Obsolescence and Life Cycle Management for Avionics

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**Technical Report Documentation Page**

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<td>September 2013</td>
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<th>9. Performing Organization Name and Address</th>
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<td>Honeywell Aerospace</td>
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<td>Columbia, MD 21046</td>
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<td>Federal Aviation Authority</td>
<td>Final</td>
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<td>FAA William J Hughes Technical Center</td>
<td>August 2011 to November 2013</td>
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<td>Atlantic City International Airport, NJ 08405</td>
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<th>15. Supplementary Notes</th>
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<tr>
<td>The Federal Aviation Administration William J. Hughes Technical Center Aviation Research Division COR was Charles Kilgore.</td>
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This research identifies ways to identify and mitigate obsolescence risks in avionics and to provide related aviation safety input to the FAA for the development of regulations, policy, guidance and training. Obsolescence and obsolescence management of avionics products is a technically challenging and costly financial problem with many adverse business impacts for both the avionics suppliers and their customers. Obsolescence is not unique to the aerospace industry but has special problems because of the typically long life cycle of aircraft and a requirement to comply with airworthiness regulations that makes continuous change complex and costly. Obsolescence is the inevitable consequence of the dependence of aerospace on a supply base whose major markets are outside of aerospace and whose technology lifecycles are much shorter than those other markets. Aerospace has a continual demand for technological progress in aircraft system capabilities and safety improvements, but on a much longer timescale than the technology turnover timescale of the supply base. Obsolescence is and always will be an inevitable occurrence and therefore the goal of obsolescence and lifecycle management is to minimize the recurring cost impacts and the disruption of supply to customers whilst maintaining continued airworthiness and regulatory compliance.

This report describes the current state of obsolescence management in the aerospace industry, the processes, standards and tools now being used and the underlying causes. The report addresses the identification, mitigation and avoidance of issues related to obsolescence in systems, software, and airborne electronic hardware development, the related design assurance and certification considerations and optimal methods for life cycle maintenance and technical refreshment. The report identifies known and emerging obstacles, problems, issues and gaps in existing standards and guidance, proposes standards and assurance techniques that may minimize the impact of obsolescence, and suggests how manufacturers can pro-actively plan and manage the life cycle of their products. The report describes the extant research on numerical methods for obsolescence risk assessment and related economic modeling and provides recommendations on further public guidance and standards that would assist industry and users in adapting to a dynamic environment. The report suggests some industry and regulatory practices that could promote best practice, reduce costs and inconvenience, and improve the product lifecycle planning process. Finally the report suggests some relevant research topics that are not well addressed presently and should be considered for future work.

The report suggests that the obsolescence problem cannot be solved only by engineering methods, but also requires pro-active measures and risk-awareness planning by both customers and suppliers. Obsolescence is complex mix of engineering, economic and business issues with many associated uncertainties. These uncertainties arise from the supply base and customer base, which requires marketing, engineering and economic planning and analysis using numerical risk assessment methods that measure uncertainty.

17. Key Words
Airborne electronic hardware, obsolescence, life cycle management, life cycle plan, avionics sustainment, COTS, intellectual property, continued airworthiness

