

ELECTRONIC PART OBSOLESCENCE DRIVEN PRODUCT REDESIGN OPTIMIZATION

P. Sandborn and P. Singh
Department of Mechanical Engineering
University of Maryland
College Park, Maryland 20742
Sandborn@eng.umd.edu
(310) 405-3167

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 result in higher 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 optimum 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.

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].

As a result of the rapid growth of the electronics industry, 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.¹ 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.

Managing the life cycle mismatch problem associated with electronic parts 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, [2]. These problems are exacerbated by manufacturing that may take place over long periods of time, and the high cost of system qualification and certification that make design refreshes using newer parts an expensive undertaking.

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, [3]: 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, [4]).

We define redesign (or design refresh) as a change in a system's hardware that requires some non-negligible non-recurring re-engineering cost. Design refresh is an obsolescence mitigation approach where, in addition to changes that improve performance, functionality and/or reliability, obsolete parts are designed out of the system in favor of newer, non-obsolete parts. Nearly all long field life systems are redesigned one or more times during their lives. Unfortunately, design refresh potentially has large non-recurring costs, and 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.

Existing work relevant to the management of part obsolescence includes: 1) part life cycle characterization, [5], 2) part obsolescence forecasting, [6]-[9], 3) product deletion (studies that address how a manufacturer or supplier of a product makes a decision to stop offering the product,² e.g., [10]), and 4) life cycle cost optimization. The state-of-the-art in the world today is to forecast an obsolescence risk index for existing parts (i.e., obsolescence forecasting to audit the bill of materials) and make part change decisions during initial design only.

This work focuses on the final category of work that addresses: if the forecast of parts obsolescence can be obtained and if a roadmap of *value* attributes for the product over time is available, how can optimum strategies be developed for the product over the product's overall life cycle? The only existing work on pro-active life cycle optimization associated with part obsolescence focuses on trading off last time buys versus delaying redesigns using Net Present Value metrics, [11]. 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). 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. The remaining sections of this paper outline the refresh planning methodology and its implementation; provide background on how the part obsolescence forecasts are determined; and describe the results of an example study performed on the Honeywell AS900 engine controller.

Design Refresh Planning Methodology

A methodology and its 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 or a short-term mitigation strategy that only applies until the next design refresh. Next 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 quantity 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 timeline 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

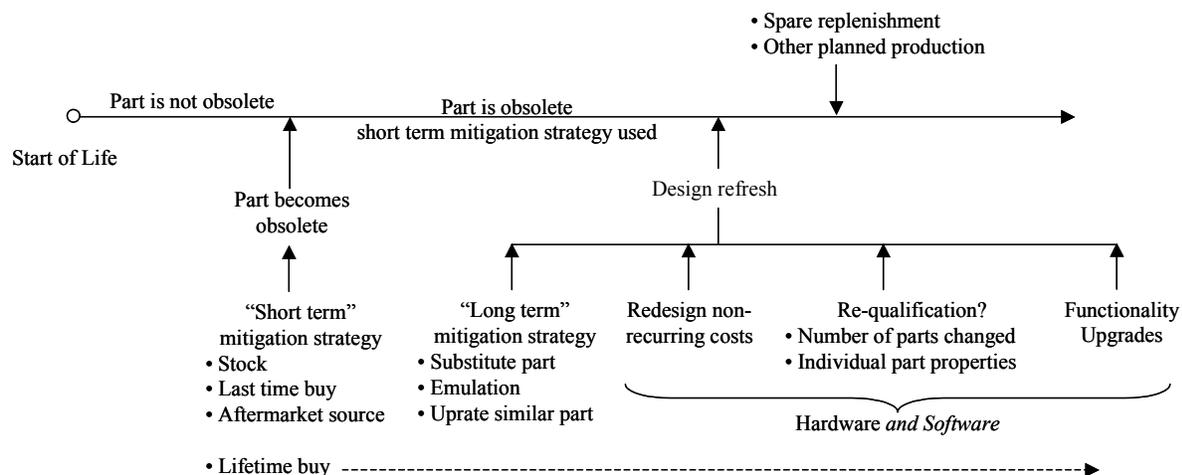


Figure 1: Design refresh planning analysis timeline (presented for one part only, for simplicity, however in reality, there are coupled parallel timelines for many parts).

orders for the product, and replenishment of spares.

