Electronic Part Obsolescence Driven Product Redesign Planning

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ABSTRACT: Many electronic parts have life cycles that are shorter than the life cycle of the product they are in. Life cycle mismatches caused by the obsolescence of electronic parts can result in high sustainment costs for long life systems. In particular, avionics and military systems often encounter part obsolescence problems before being fielded and nearly always experience part obsolescence problems during their field life. This paper presents a methodology for determining the design refresh (redesign) schedule for long field life electronic systems based on forecasted electronic part obsolescence and a mix of obsolescence mitigation approaches ranging from lifetime buys to part substitution.

1. INTRODUCTION

The electronics industry is one of the most dynamic sectors of the world economy. In the United States, this industry has grown at a rate three times that of the overall economy in the last ten years. The semiconductor industry is now number one in value-added to the United States economy, and the computer and consumer electronics industry segments dwarf most other market segments. For example, Intel's market capitalization alone was higher than the three largest U.S. automakers combined [1].

The rapid growth of the electronics industry has spurred dramatic changes in the electronic parts that comprise the products and systems that the public buys. Increases in speed, reductions in feature size and supply voltage, and changes in interconnection and packaging technologies are becoming events that occur nearly monthly. Consequently, many of the electronic parts that compose a product have a life cycle that is significantly shorter than the life cycle of the product they go into. A part becomes obsolete when it is no longer manufactured, either because demand has dropped to low enough levels that it is not practical for manufacturers to continue to make it, or because the materials or technologies necessary to produce it are no longer available. Therefore, unless the system of interest has a short life (manufacturing and field), or the product is the driving force behind the part's market (e.g., personnel computers driving the microprocessor market), there is a high likelihood of a life cycle mismatch between the parts and the product.

Electronic part obsolescence began to emerge as a problem in the 1980s when the end of the Cold War accelerated pressure to reduce military outlays and lead to an effort in the United States military called *Acquisition Reform*. Acquisition reform included a reversal of the traditional reliance on military specifications ("Mil-Specs") in favor of commercial standards and performance specifications [2]. One of the consequences of the shift away from Mil-Specs was that Mil-Spec parts that were qualified to more stringent environmental specifications than commercial parts and manufactured over longer-periods of time were no longer available, creating the necessity to use Commercial Off The Shelf (COTS) parts that are manufactured for non-military applications and are often available for much shorter periods of time. Although this history is associated with the military, the problem it has created reaches much further, since many non-military applications depended on

Mil-Spec parts, e.g., avionics, oil well drilling, and automotive.

Managing the life cycle mismatch problem requires that during design, engineers be cognizant of which parts will be available and which parts may be obsolete during a product's life. Avionics and military systems may encounter obsolescence problems before being fielded and nearly always experience obsolescence problems during field life [3]. These problems are exacerbated by manufacturing that may take place over long periods of time, the need to support the system for a long period of time (i.e., providing spares), and the high cost of system qualification and certification that make design refreshes using newer parts an expensive undertaking. However, obsolescence problems are not the sole domain of avionics and military systems. Consumer products, such as pagers, naturally divide into two groups – 1) cutting edge (the latest technology and features), and 2) *workhorse*, minimal feature set products (such as the pagers used to tell restaurant patrons that their table is ready). While the first set is unlikely to encounter obsolescence problems, the second set often does. Because original equipment manufacturers require long lifetimes out of *workhorse* products, critical parts often become obsolete before the last product is manufactured.

If a product requires a long application life, then a parts obsolescence management strategy may be required. Many obsolescence mitigation approaches have been proposed and are being used. These approaches include [4]: lifetime or last time buys (buying and storing enough parts to meet the system's forecasted lifetime requirements or requirements until a redesign is possible), part substitution (using a different part with identical or similar form fit and function), and redesign (upgrading the system to make use of newer parts). Several other mitigation approaches are also practical in some situations: aftermarket sources (third parties that continue to provide the part after it's original manufacturer obsoletes it), emulation (using parts with identical form fit and function that are fabricated using newer technologies), reclaim (parts salvaged from other products), and uprating (a part beyond the manufacturer's specifications, usually at a higher temperature, [5]).

Redesign (or design refresh) is the ultimate obsolescence mitigation approach where obsolete parts are designed out of the system in favor of newer, non-obsolete parts.[1] Nearly all long field life systems are redesigned one or more times in their lives. Unfortunately, design refresh potentially has large non-recurring costs, and it may require the system to be re-qualified, which is costly. Therefore, design refreshes are not a practical solution every time a part becomes obsolete and must be prudently planned.

1.1 Existing Work

Existing work relevant to the management of part obsolescence includes: 1) part life cycle characterization, 2) part obsolescence forecasting, 3) product deletion, and 4) life cycle planning. Life cycle characterization [7] and obsolescence forecasting [8]-[12], are addressed in Section 3 of this paper. The state-of-the-art in the world today is to use obsolescence forecasting to audit the bill of materials and make part change decisions during design only. Another relevant area is product deletion studies that address how a manufacturer or supplier of a product makes a decision to stop offering the product, e.g., [13]. Alternatively, obsolescence (which is the topic of this paper) focuses on the management of the consequences to the customer of a product deletion decision made by others.

