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Determining Optimum Redesign Plans for Avionics Based on Electronic Part Obsolescence Forecasts

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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 significantly sustainment costs for long life systems. In particular, avionics often encounters 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

As a result of the rapid growth of the electronics industry, many of the electronic parts that compose avionics products 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 sustainment), or the product is the driving force behind the part's market (which avionics products are not), 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, [1]. Manufacturing that takes place over long periods of time exacerbates these problems, and the high cost of system qualification and certification make design refreshes using newer parts an expensive undertaking.

For avionics, a electronic parts obsolescence management strategy will generally be required. Many different obsolescence mitigation approaches have been proposed and are being used, [2]. These approaches include: 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), 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 (using a "commercial" version of the part beyond the manufacturer's specifications, usually at a higher temperature).

Unfortunately the mitigation approaches listed above are usually applied in a *reactive* manner only after an obsolescence event has occurred, i.e., in "firefighting mode" with very little thought or planning given to how the system could have been optimally designed to minimize the cost of managing inevitable obsolescence problems. If some information (with appropriate uncertainties considered) regarding the expected lifetimes of parts is available during the design phase, then a *pro-active* approach that enables the estimation of lifetime sustainment costs via life cycle planning should be possible, and even if such a plan is "foggy" (due to the uncertainties), the opportunity for sustainment cost savings is still significant.

The design strategy adopted in this work is one in which the common obsolescence mitigation approaches listed above are applied in either a short-term (until the next redesign) or long-term (until the end of support of the product) and the planning exercise undertaken is to determine when to redesign the product and what actions to take at each redesign, where we define redesign (or design refresh) as a change in a system's hardware that requires some non-zero non-recurring re-engineering cost. At design refresh, 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.

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. The 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 and describe the results of an example study performed on the Honeywell AS900 engine controller.

PLANNING DESIGN REFRESHES

This work focuses on the question: if the forecast of parts obsolescence can be obtained and if a roadmap of *value* attributes for the product over time is available, can optimum redesign 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, [3]. This type of 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.

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,

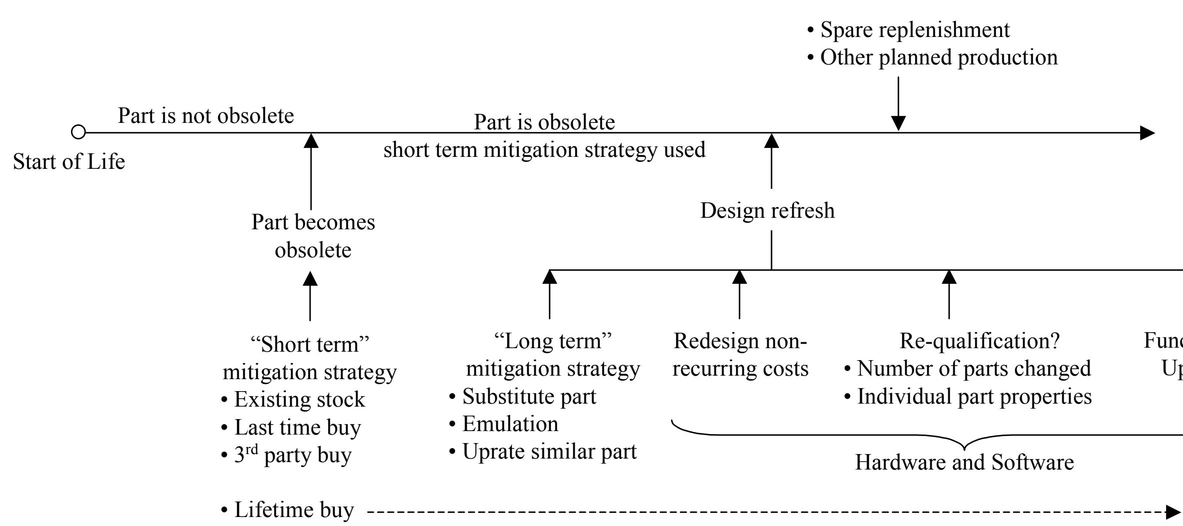

Figure 1. Design refresh planning analysis timeline (presented for one part only, for simplicity, however in reality, there are coupled parallel timelines for all the parts in the product).

