Forecasting Technology Insertion Concurrent with Design Refresh Planning for COTS-Based Electronic Systems

Peter Sandborn and Pameet Singh
CALCE, Dept. of Mechanical Engineering, University of Maryland

ABSTRACT

This paper describes a methodology for forecasting technology insertion concurrent with obsolescence driven design refresh planning. The optimized parameter is the life cycle cost of the system. The resulting analysis provides a design refresh schedule for the system (i.e., when to design refresh) and predicts the design refresh content for each of the scheduled design refreshes. Optimal design refresh content is determined using a hybrid analysis scheme that utilizes Monte Carlo methods to account for uncertainties (in dates) and Bayesian Belief Networks to enable critical decision making after candidate refresh dates are selected.

INTRODUCTION

There are many types of products and systems that have life cycles longer than their constituent parts (specifically Commercial Off The Shelf – COTS electronic parts). These life cycle mismatches often result in high sustainment costs for long field life systems. Sustainment in this context means all activities necessary to: keep an existing system operational, and continue to manufacture and field versions of the system that satisfy the original and evolving requirements. Examples of sustainment-dominated systems include: avionics, military systems, and industrial equipment. Such products are characterized by: 1) field life (sustainment) costs that are many times the original purchase price, 2) little or no control over their supply chain due to their low production volumes, and 3) high costs associated with their redesign due to stringent qualification/certification requirements. Ultimately systems are redesigned one or more times during their lives to update functionality and manage technology obsolescence. Unfortunately, redesign of sustainment-dominated systems like those mentioned above often entails very large non-recurring engineering and system re-qualification costs. Unlike high-volume commercial products in which redesign is driven by improvements in manufacturing, equipment or technology; for sustainment-dominated systems, design refresh is driven by technology obsolescence that would otherwise render the product un-producible and/or un-sustainable.

Most of the emphasis associated with methodology, tool and database development targeted at the management of electronic part obsolescence has been focused on accurately tracking and managing the availability of parts, forecasting the risk of parts becoming obsolete, and enabling the application of mitigation approaches when parts do become obsolete. While there is unquestionable merit in optimizing the *reactive* management of obsolescence, and it does save sustainment dollars, ultimately much larger savings may be possible if methods targeted at *pro-active* design and life cycle planning of systems could be successfully developed and applied. Methodologies are needed that address how to optimally design a system in order to minimize the cost of concurrently managing both inevitable obsolescence problems and technology insertion. If information regarding the expected production lifetimes of parts (with appropriate uncertainties considered) is available during a system's design phase, then more strategic pro-active approaches that enable the estimation of lifetime sustainment costs should be possible, and even with data that is incomplete and/or uncertain, the opportunity for sustainment cost savings is still potentially significant with the application of the appropriate decision making methods.

Ideally, a methodology that determines the best dates for design refreshes, and the optimum mixture of actions to take at those design refreshes is needed. The goal of refresh planning is to determine:

- When to design refresh
- What obsolete system components should be replaced at a specific design refresh (versus continuing with some other obsolescence mitigation strategy)
- What non-obsolete system components should be replaced at a specific design refresh.

This paper discusses a methodology focused on the question: if a 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?

PRO-ACTIVE OBSOLESCENCE-DRIVEN DESIGN REFRESH PLANNING

A methodology and it's implementation (Mitigation of Obsolescence Cost Analysis - MOCA) have been developed for determining the part obsolescence impact on life cycle sustainment costs for long field life electronic systems based on future

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production projections, maintenance requirements and part obsolescence forecasts (Figure 1), [1,2]. Based on a detailed cost analysis model, the methodology determines the optimum design refresh plan during the life of the product (from design through O&S). The design refresh plan consists of the number of design refresh activities, their respective calendar dates and content necessary to minimize the life cycle sustainment cost of the product (Figure 2). 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, and allows for inputs to be specified as probability distributions.

Figure 3 shows results from an example case study was performed for an avionics unit consisting of 2 boxes that contained a total of 20 boards (12 of the boards are unique and one board is common to both boxes). A total of 831 parts (116 unique) were included on the boards. The system is designed for a 20 year sustainment life with scheduled manufacturing taking place during the first 12 years. The original design for the avionics unit was performed in 1998. In order to verify the MOCA analysis, the system was modeled as though the analysis was being performed in 1998 using TACTech part lifecode forecasts (part-specific obsolescence risk forecasts) performed when the original unit design was performed. The optimum refresh plan forecasts from MOCA are compared to the actual refresh plans determined from the state of the obsolescence events and production.