This paper addresses life cycle planning: if a forecast of part obsolescence can be obtained, how can that forecast be used to plan (and ultimately optimize) the product's overall life cycle? Numerous research efforts have worked on the generation of suggestions for redesign in order to improve manufacturability, e.g., [14], [15]. Design refresh planning has also been addressed outside the manufacturing area, e.g., general strategic replacement modeling [16], re-engineering of software [17], capacity expansion [18], and equipment replacement strategies [19], [20]. All of this work represents redesign driven by improvements in manufacturing, equipment or technology, <u>not</u> design refresh driven by technology

[1] In this paper we have used the terms "redesign" and "design refresh" interchangeably, however, there is a difference [6]. Refresh is used as a reference to system changes that "Have To Be Done" in order for the system functionality to remain viable. Insertion (redesign) is used to identity the "Want To Be Done" system changes, which include both new technologies to accommodate system functional growth and new technologies to replace and better the existing functionality of the system.

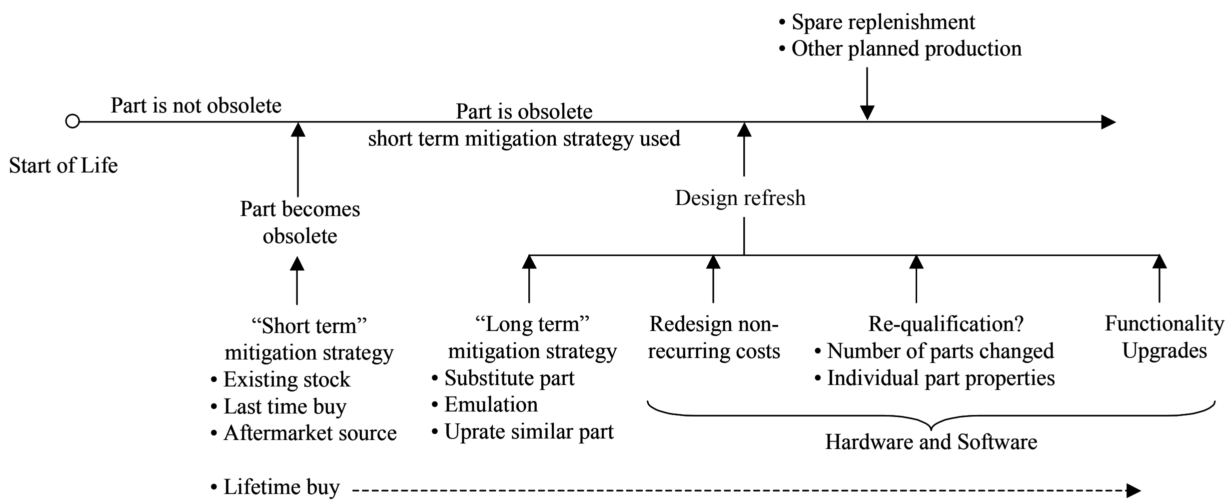

Figure 1. Design refresh planning analysis timeline (presented for one part only for simplicity, however in reality, there are coupled parallel timelines for many parts).

obsolescence that would otherwise render the product un-producible and/or un-sustainable.

The only existing work on pro-active life cycle planning associated with part obsolescence focuses on trading off last time buys[2] versus delaying redesigns using Net Present Value metrics [21]. This model is relevant to cost-plus business models that provide incentive for the OEM to defer redesigns as long as possible (thereby letting the customer pay for both the obsolescence-driven upgrade and the performance improvements concurrently. This type of model is common for military products. Alternatively, in a price-based (fixed price) business model the OEM is allowed to "pocket" all or some of the recurring cost savings that are recognized on a fixed cost subsystem, thus providing incentive for the OEM to redesign the system as soon as it makes economic sense. In this case a different model is needed that minimizes the life cycle cost of the system with respect to design refreshes.

This paper presents a methodology that enables determination of the optimum product design refresh schedule based on forecasting the years to obsolescence for electronic parts. Unlike trading off only last time buys and redesigns, this methodology accommodates a broad range of obsolescence mitigation approaches, and addresses functional upgrade at redesigns. Section 2 outlines the refresh planning methodology and its implementation; Section 3 provides background on how the part obsolescence forecasts are determined; and Section 4 describes the results of an example study performed on the Honeywell AS900 engine controller.

2. DESIGN REFRESH PLANNING METHODOLOGY

A methodology and it's implementation have been developed for determining the part obsolescence impact on life cycle sustainment costs for the long field life electronic systems based on future production projections, maintenance requirements and part obsolescence forecasts. Based on a detailed cost analysis model, the 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, and their content and respective calendar dates that minimize the life cycle sustainment cost of the product.

Figure 1 shows the design refresh planning timeline. Fundamentally, the methodology must support a design through periods of time when no parts are obsolete, followed by multiple part-specific obsolescence events. When a part becomes obsolete, some type of mitigation approach must take effect immediately, either a lifetime buy of the part is made[3] or a short-term mitigation strategy that only applies until the next design refresh. Next

[2] Only enough parts are purchased to satisfy the product's forecasted production and sustainment needs until the next redesign.