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 (including forecasting the obsolescence of future parts). All the design refresh activities should accommodate both hardware and software redesign and re-qualification (note, the MOCA tool introduced in the next section only treats hardware). 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, addi-tional orders for the product, and spare replenishment.

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. Another key attribute is the 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. A more detailed description of the treatment of uncertainties and the selection of time steps for use in this methodology appears in [4].

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. A discussion of the key attributes of the MOCA tool follows.

INPUTS

The basic inputs for the MOCA tool are a bill of materials (parts list) corresponding to the system to be analyzed, the partitioning of the parts onto boards, and production plans. The critical information included in the parts list is the quantity, price, obsolescence date, and obsolescence mitigation plans. Figure 2 shows the interface of collecting the part information. For each part an obsolescence date is determined from any of several sources, [5-8]. Since obsolescence dates are highly uncertain, so every date is actually treated as a probability distribution with user definable shape and characteristics (Obs. Date Dist. in Figure 2). Each part also has an obsolescence mitigation approach assigned

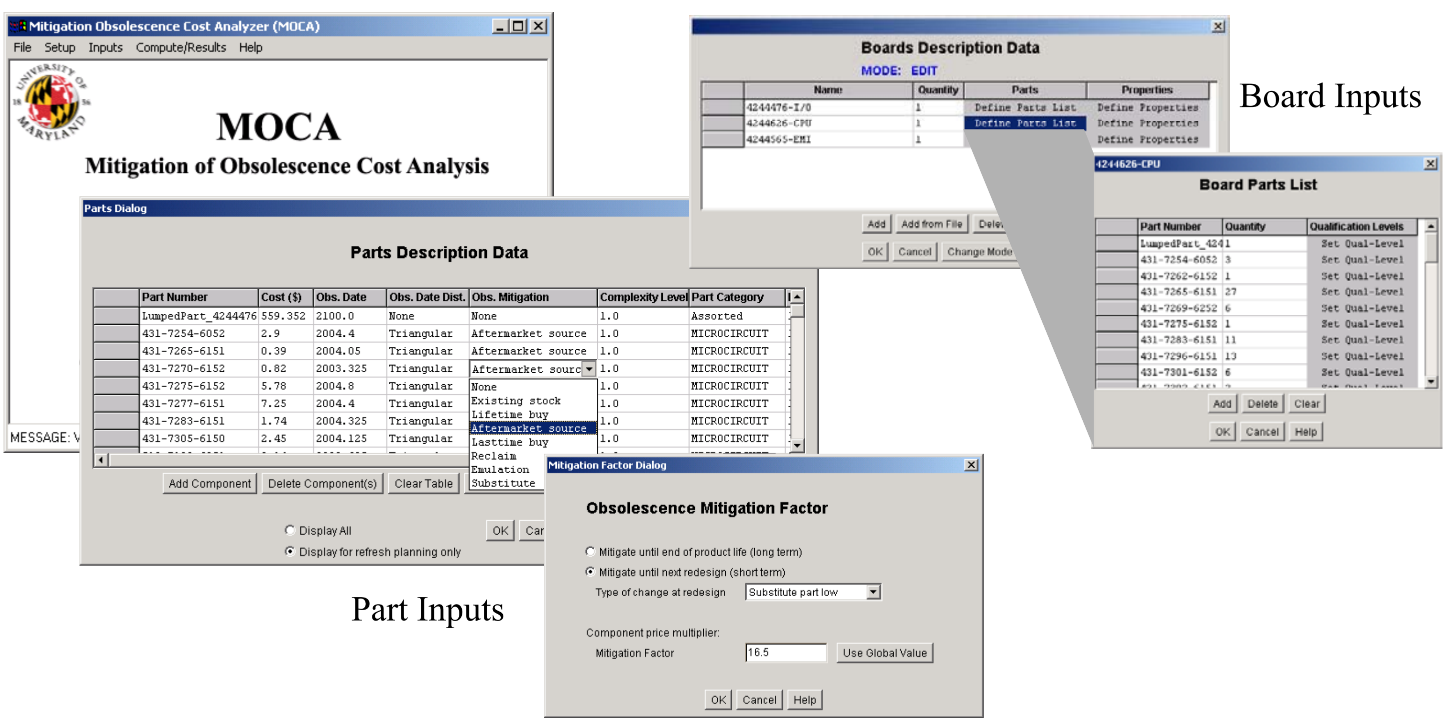

Figure 2. MOCA part and board-level input interfaces.