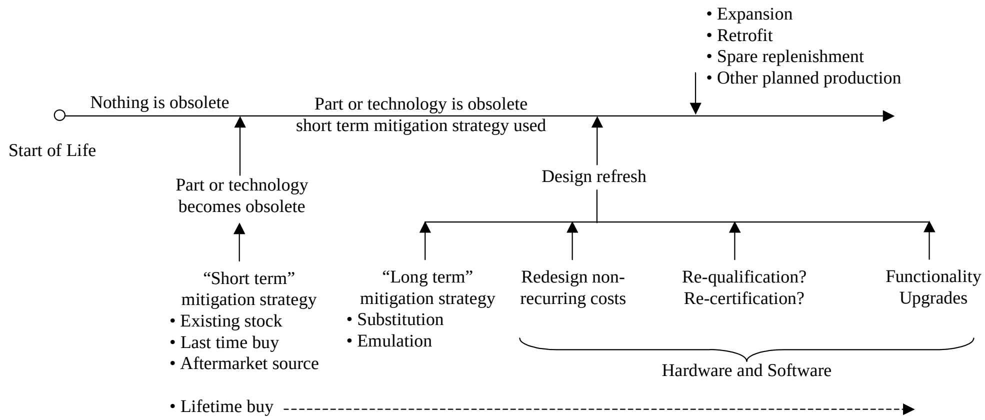

Figure 1. Timeline of events managed in the MOCA design refresh planning tool.

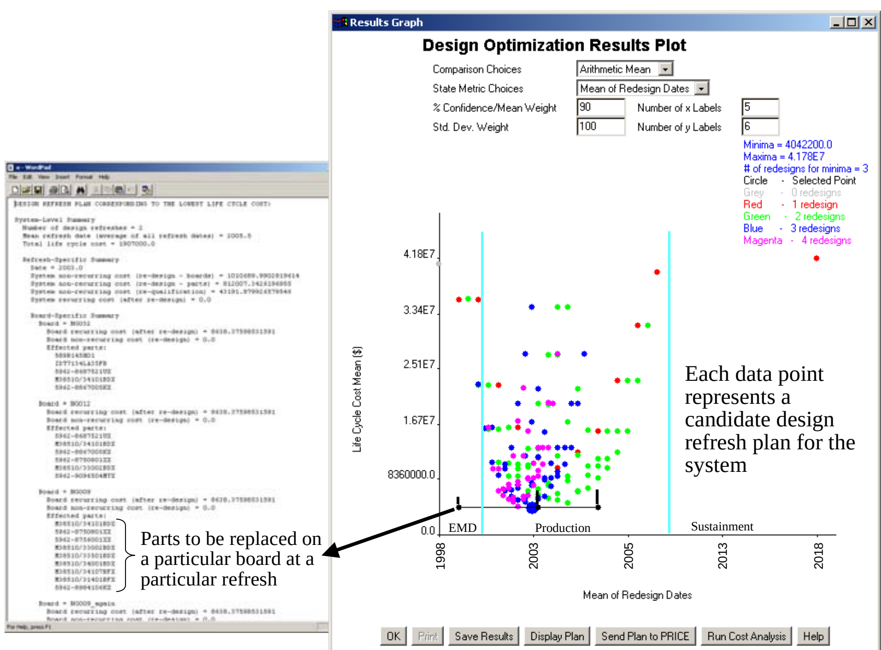

Figure 2. MOCA output for an electronic system. MOCA generates results for all possible combinations of design refresh locations (dates). The data points on the plot each represent a different refresh plan (a refresh plan is a group of one or more design refreshes). One plan is expanded to show the refreshes associated with it.