The methodology described above supports user determined short- and long-term obsolescence mitigation approaches on a per part basis, and variable look-ahead times associated with design refreshes.

One of the key attributes of the methodology is its treatment of uncertainties. Obviously, much of the data that the method depends on to make design refresh decisions is highly uncertain. In order to solve the problem two types of uncertainties must be managed, 1) uncertainties in the inputs to the cost analysis, for example, the re-qualification cost associated with a particular type of qualification test; and 2) uncertainties in dates. The first type of uncertainty is handled through Monte Carlo modeling. The second type of uncertainty (dates) is more complex to accommodate. At the highest level in the solution, an algorithm that selects a candidate refresh plan is used. A candidate refresh plan consists of the quantity of design refreshes in the lifetime of the product and the dates of those refreshes relative to production events, Figure 2. A production event is any event that results in the need to produce additional instances of the product, i.e., additional orders or spare replenishment necessary for sustainment.³ Once a candidate refresh plan is chosen, an actual sampling of dates for the production events is chosen (the date for each production event is input as a probability distribution). After the probability distributions for the dates are sampled, a sample refresh plan (with real dates) is available. The methodology then computes the life cycle cost of the candidate refresh plan for the sample. Using a basic Monte Carlo approach, the methodology repeats the process of sampling production dates and computing life cycle costs a statistically relevant number of times producing a histogram of the life cycle costs for the candidate refresh plan.

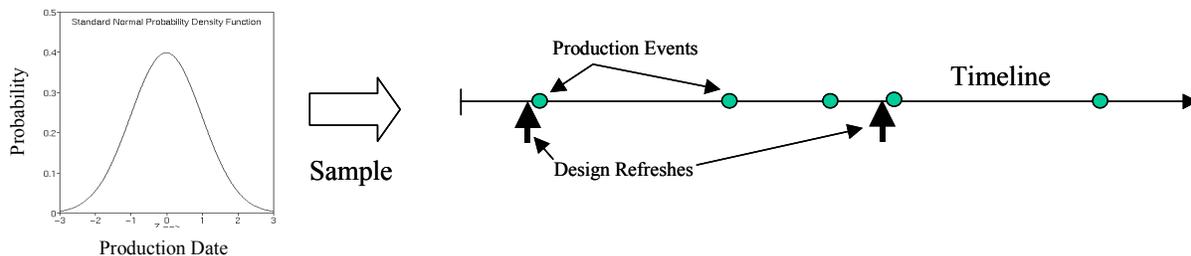


Figure 2: A candidate refresh plan in defined as one or more design refreshes and their dates relative to production events.

Another important aspect of the algorithm is the identification and use of a time step. Unlike physical simulations, where the smaller the time step chosen for the simulation, the more accurate the answer; in this simulation, too small a time step may be just as inaccurate as too large a time step. The correct time step to use is one that corresponds to the OEMs procurement cycle, i.e., how quickly are part procurement decisions made, vendors approved, and procurements completed (parts in-house and ready for use in products) – normally, we assume times steps on the order of 1-2 quarters. In this methodology, for a given time step size, after the sampled candidate refresh plan is determined, the resulting timeline is dropped onto a grid that corresponds to the time step (each date in the sample is moved to the closest point on the time step grid).

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 3 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 quantity, price, obsolescence date (see the next section), and qualification impact. In addition to the parts list, the partitioning of the parts onto boards is input. 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 timeline called an event list.
- Determine cost of no refresh case – Determine the effective life cycle cost of the event list with no added 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.