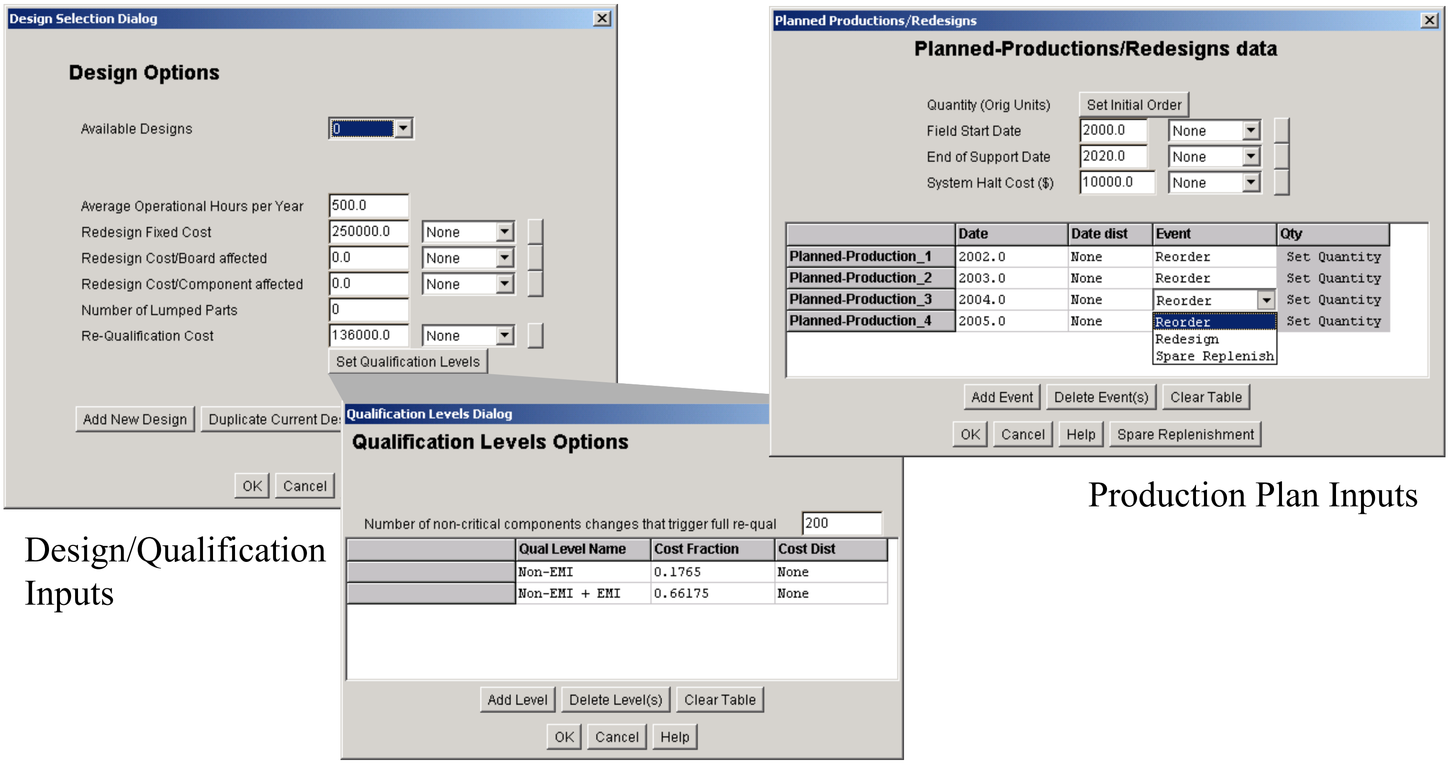

Figure 3. MOCA design/qualification and production plan input interfaces.

to it (a list of possible approaches are shown in Figure 2). A selected mitigation approach may be defined as long-term (in effect until the end of the sustainment life for the product), or short-term (in effect until the next redesign). In both cases, a factor (mitigation factor) that multiplies the purchase price of the part when the mitigation approach is in effect is defined.