[3] Enough parts are purchased to satisfy the product's forecasted production and sustainment needs through the end of the product's life.

there are periods of time when one or more parts are obsolete, lifetime buys or short-term mitigation approaches are in place on a part-specific basis. When design refreshes are encountered (their date is defined either by the user or by the methodology during its optimization process) the change in the design at the refresh must be determined and the costs associated with performing the design refresh must be computed. At a design refresh a long-term obsolescence mitigation solution is applied (until the end of the product life or possibly until some future design refresh), and non-recurring, recurring, and re-qualification costs computed. Re-qualification may be required depending on the impact of the design change on the application – the necessity for re-qualification depends the role that the particular part(s) play and the volume of non-critical changes made. If the expense of a redesign is to be undertaken, then most likely functional upgrades will also occur during the redesign. The system functional upgrades must be forecasted and (including forecasting the obsolescence of future parts). All the design refresh activities have to accommodate both hardware and software redesign and re-qualification. The last activity appearing on the landscape is production. Product often has to be produced after parts begin to go obsolete due to the length of the initial design/manufacturing process, additional orders for the product, and replenishment of spares needed to sustain fielded systems.

The methodology described above supports user determined short- and long-term obsolescence mitigation approaches on a per part basis, variable look-ahead times associated with design refreshes, and allows for inputs to be specified as probability distributions that can vary with time.

2.1 The MOCA Software Tool

Mitigation of Obsolescence Cost Analysis (MOCA) is a software tool developed to enable the prediction of an optimum design refresh plan. Figure 2 describes the organization of the MOCA tool.

- Inputs – The basic input for the MOCA tool is a bill of materials (parts list) corresponding to the system to be analyzed. The critical information included in the parts list is the price, obsolescence date (see Section 3), and qualification impact. In addition to the parts

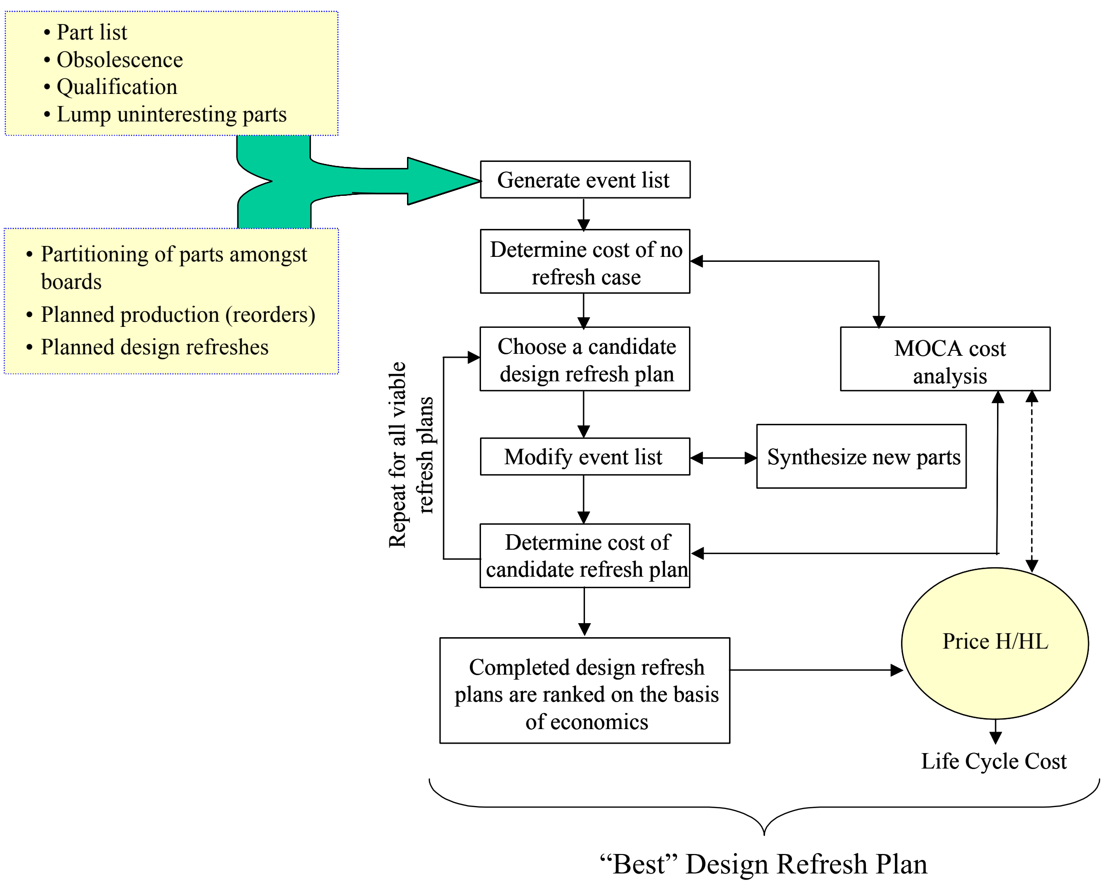

Figure 2. MOCA architecture.

list, the partitioning of the parts onto boards is input (number of instances of a part on each board). The other classes of inputs are the production plans, i.e., how many of each board are produced as a function of time (both initial manufacturing quantity and any subsequent manufacturing), and the dates of any pre-planned design refreshes.