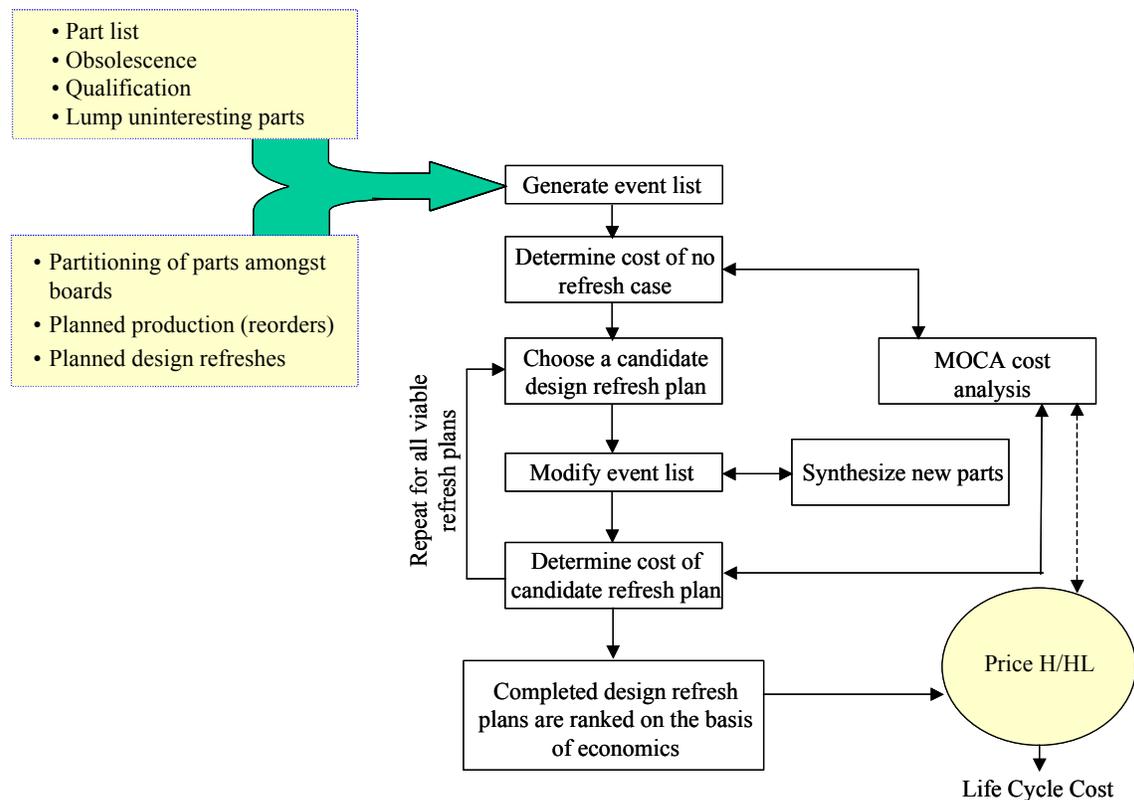


Figure 3: MOCA architecture.