In addition to the parts list, the partitioning of the parts onto boards is an input (the parts are defined independently of the boards that they are in). Figure 2 also shows the board-level inputs. In the case shown, there are three boards (one instance of each in the design). Each board has a set of parts assigned to it (the same part may appear on multiple boards). Two part-specific inputs are collected at the board level: 1) quantity of the part on the board, and 2) the board- or system-level qualification affected by the part. Each part assigned to a board, can also optionally be designated as a non-unique driver behind one or more board- or system-level qualification activities, i.e., if the part is replaced at a redesign, the qualification activity will have to be performed. The qualification activities are user defined (on an application-specific basis) and can be broken down to any level of detail, see Figure 3. Note, parts need not drive any specific qualification activity. Additional board properties (not shown in Figure 2) are also collected, including various manufacturing costs and board-level reliability information.

Qualification information can be defined at the system level (a system consists of several boards), or at the board level. Figure 3 shows the interface for defining the qualification levels for a system. Besides changes to specific critical parts causing re-qualification, re-qualification can also result from a specified number of non-critical part changes.

The final set 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 (fixed date) design refreshes. The interface for the planned production inputs is shown in Figure 3. Each planned production event can be defined as a reorder (additional production due to additional orders), redesign (a user-specified planned redesign of the system or a board at a fixed date – note, MOCA will optimize additional redesigns around this type of event), or spare replenishment (additional systems or boards that need to be manufactured to provide spares for fielded units). Whatever the production event, the quantity of systems (or of specific boards within the system) can be input. Note, spare replenishment dates and quantities can be automatically computed and added to the production plan inputs by MOCA.

ANALYSIS

The MOCA analysis proceeds through the following steps:

1) Generate event list – Combine all the events (production, fixed design refreshes, and individual part obsolescence) onto a single timeline called an event list.

2) 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).

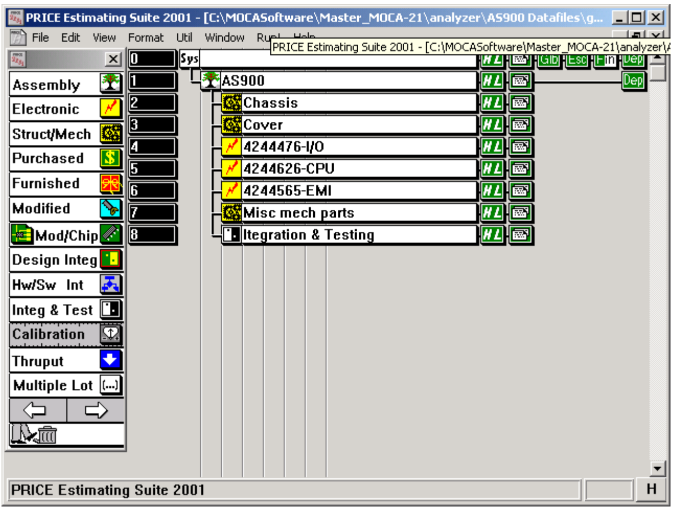

Figure 4. Price H/HL interface (AS900 application treated in the next section is shown).

3) 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 4). 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.

4) Choose a candidate design refresh plan – A candidate set of design refreshes (date of each specific refresh) is automatically chosen for analysis.

5) Modify event list – The original event list is modified to include the candidate design refreshes.

6) 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).