- Generate event list – Combine all the events (production, fixed design refreshes, and individual part obsolescence) onto a single time line called an event list.
- Determine cost of no refresh case – Determine the effective life cycle cost of the event list with no additional design refreshes. The solution serves as a baseline for the MOCA analysis. In this case obsolete parts are assumed to be either from existing stock, subject to lifetime buys or purchasable in the aftermarket (depending on user preferences on a per part basis).
- MOCA cost analysis – The MOCA cost analysis determines the life cycle cost of an event list. The non-recurring and the new production costs at design refreshes are computed through an interface to the Price Systems H and HL tools.
- Choose a candidate design refresh plan – A candidate set of design refreshes (date of each specific refresh) is chosen for analysis.
- Modify event list – The original event list is modified to include the candidate design refreshes.
- Synthesize new parts – When parts are replaced at design refresh events, they must be replaced by a newer part that does not exist today. MOCA synthesizes a new part. Key to the synthesis activity is the forecasting of the obsolescence date for the new part(s) (see Section 3).
- Determine cost of candidate refresh plan – The MOCA cost analysis is used to determine a life cycle cost of the event list containing the candidate design refresh plan.
- Completed design refresh plans are ranked on the basis of economics – All the candidate design refresh plans considered are ranked and the lowest effective life cycle cost solution is chosen.
- Price H/HL (commercial Life Cycle Cost tool), [22] – Price life cycle cost analysis tools are used both in the evaluation of specific design refresh plan candidates and to determine the final life cycle cost of the system once a final refresh plan is chosen.

MOCA is implemented in JAVA, examples from the MOCA interface are shown in Figure 3.

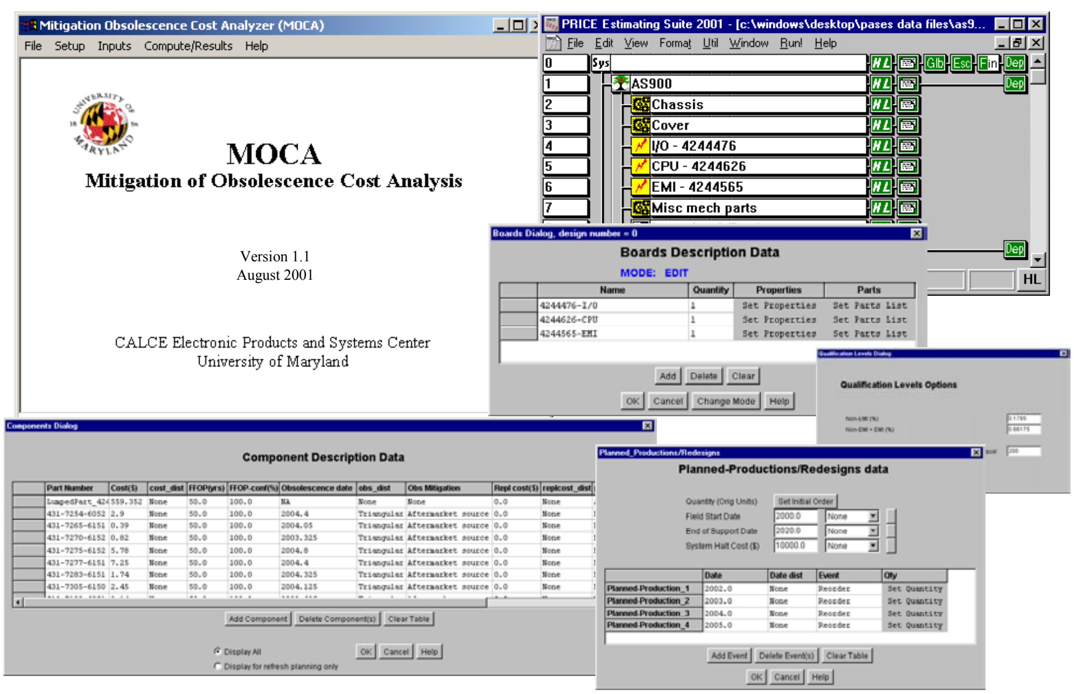

Figure 3. Examples from the MOCA software tool interface.

3. PART OBSOLESCENCE FORECASTING

Electronic product life cycles are modeled in terms of product life cycle stages, product life, extension of product life, and product marketing issues [7]. Studies indicate that most electronic parts pass through several life cycle stages corresponding to changes in part sales: introduction, growth, maturity (saturation), decline, and phase-out [23], [24][4]. Part obsolescence forecasting is based on the development of models for the part's life cycle. The traditional method of life cycle forecasting is the "scorecard" approach, in which the life cycle stage of the part is determined from an array of technological attributes. Each attribute is given a life cycle code, and a corresponding weight. The overall stage for the part is determined by computing a weighted average of the life cycle codes for the attributes. The disadvantages of this approach are that it may not capture market trends accurately, because it relies on unquantifiable, technological attributes such as technology complexity and soft market attributes such as usage. This approach has also traditionally used the erroneous assumption that all ICs follow the same life cycle curve, all life cycle stages are of the same length, and does not give a measure of confidence in the forecasting. Another approach includes an "Availability Factor" method, which projects a "safe" usage window for a part. This approach uses market and technology factors to predict the obsolescence of devices with similar technology and market characteristics. This approach does not explicitly use the "life cycle curve".