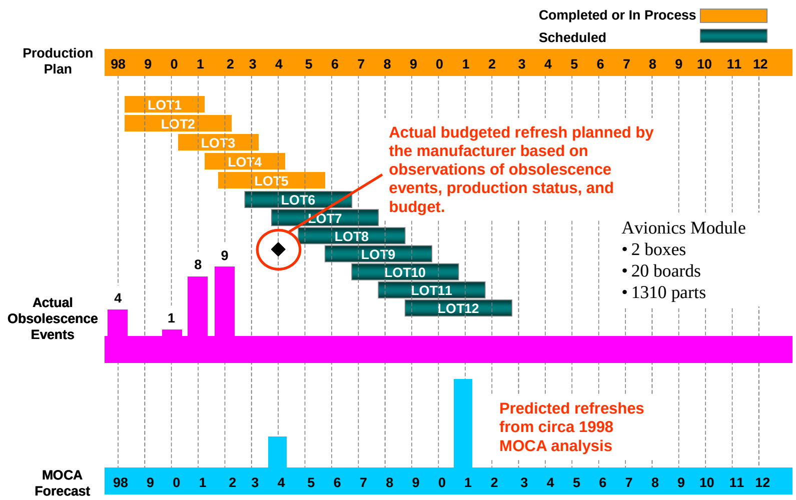

Figure 3. Comparison of MOCA forecasted optimum design refresh dates (forecasted from the 1998 design data), and the first major redesign date determined by the manufacturer.

DETERMINING PRACTICAL DESIGN REFRESH CONTENT: TECHNOLOGY INSERTION

The basic MOCA methodology presented in last section targets technology sustainment, i.e., maintaining a static functional capability. But technology and requirements evolve over time and planning system redesigns solely on the basis of the obsolescence of its constitute pieces, while sometimes necessary, is not often practical or justifiable. An extension to the MOCA methodology that expands the design refresh value proposition to include more than obsolescence effects has been developed.[1] The extension to MOCA moves it in the direction of enabling optimum technology insertion into systems based on a value proposition that includes performance, reliability, cost and elements of a conceptual assessment criteria called *viability* [4]. Viability is a measure of the producibility, supportability, and evolvability of a system. The value proposition and viability must also consider more than just hardware, in addition, it must consider these same or similar 'ility' elements for software, information and intellectual property.

The decisions that govern whether a technology is changed (replaced or upgraded) or not changed at a design refresh depend on the obsolescence attributes of the specific technology and on the "utility" to the system realized by changing the technology (economic, performance, and reliability). To make the decision in a coupled-technology process we formulate Bayesian Belief Networks (BBNs), [5].

BBNs are applicable for reasoning about beliefs under conditions of uncertainty and using disparate sources of evidence (diverse data sources, including subjective beliefs and when all of the data entering into the decision is highly uncertain). A second motivation for using BBNs is that sharing an understanding among many heterogeneous stakeholders (procurement, design, manufacturing, etc.) using both qualitative and explicit data is a necessity.

The approach followed in this work is to use decision analysis to decide design refresh content for candidate design refresh dates generated by the MOCA tool. Decision analysis has the capability to consider all the decision affecting variables at the same time in the model, e.g., availability of a new part to replace the old part, available stock of the old part, performance and reliability change due to the part changes, impacts on the system software due to hardware changes, re-qualification that may be triggered by part changes, etc. This approach ensures that we consider both dimensions of optimization, i.e., date of the design refresh along with what is changed at the design refresh. Using the technology sustainment version of MOCA (last section) it is possible that MOCA decides to design refresh all the parts during a design refresh simply because they are all obsolete (not a completely unrealistic situation for avionics and military systems). However, for some of the parts, continuation of mitigation approaches might have been preferable to replacement at the refresh due to the cost, reliability, and/or performance penalties that may be associated with the replacement. For this kind of situation a BBN model helps prevent "over design refreshing" of the system due to view that is limited to part obsolescence. Another possibility is that a replacement for a non-obsolete part might be preferred because it is less expensive, more reliable, improves the performance, or will become obsolete in the near-term. By replacing this part, a life cycle system advantage can be realized.

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[1] Technology refresh is used as a reference to system changes that "Have To Be Done" in order for the system functionality to remain useable. Technology insertion is a term used to identity the "Want To Be Done" system changes, which include both the new technologies to accommodate system functional growth and new technologies to replace and improve the existing functionality of the system, see [3].