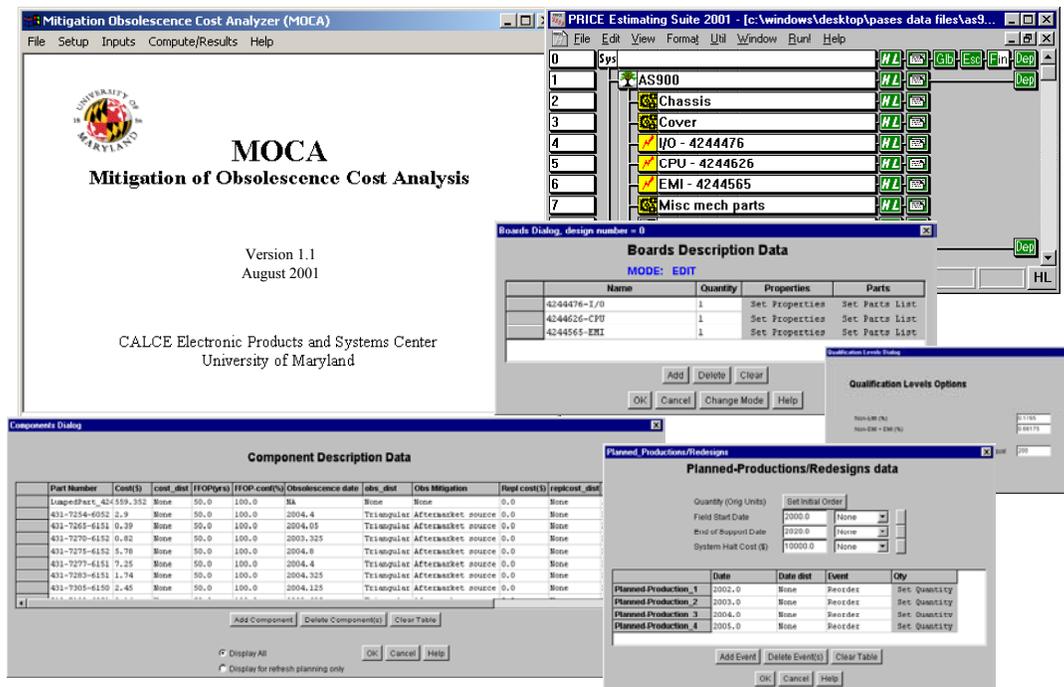


Figure 4: Selected views from the MOCA software tool interface.

- 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, including forecasting of the obsolescence date for the new part(s).
- 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 LCC tool) – 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 4.

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 issue, [5]. 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, [12].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 life cycle stage for the part is determined by computing a simple weighted average of the life cycle codes for the attributes. The disadvantages of this approach are that it does 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 also makes 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 use the "life cycle curve", and cannot be used to determine the life cycle stage of the part.

MOCA uses two different methods for the prediction of electronic obsolescence dates. In the first method obsolescence dates are predicted from obsolescence lifecodes [6] using,

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

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 TACTech obsolescence lifecode that indicates the obsolescence risk associated with the component; i varies from 1 (beginning of life), to 5 (end of life). MOCA also uses a methodology based on forecasting part sales curves, [9]. 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 5 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 5). The equation of the life cycle curve is,

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

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. Note, by its nature, this method supports the prediction of obsolescence dates for future parts (parts that do not exist today). Alternatively, combining technology trends with obsolescence dates predicted by (1) can allow the obsolescence of future parts to be obtained from the TACTech method, [13].