MOCA uses two different methods for the prediction of electronic obsolescence dates. In the first method obsolescence dates are predicted from obsolescence lifecodes [8] using equation 1,

$$\text{Obsolescence date} = B + L\left(1 - \frac{(i-1)}{4}\right) \tag{1}$$

where B is the base year (the date on which the obsolescence analysis was performed), L is the life span of the component, and i is the obsolescence lifecode that indicates the obsolescence risk associated with the component; to use equation (1), i is assumed to vary from 1 (beginning of life), to 5 (end of life). MOCA also uses a methodology based on forecasting part sales curves [11]. In this method, sales data for a part is curve fit and an equation is obtained in terms of a primary attribute of a part. Figure 4 shows the curve fit for a 16M DRAM (in the case of a DRAM the primary attribute is the memory size). By fitting the sales data for DRAM of various sizes with normal distributions, the trend equations for the mean and standard deviation can be formed (also shown in Figure 4). The form of the equation of the life cycle curve is,

$$f(x) = ke^{\frac{-(x-\mu)^2}{2\sigma^2}} \tag{2}$$

where f(x) gives values for the sales revenue of the device/technology group (or number of units shipped, or the percentage market demand), x is the year, f(x) is defined by the mean μ, which denotes the point in time of the sales-peak of the curve, and the standard deviation σ. The factor k is the sales peak, the number of units shipped, or the percentage demand.

With the trend equations and a definition of the zone of obsolescence (3σ to 4σ to the right of the mean), the future obsolescence date for a part can be predicted. The same sales forecasting process has to be performed on secondary attributes such as bias level and package type too, and the minimum prediction of the zone of obsolescence is finally used for the part.

We also must forecast the obsolescence of parts that do not exist today, i.e., parts that will be used to replace the obsolete parts at the design refreshes. In order to do this we must forecast the introduction and phase-out dates of the basic building blocks associated with the part. As an example, consider Figure 5. In this case we are forecasting the life cycle changes in integrated circuit logic families. Using the trends, we can predict the length of the life cycle of a future logic family even through we don't know the details of how that future logic approach will work.[5] Using the data in Figure 5 as an example, the forecasted obsolescence date of a logic family that you might implement in a design

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[4] Several additional phases have been proposed [25] including: Introduction Pending (prior to introduction), and splitting the Phase-out stage into Last Shipment and Discontinued or Purged.

[5] Note, if disruptive technologies appear in the future, and they follow the tends of how past disruptive technologies associated with the particular attribute changed the design/manufacturing/performance paradigm, then they are accounted for within the model example presented herein.