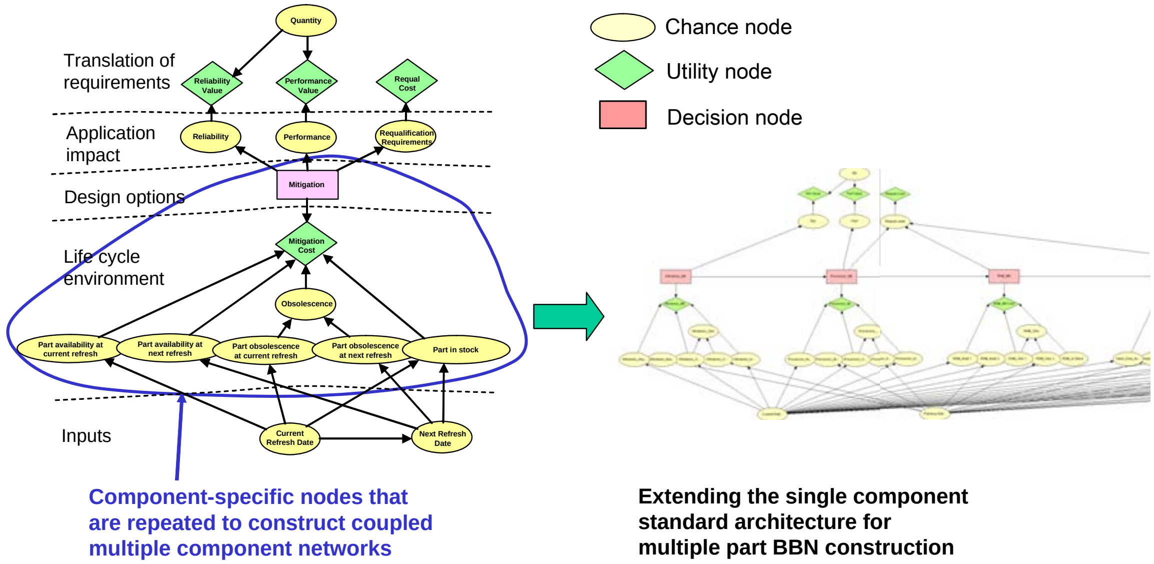

Figure 4. Example Bayesian Belief Network (BBN) for determining whether to replace or not replace electronic components at a specific re-design point.

In MOCA, BBNs are used to determine the optimal design refresh content at each design refresh in a plan. A BBN representing the bill of materials is constructed at the start of a MOCA design refresh planning analysis, Figure 4. The structure of the BBNs corresponding to a part is created automatically from the system description by assembling predefined network fragments. The probability tables associated with the chance nodes are populated automatically from uncertain data inputs. The data associated with utility nodes represent the inputs from various stakeholders, i.e., "customer-directed value". At each design refresh (i.e., one that is in a MOCA generated candidate design refresh plan), MOCA sets the current, and the prospective future design refresh date in the BBN. When this happens, all the part-specific and system-specific nodes are updated. Their respective probabilities are also updated. After propagation of the network, the updated decision node for each part contains the decision associated with design refreshing that part. Based on that decision a list of parts affected and to be replaced during the current design refresh is generated.

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), and 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.

As an example, two cases are have been considered for the AS900 FADEC, 1) where the design refresh planning is performed assuming replacement of all obsolete parts at a design refresh (from the "technology sustainment" version of MOCA described in the last section); and 2) where the design refresh planning is performed using BBN to make decisions to replace parts at a design refresh. In both the cases the inputs are comprised of production schedule data for AS900 FADEC over the next 20 years, Bill of Materials of AS900 FADEC along with all the part specific information, e.g., part prices and predicted obsolescence dates, etc. Each of the points in the graph shown in Figure 5 represents a design refresh plan for the AS900 FADEC.

Due to the complexity of the BBN for the AS900 FADEC, it is important to build the BBN for only those parts that are expected to contribute significantly to the system cost. Other criterion to choose the parts used in the BBN could be part reliability, re-qualification, etc. For the parts not included in the BBN analysis, a strategy of replacing the part whenever it is obsolete at a design refresh is adopted. In the example presented, a group of eleven parts were selected for the BBN analysis. Their total cost contribution to the system was approximately 30% of the total system cost.

For this example, the minimum life cycle cost with and without the BBN used in Figure 5 is approximately the same, however the number of design refreshes and their respective content (i.e., which parts to replace at a particular design refresh) is different. Without the BBN, the optimization analysis results in 4 design refreshes (in the years 2001, 2003, 2004, and 2005) and with the BBN the analysis results in 3 design refreshes (in the years 2001, 2004, and 2005) as the minimum life cycle cost solution. However, more importantly, the risk of higher cost solutions has been reduced (the cost of all the high cost refresh