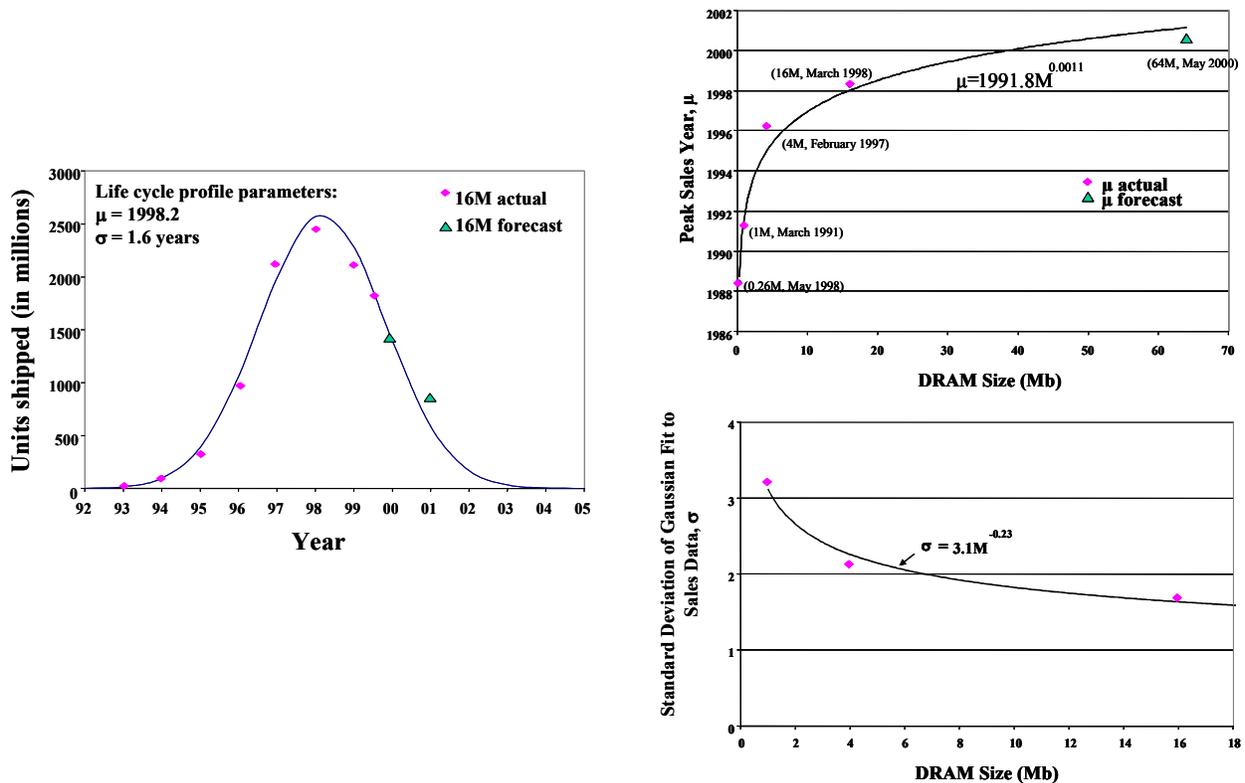


Figure 5: Trend equation formation for DRAMs. Left: 16M DRAM sales curve fit; Top right: trend equation for peak sales year formed from DRAM sales curve; Bottom left: trend equation for standard deviation formed from DRAM sales curve.

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 .

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.

Image Removed

Figure 6: AS900 FADEC example application.

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

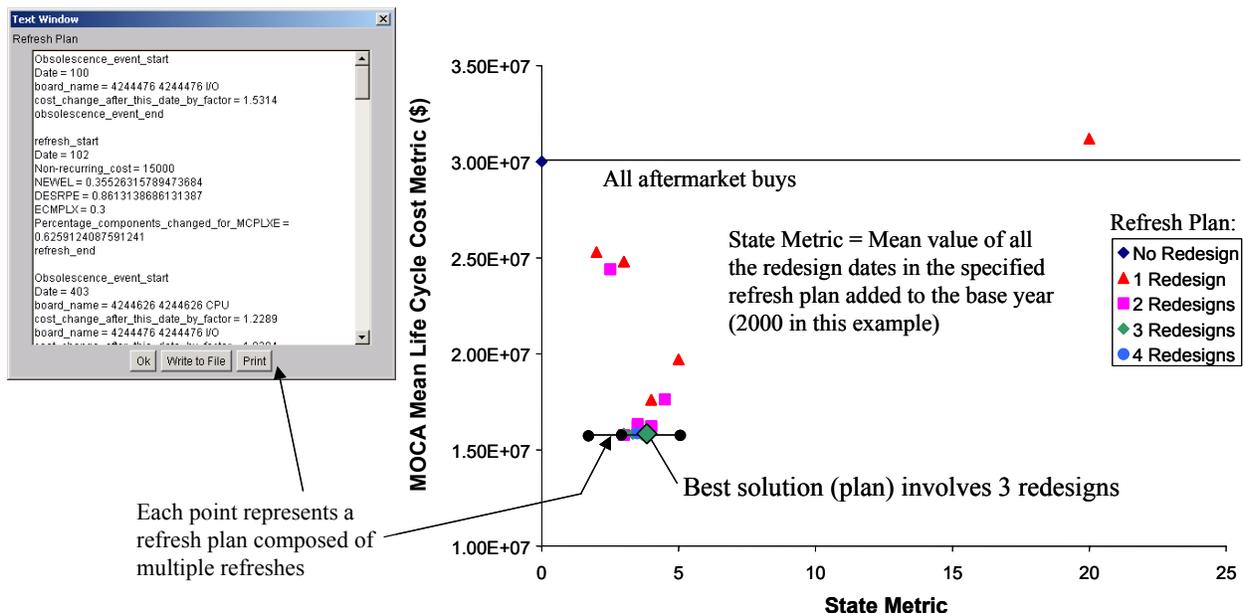


Figure 7: Example MOCA design refresh solution for the AS900 FADEC. This solution assumes: 1 year look-ahead time, 200 component re-qualification trigger, and \$136,000 full re-qualification cost.