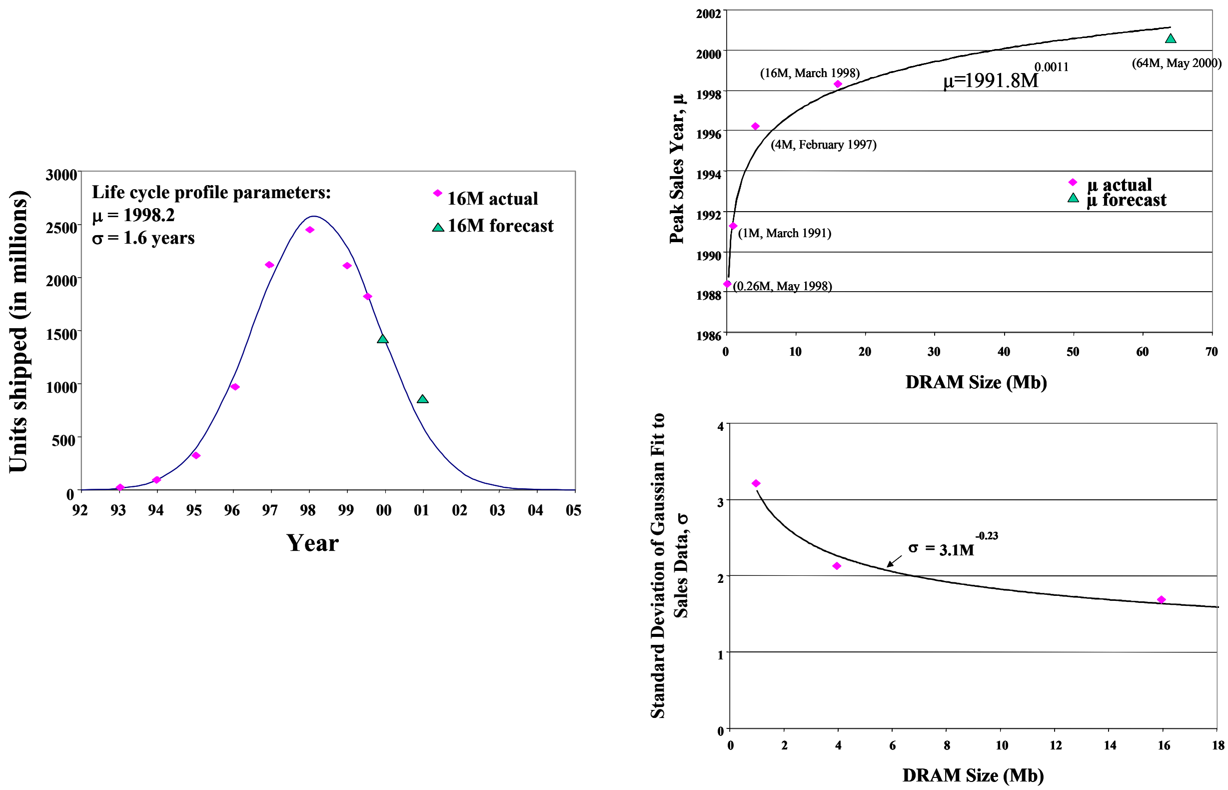

Figure 4. Trend equation formation for DRAMs. Left: 16M DRAM sales curve fit; Top Right: trend equation for peak sales year formed from DRAM sales curve; Bottom Right: trend equation for standard deviation formed from DRAM sales curve.

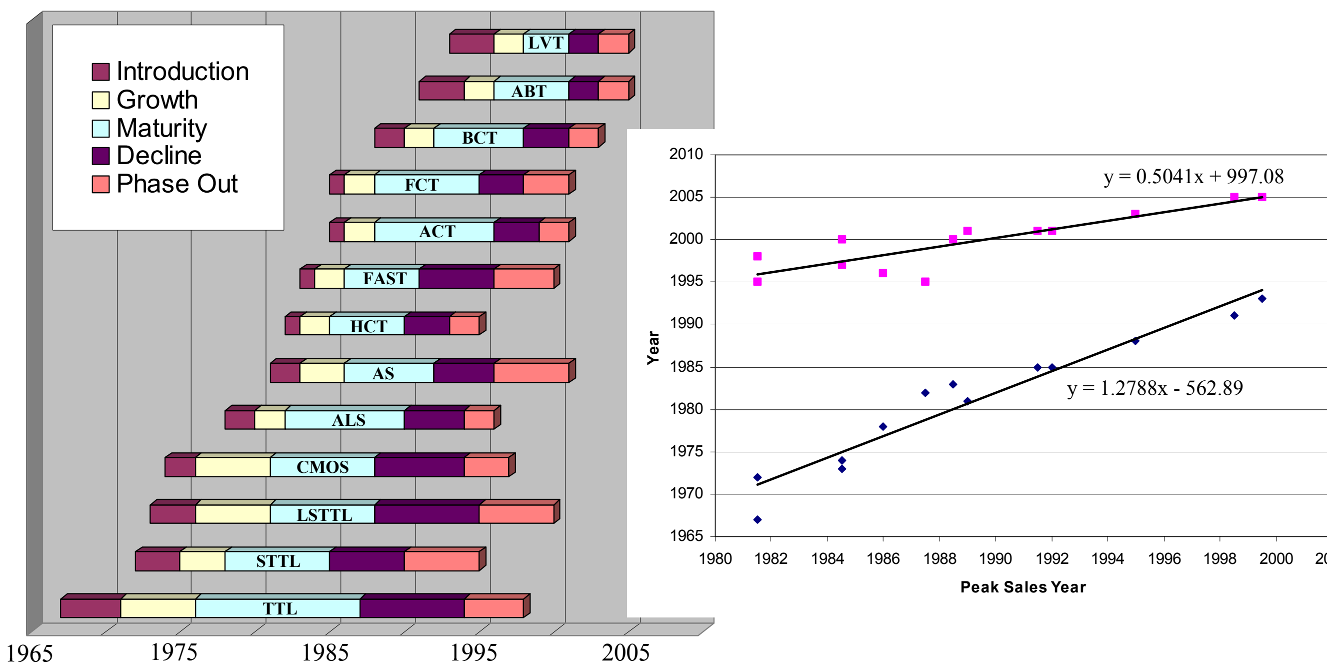

Figure 5. Example of logic family trends that allow prediction of future family life cycles.

refresh activity in 2005 is given by equation 1 with B set to 2005, and L given by,

$$L = 0.5041B + 997.08 - 1.2788B + 562.89 \qquad (3)$$

Assuming that the original part has an obsolescence index of 3 and that the customer wishes to replace it with a part that has an

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Figure 6. AS900 FADEC example application.

equivalent level of maturity, i.e., i = 3, the obsolescence date of the new part would be 2008.4.

Since the obsolescence forecasting is based on curve fits of sales data (both real and forecasted) and the world is fraught with unforeseen changes that cannot be included in these predictions, each obsolescence forecast is treated by MOCA as a distribution that ranges from 0.8 to 1.0 times obsolescence data predicted by equation 1. In the case of the sales curve fits, we assume a uniform distribution ranging from 3σ to 4σ.

4. EXAMPLE ANALYSIS

The AS900 engine's Full Authority Digital Electronic Controller (FADEC) manufactured by Honeywell International, Inc. is a long field life (20 years), low volume (~3200 units), long manufacturing life (5-6 years), 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. Figure 6 shows the AS900 FADEC board layouts.