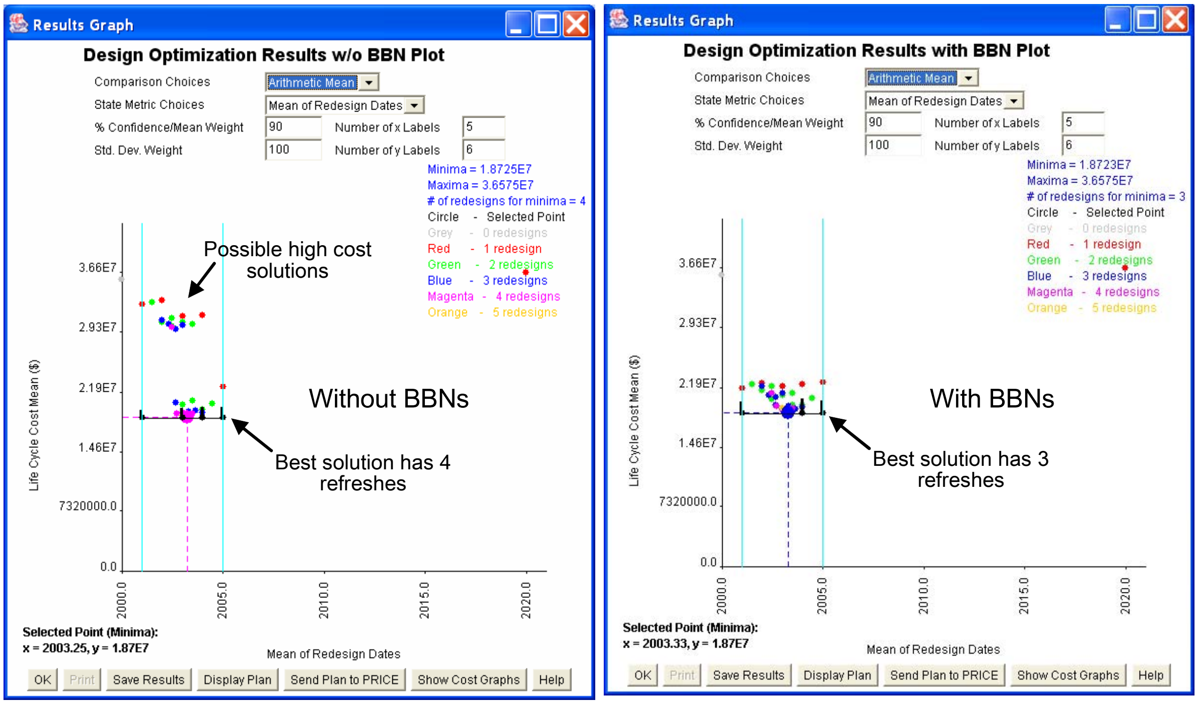

Figure 5. Results for the analysis with (right) and without (left) a BBN used to make part replacement decisions at a design refresh.

plans appearing in the non-BBN solution on the left side of Fig. 8 have been reduced when BBNs are used to select refresh content. Given the uncertainties associated with this type of problem, the solution with BBNs above represents considerable risk avoidance.

The solutions with BBNs and without BBNs are different in this particular case because some of the parts that are replaced at a design refresh without the BBN analysis are obsolete but are not required in the future or are less expensive to procure later. This incurs a design refresh cost even though we can do better without it thereby increasing the over all lifecycle cost of the system. The BBN analysis estimates the part usage in the future and then compares it with current design refresh cost. This feature enables MOCA to choose not to design refresh a part even though it is obsolete. Therefore, MOCA is essentially determining an optimal mix of obsolescence mitigation strategy for each part during the system's lifetime. The cost avoidance is therefore realized in terms of fewer numbers of design refreshes and a more optimal mix of design refresh content at each of these redesigns.

DISCUSSION

The problem at hand is not that people can't figure out when to refresh a design and what the content of the refresh ought to be, it's that they can't figure these things out soon enough to put the necessary resources in place (e.g., budget) at the optimum point(s) in time. Using a methodology like MOCA enables earlier and more complete refresh planning.

There are several real payoffs from pro-active life cycle planning that reactive methodologies will never be able to provide. Pro-active treatment of electronic part obsolescence has the potential to provide the program manager with the ability to predict as early as possible (while the input data is uncertain) how to best design and plan for system sustainment:

- more accurate allocation of budget earlier in program development phases
- more accurate guidelines for how systems are modified at design refreshes
- improved operational availability
- enables broader impacts to be considered when mitigation approach decisions are made
- enables the opportunity for shared solutions across multiple systems and applications.
- improved capability to execute the performance improvement roadmap (i.e., with the optimum balance between mission needs and cost).

Realizing this payoff however requires the incorporation of decision process approaches (decision making under uncertainty), design optimization, product planning concepts, and data mining and data fusion methodologies.

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