7) 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

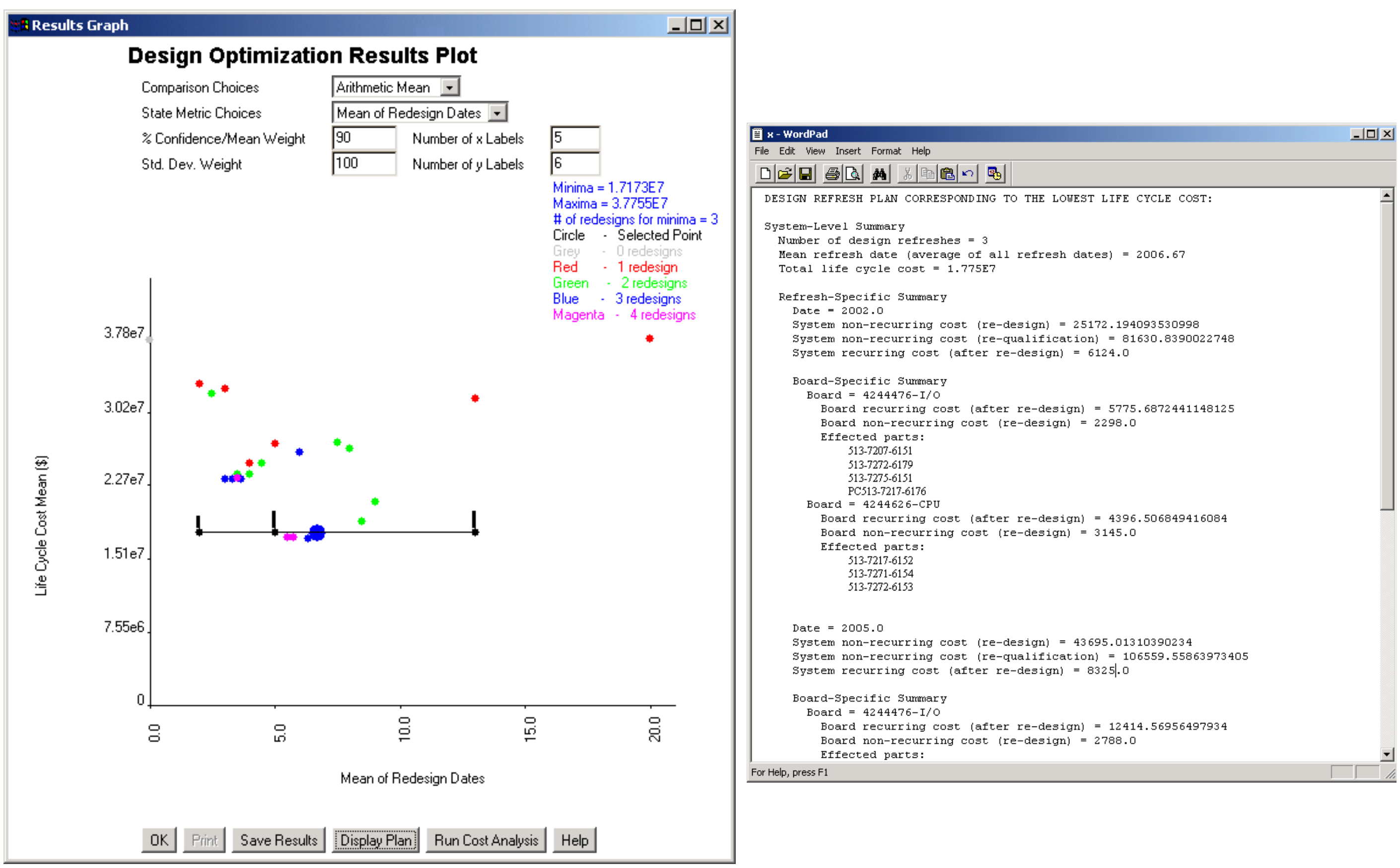

Figure 5. Example output from the MOCA tool. Left = results plot with one refresh plan expanded, right = the actual refresh plan corresponding to the expanded point.

refresh plan.

8) 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.

OUTPUTS

An example set of results from MOCA is shown in Figure 5. MOCA generates results for all viable cases up to a user specified maximum number of design refreshes during the life of the product (4 refreshes, 20 year life in in Figure 5). 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 (one that consists of 3 redesigns) is expanded in Figure 5 to show the actual refreshes that comprise the plan. Small bars are plotted above each of the actual refresh dates to indicate the relative magnitude of the non-recurring redesign cost (including re-qualification) at each redesign. A refresh plan is also generated by MOCA 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 necessarily correspond to total life cycle costs for the system, but a smaller value of the metric does indicate lower life cycle cost.

ANALYSIS OF A FADEC

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.

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Figure 6. AS900 FADEC example application.