As an example, three analyses were run on the AS900 FADEC, 1) the life cycle cost was assessed assuming no electronic part obsolescence (this is the state-of-the-art of commercial life cycle cost modeling, tools today); 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); and 3) design refresh planning was performed by MOCA using various part-specific short-term obsolescence mitigation approaches.

Figure 7 shows an example result from MOCA that includes the results of the aftermarket purchase case and the refresh planning. In the refresh planning case, the reorders are accumulated on a yearly basis. However, for the first two years all the reorders are accumulated and added to the initial order as they are assumed to sustain the system and provide spares for it during that period, which is consistent with Price-H AS900 FADEC model. The economic inflation rate is set to 5% per year.

The results in Figure 7 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 "State Metric" is the average duration of a redesign (it is not important to the

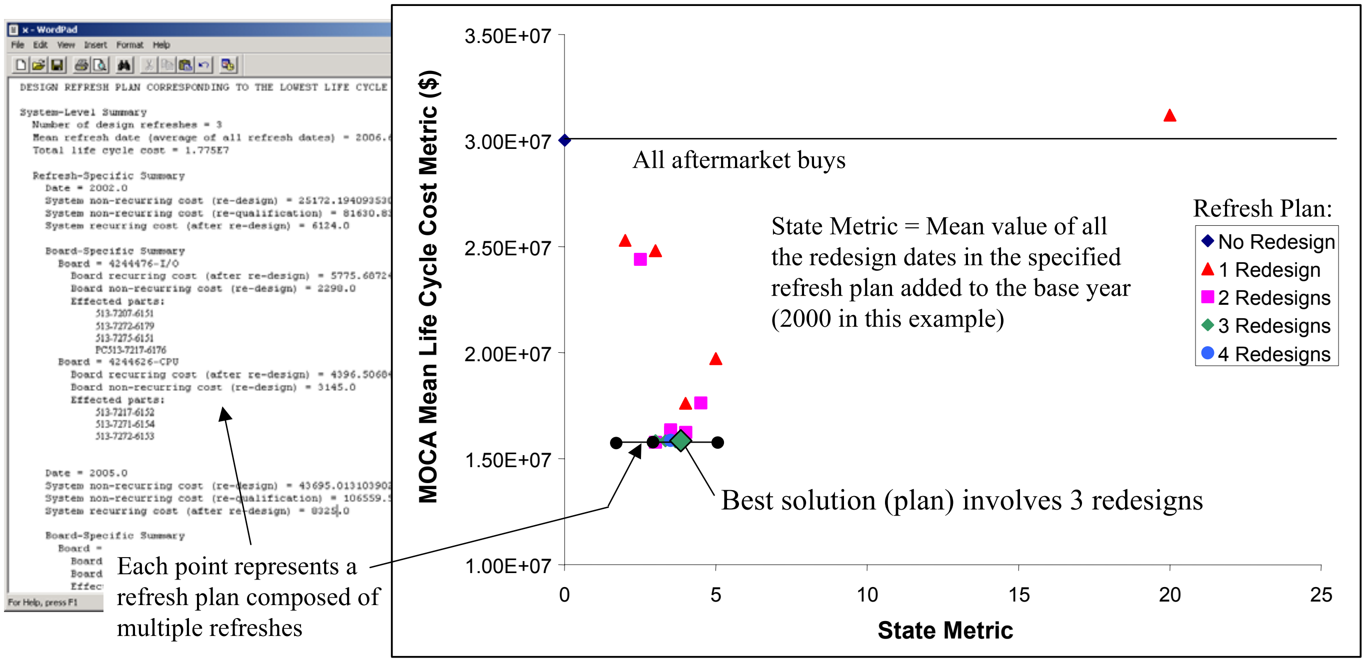

Figure 7. Example MOCA design refresh solution for the AS900 FADEC. This solution assumes: 1 year look ahead, 200 component re-qualification trigger, and $136,000 full re-qualification cost.

solution, i.e., it is just a way of spreading the results out along the horizontal axis for viewing). One of the plans is expanded in Figure 7 to show the actual refreshes that comprise the plan. A refresh plan is generated by MOCA as well that summarizes the actual refresh dates and content of each refresh. The best refresh plan is passed to Price for final life cycle cost analysis. The cost axis is a cost metric that does not correspond to actual life cycle costs for the system, but a smaller value of the metric does indicate lower life cycle cost.

The actual life cycle costs generated after Price H/HL analysis for the three cases considered in this example are given in Table 1.

Table 1. Predicted AS900 FADEC life cycle costs for ~3200 units sustained for 20 years.