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 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 $\pm 20\%$ 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 obsolescence within the next 5+ years, you may be replacing nearly all the components at every refresh.

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

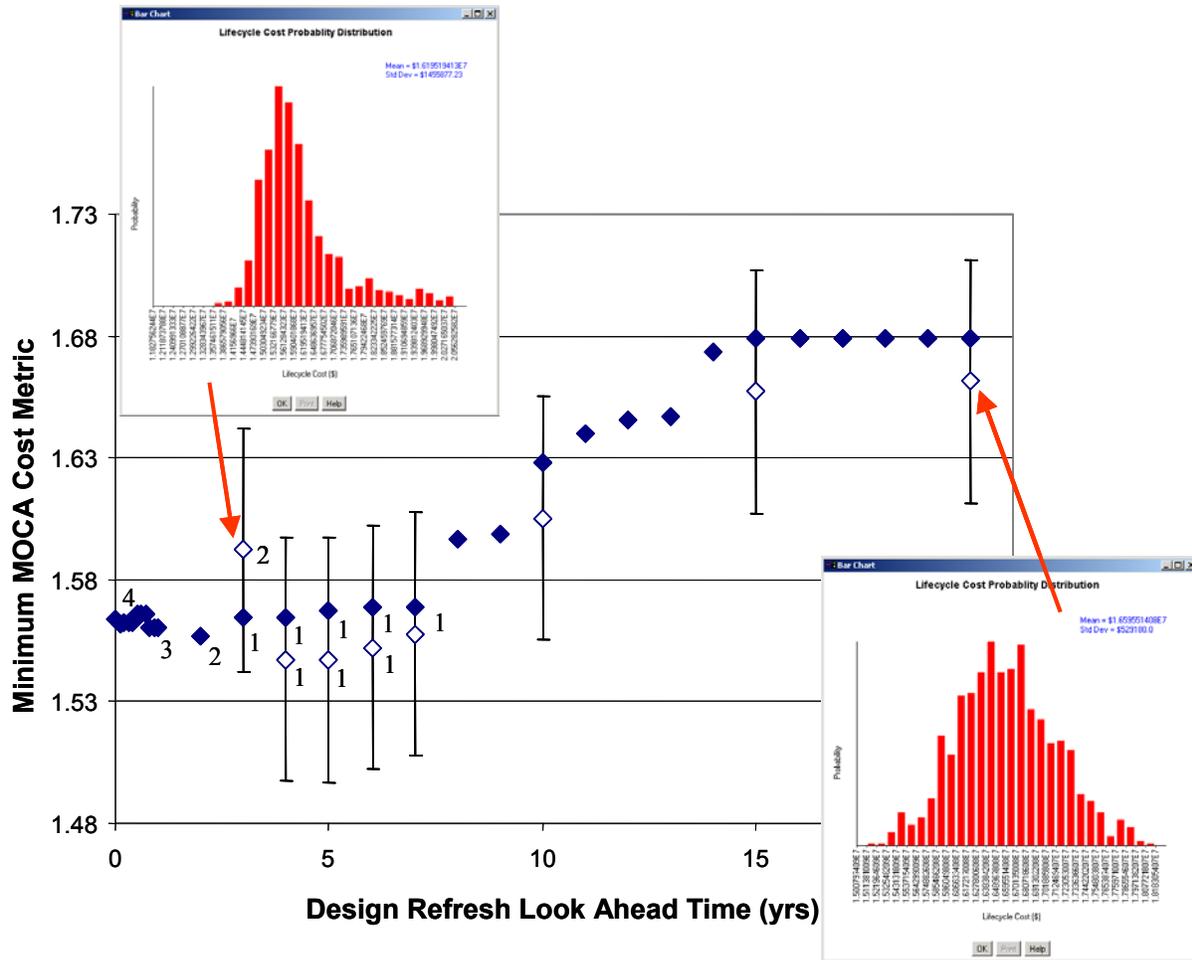


Figure 8: The best design refresh plan as a function of the look-ahead time at the design refresh. Solid points = no uncertainties in input data, open points include uncertainties. The inset graphs show histograms of the costs for the indicated points (the points plot the mean).

