine controller has a long field life (20 years), low volume (~3200 units), long manufacturing life (5-6 years), and is a safety critical component used in engines for regional jets. The AS900 FADEC is comprised of 3 boards: EMI, I/O and CPU containing over 4000 components; the AS900 FADEC also contains sensors and various mechanical elements that are necessary to assemble the boards into an enclosure.

The MOCA analysis employed various part-specific short-term obsolescence mitigation approaches and was compared to analyses in which: 1) the life cycle costs were assessed assuming no electronic part obsolescence (this is the state-of-the-art of

commercial life cycle cost modeling, tools today, and 2) part obsolescence events were forecasted, but no action was taken to redesign the system (in this case all obsolete parts were assumed to be obtainable from aftermarket sources at an appropriate price penalty).

Figure 5 shows an example result from MOCA that includes several refresh plans and a case with no refreshes (all obsolescence mitigated using aftermarket purchases). In the refresh planning case, the reorders are accumulated on a yearly basis. The results in Figure 5 are for a one year look-ahead time – this means that at a design refresh, parts that are forecasted to become obsolete within one year after the conclusion of the design refresh are designed out, in addition to those that have already become obsolete. MOCA generated results for all viable cases where there was exactly one, two, three, or four refreshes during the 20 year life of the product. The point shown on the graph in Figure 5 each represent a unique combination of refresh dates and are plotted at the average of the dates for the refreshes in the plan. One of the plans is expanded in the figure to show the actual refresh dates that comprise the plan. A refresh report is generated by MOCA as well that summarizes the actual refresh dates and content of each refresh (i.e., what parts should be address at the refresh).
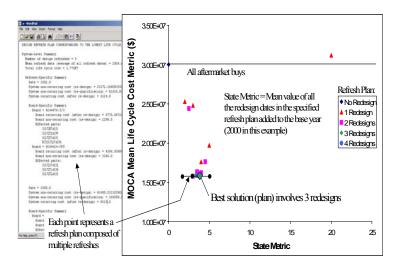

Figure 5. Example MOCA design refresh solution for the AS900 FADEC.

While managers of many sustainment-dominated products seek design refresh solutions, design refreshing solely to manage obsolescence is not practical for every system. For many systems, technology insertion roadmaps are developed to dictate how the system's functionality and performance must be changed over time. Technology roadmaps reflect an organization's internal technology goals and budget cycles, and may be dictated by the customer. The MOCA tool has been extended to include technology roadmapping constraints, Sandborn *et al.*, 2003 and Myers and Sandborn, 2007. The integration of technology roadmap information into MOCA's decision analysis ensures that selected refresh plans meet roadmap imposed timing and budget constraints, and that the costs of roadmap specified actions are included in relevant refreshes.

6 SUMMARY

Procurement lifetime trends for operational amplifiers reveal that the length of time that these parts are available has declined steadily over the past thirty years. The shrinkage in market availability suggests that parts introduced in the future will be withdrawn even more quickly and illustrates the need to consider the risks of availability in selecting microelectronic parts during the design process. Access to historical data from industry leaders and manipulation of that data into a useful metric (i.e., procurement lifetime) can be used to construct prediction intervals and obsolescence forecasts for other technologies.

Bayus (1998) observed that product technology and product model lifetimes have not accelerated within the PC industry but noted that new products containing older technologies will likely have shorter lifetimes than those composed of newer versions. Analysis of historical data indicates that op amps, as a product technology, have had procurement lifetimes that are shrinking at constant rate (i.e., linearly) rather than accelerating. This may present a glimmer of hope to product managers: accurate predictions of procurement lifetimes provide a higher level of understanding and reduce the uncertainty associated with the obsolescence dates of these component parts. Better awareness of component availability may help to improve decision-making regarding obsolescence problems experienced at the system level, ultimately facilitating a shift from triage efforts to proactive management.

The analysis of market data of flash memory products and operational amplifiers reveals distinct market availability profiles. These trends may be unique to these technologies, but they are a harbinger of obsolescence concerns for both COTS (Commercial Off The Shelf) and military products. The leading edge products that rely on microelectronics care about trends in product lifetimes because the availability of parts impacts their product support planning and services; the trailing edge cares more because obsolescence is intrinsic to the nature of their programs, an unavoidable challenge from the onset of planning. Pahl and Beitz (1996) define engineering as the application of knowledge to the resolution of technological problems. This activity includes the task of determining the most favorable solution within design specifications and restrictions. Obsolescence imposes complex restrictions on product design; forward-thinking engineering decision-makers should include it from the beginning of the engineering design and product development process.

7 ACKNOWLEDGEMENTS

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