Case	Life Cycle Cost
Perfect world (no obsolescence)	$4.24 M
Obsolescence forecasts (mitigation approach = aftermarket source buys only)	$51.16 M
Obsolescence forecasts (design refresh planning)	$31.12 M

The analysis above was performed assuming a one year look ahead time and without considering uncertainties in any of the characteristics defining the AS900 FADEC or its lifetime. When we broaden the scope of the analysis to a range of look ahead times and include ±1 year on all dates (obsolescence forecasts and production events) and a ±20% uncertainty on all other inputs we obtain the result in Figure 8. In this case the distributions are assumed to be symmetric triangular distributions. In Figure 8, the solid points represent the minimum cost design refresh plan as a function of the look ahead time, i.e., these are each the lowest solution in graphs like the one in Figure 7 (the number next to the points is the number of refreshes in the plan). The point with the "3" next to it on the left side of the graph is the lowest point from Figure 7. Actually, a lower life cycle cost solution exists for 2 design refreshes when a 2 year look-ahead time is assumed. The open points in Figure 8 are the same solution, but with the uncertainties included (mean costs are plotted with error bars). As can be seen, when uncertainties are considered, the choice of the optimum look-ahead time and number of refreshes may be different (based on the mean costs, 1 refresh and a look ahead time of 4 years is the best solution). In both solutions, as the look ahead time lengthens, 5 years and greater, more expensive solutions result, i.e., if you are always forced to replace components that have forecasted

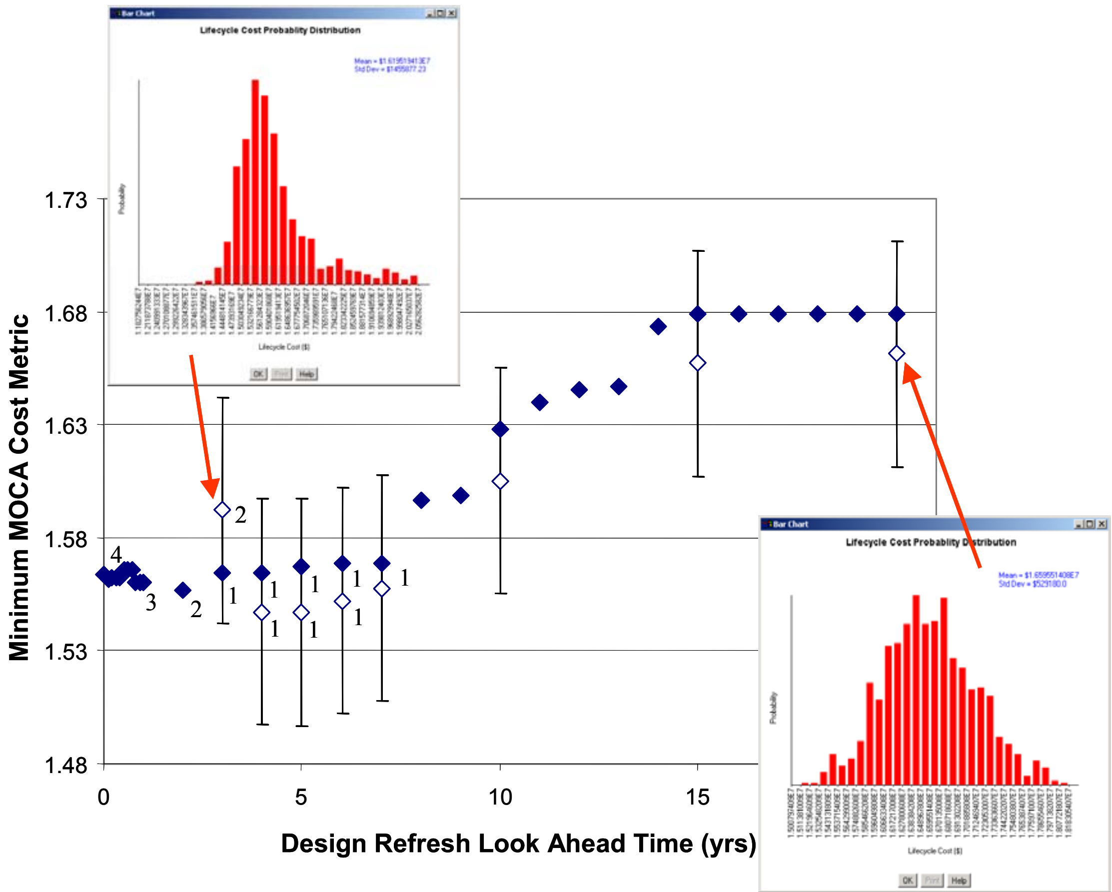

Figure 8. The best design refresh plan as a function of the look-ahead time at the design refresh. Solid points = no uncertainties in input data, open points include uncertainties. The inset graphs show histograms of the costs for the indicated points (the points plot the mean).

obsolescence within the next 5+ years, you may be replacing nearly all the components at every refresh.

5. SUMMARY

This paper presented a design refresh scheduling and optimization methodology and its implementation (MOCA). Design refresh scheduling is performed by associating design refreshes to the planned production schedules. The methodology has been demonstrated on a Full Authority Digital Electronic Controller (FADEC) from Honeywell. MOCA represents the first methodology for part obsolescence driven design refresh scheduling and optimization. Based on a detailed cost analysis model, the 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 and their respective calendar dates and content to minimize the life cycle sustainment cost of the product. The methodology supports user determined short- and long-term obsolescence mitigation approaches on a per part basis, variable look ahead times associated with design refreshes. Part obsolescence mitigation strategies can be compared to design refreshing part obsolescence elimination strategy.

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