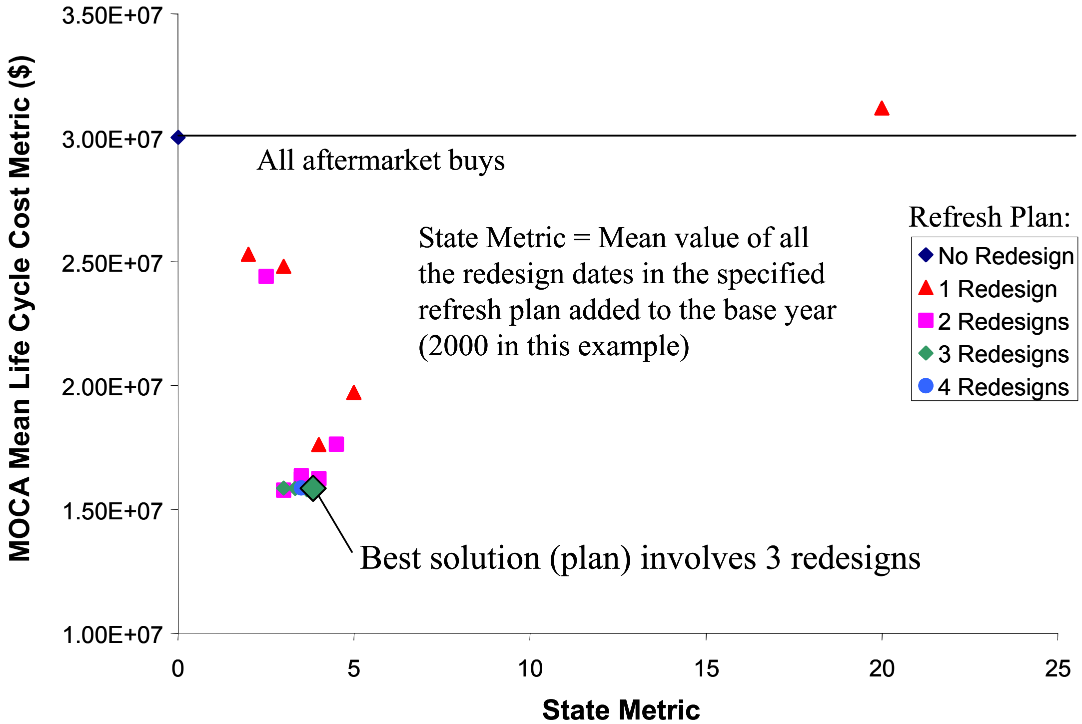

Figure 7. MOCA design refresh solution for the AS900 FADEC. This solution assumes: 1 year look-ahead time, 200 component re-qualification trigger, and $136,000 full re-qualification cost.

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 Figures 5 and 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.