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.

Acknowledgements

This work was supported in part by the Physics of Failure Approach to Sustainable Electronic Systems (PASES) contract from Air Force Research Laboratory and Wright-Patterson AFB, sponsored by the ManTech Sustainment Initiative, Manufacturing for Sustainment under contract F33615-99-2-5503.

REFERENCES

1. Foucher, B., Kennedy, R., Kelkar, N., Ranade, Y., Govind, A., Blake, W., Mathur, A., and Solomon, R., Why a New Parts Selection and Management Program?, *IEEE Transactions on Components, Packaging and Manufacturing Technology, Part A*, Vol. 21, No. 2, pp. 375-382, 1998.
2. Bumbalough, A. 1999. USAF Manufacturing Technology's Initiative on Electronics Parts Obsolescence Management, *Proceedings of 44th International SAMPE Symposium*, pp. 2044-2051, 1999.
3. Stogdill, R.C., Dealing with Obsolete Parts, *IEEE Design & Test of Computers*, 16(2): 17-25, 1999.
4. Wright, M., Humphrey, D., and McCluskey, P., Upgrading Electronic Components for Use Outside Their Temperature Specification Limits, *IEEE Trans. on Components, Packaging, and Manufacturing Tech., Part A*, Vol. 20, No. 2, pp. 252-256, 1997.
5. Levitt, T., Exploit the Product Life Cycle, *The Harvard Business Review*, Nov–Dec, 1965.
6. TACTech, <http://www.tactech.com>
7. Henke, A.L., and Lai, S., Automated Parts Obsolescence Prediction, *Proc. DMSMS Conference*, (<http://smaplab.ri.uah.edu/dmsms/laip.pdf>), 1997.
8. Amspaker, M., Expanding Current Obsolescence Tools to Non-Electronic Areas, *Proc. DMSMS Conference*, (<http://smaplab.ri.uah.edu/dmsms98/papers/amspaker.pdf>), 1999.
9. Solomon, R., Sandborn, P. and Pecht, M., Electronic Part Life Cycle Concepts and Obsolescence Forecasting, *IEEE Trans. on Components and Packaging Technologies*, Vol. 23, No. 4, pp. 707-713, Dec. 2000.
10. Avlonitis, G. J., Product Deletion Decision and Strategies, *Industrial Marketing Management*, Vol. 12, pp. 31-43, 1983.
11. Porter, Z., An Economic Method for Evaluating Component Obsolescence Solutions, Boeing Corporation, 1998.
12. ANSI/EIA, *Product Life Cycle Data Model*, American Standard ANSI/EIA-724, Sept. 19, 1997.
13. P. Singh, P. Sandborn, T. Geiser, and D. Lorenson, Electronic Part Obsolescence Driven Product Redesign Optimization, Proc. ISPE International Conference on Concurrent Engineering, pp. 961-970, July 2002.
14. Perry, W., U.S. Secretary of Defense, June 1994.

15. Sherwood, E., Product Life Cycle (PLC) Code Definitions and Applications, *Proposal to EIA*, 2000.

ENDNOTES

1. 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, [14]. 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.
2. 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.
3. Note, we are defining a production event to include both a continuous stream of manufacturing on a manufacturing line, such as the initial product manufacturing; and smaller production runs to build upgraded units, spares, or additional orders at future times.
4. Several additional phases have been proposed [15] including: Introduction Pending (prior to introduction), and splitting the Phase-out stage into Last Shipment and Discontinued or Purged.