CONCLUSION

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

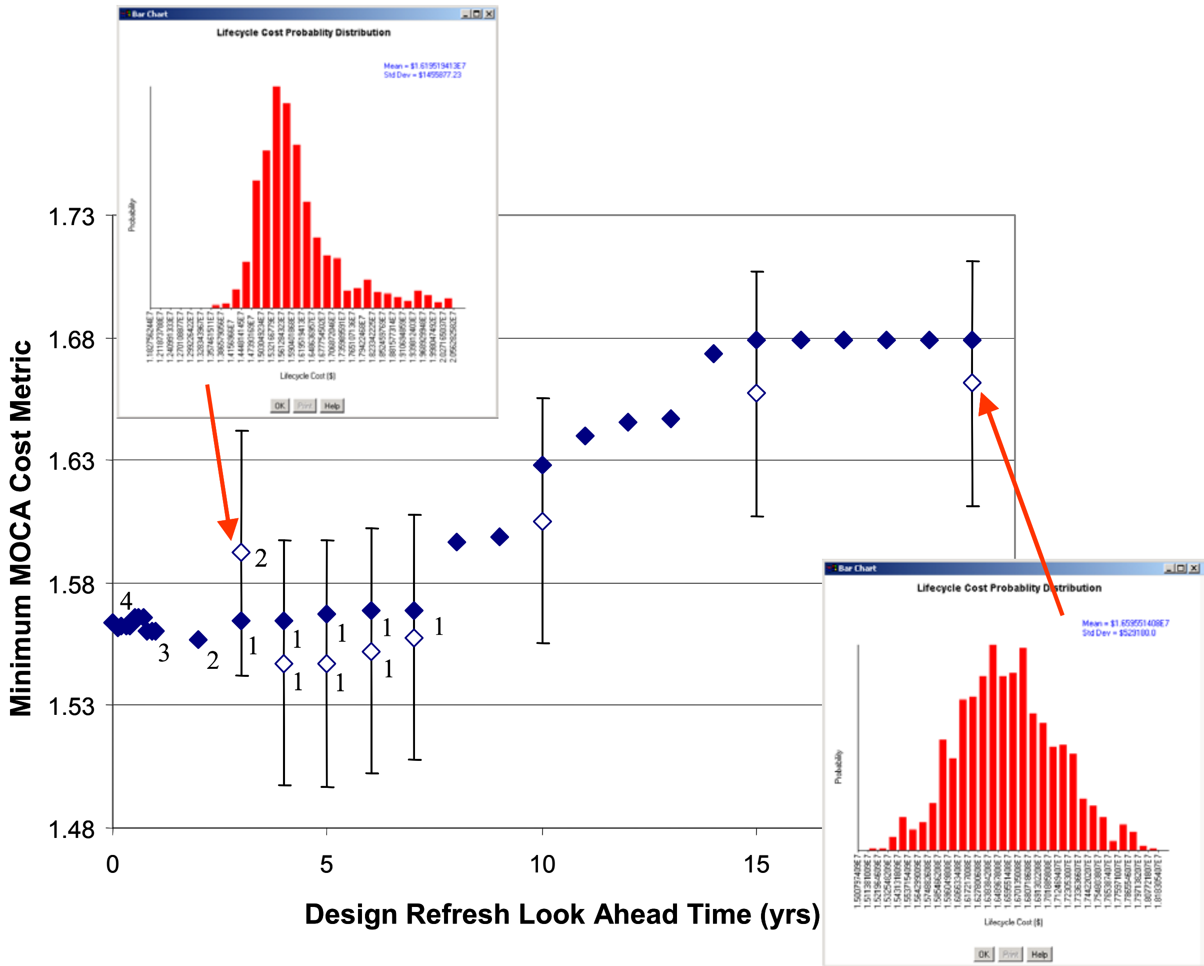

Figure 8. The best design refresh plan as a function of the look-ahead time at the design refresh. Solid points = no uncertainties in input data, open points include uncertainties. The inset graphs show histograms of the costs for the indicated points (the points plot the mean).

ahead times associated with design refreshes. Part obsolescence mitigation strategies can be compared to design refreshing part obsolescence elimination strategy.

MOCA (Design Refresh Planning) coupled with Price (Life Cycle Cost Analysis) represents two pieces of a larger vision of pro-active life cycle planning and optimization for sustainment dominated systems, Figure 9. In order to make true value-based decisions about how to best sustain a system, financial and decision support analysis need to be added. All these elements must be managed by a platform that provides access to historical databases (e.g., AFTOC), obsolescence forecasting (e.g., i2, Total Parts Plus, Precience, etc.), and technology roadmapping, (e.g., [9]).

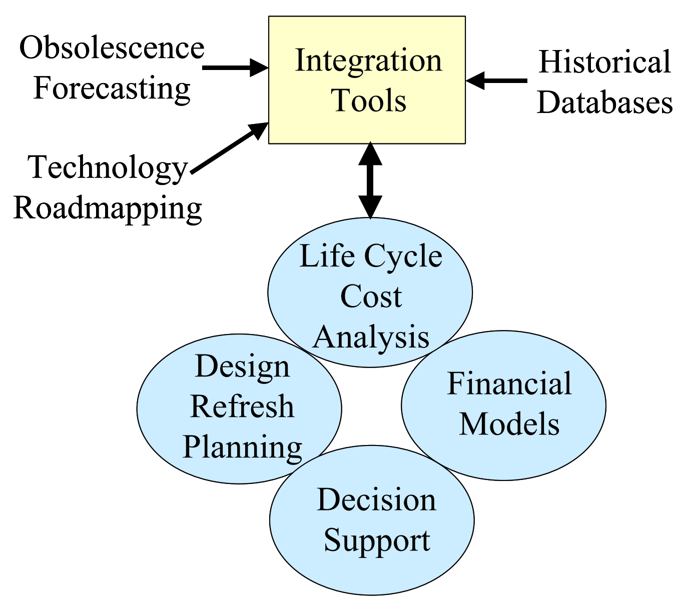

Figure 9. Vision of the design tool space for pro-active life cycle planning of sustainment-dominated systems.

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