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<tr>
<td>AEH</td>
<td>Airborne Electronic Hardware</td>
</tr>
<tr>
<td>AIRE</td>
<td>Atlantic Interoperability Initiative to Reduce Emissions</td>
</tr>
<tr>
<td>AMPL</td>
<td>Approved Manufacturers and Parts List</td>
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<tr>
<td>ANSP</td>
<td>Air Navigation Service Provider</td>
</tr>
<tr>
<td>AOG</td>
<td>Aircraft on Ground</td>
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<tr>
<td>APU</td>
<td>Auxiliary Power Unit</td>
</tr>
<tr>
<td>AQEC</td>
<td>Aerospace Qualified Electronic Components</td>
</tr>
<tr>
<td>ARMS</td>
<td>Advanced Reconfigurable Manufacturing for Semiconductors</td>
</tr>
<tr>
<td>ASIC</td>
<td>Application Specific Integrated Circuit</td>
</tr>
<tr>
<td>ATM</td>
<td>Air Traffic Management</td>
</tr>
<tr>
<td>B2B</td>
<td>Business to Business (e.g., for electronic data interchange)</td>
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<tr>
<td>BB</td>
<td>Bridge Buy</td>
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<tr>
<td>BFE</td>
<td>Buyer Furnished Equipment</td>
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<tr>
<td>BGA</td>
<td>Ball Grid Array (e.g., for an electronic component package)</td>
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<tr>
<td>BOM</td>
<td>Bill of Materials</td>
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<tr>
<td>BSI</td>
<td>British Standards Institute</td>
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<tr>
<td>CAST</td>
<td>Certification Authorities Software Team</td>
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<td>CCA</td>
<td>Circuit Card Assembly</td>
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<td>CFR</td>
<td>Code of Federal Regulations in the United States</td>
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<td>CIA</td>
<td>Change Impact Analysis</td>
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<td>CM</td>
<td>Configuration Management</td>
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<td>CMM</td>
<td>Capability Maturity Model</td>
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<td>COTS</td>
<td>Commercial off the Shelf</td>
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<td>COTS IP</td>
<td>Commercial off the Shelf Intellectual Property (i.e., Software HDL defining the function of a programmable logic device)</td>
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<td>CPDLC</td>
<td>Controller-Pilot Data Link Communication</td>
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<tr>
<td>DAH</td>
<td>Design Approval Holder</td>
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<tr>
<td>DAL</td>
<td>Design Assurance Level</td>
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<tr>
<td>DoD</td>
<td>Department of Defense (U.S.)</td>
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<tr>
<td>DLA</td>
<td>Defense Logistics Agency (U.S.)</td>
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<tr>
<td>DLS</td>
<td>Data Link Services</td>
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<tr>
<td>DMEA</td>
<td>Defense Micro-Electronics Activity (U.S.)</td>
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<td>DMSMS</td>
<td>Diminishing Manufacturing Sources and Material Shortages</td>
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<td>EASA</td>
<td>European Aviation Safety Authority</td>
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<td>ECMP</td>
<td>Electronic Components Management Plan</td>
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<td>ECS</td>
<td>Environmental Control System</td>
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<td>EHCOR</td>
<td>Electronic Hardware Center of Excellence</td>
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<td>EIA</td>
<td>Electronic Industries Association</td>
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<tr>
<td>EOL</td>
<td>End of Life</td>
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<td>EOS</td>
<td>End of Support</td>
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<tr>
<td>E.U.</td>
<td>European Union</td>
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<td>EUR</td>
<td>European Upper Flight Information Region</td>
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<td>FAA</td>
<td>Federal Aviation Authority</td>
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<tr>
<td>Acronym</td>
<td>Definition</td>
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<tr>
<td>FFPA</td>
<td>Functional Failure Path Analysis</td>
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<tr>
<td>FPGA</td>
<td>Field Programmable Gate Array</td>
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<td>GA</td>
<td>General Aviation</td>
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<tr>
<td>GIDEP</td>
<td>Government-Industry Data Exchange Program</td>
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<tr>
<td>HAL</td>
<td>Hardware Abstraction Layer</td>
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<tr>
<td>HCx</td>
<td>Hardware Control (e.g., for a Configuration Management Category)</td>
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<tr>
<td>HDL</td>
<td>Hardware Description Language, e.g. VHDL, Verilog</td>
</tr>
<tr>
<td>HLR</td>
<td>High Level Requirements</td>
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<tr>
<td>HMI</td>
<td>Hazardously Misleading Information</td>
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<tr>
<td>ICA</td>
<td>Instructions for Continued Airworthiness</td>
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<tr>
<td>ICAO</td>
<td>International Civil Aviation Organization</td>
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<tr>
<td>IEC</td>
<td>International ElectroTechnical Commission</td>
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<tr>
<td>IECQ</td>
<td>International ElectroTechnical Commission Quality (e.g., for an Assessment System For Electronic Components)</td>
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<tr>
<td>IFR</td>
<td>Instrument Flight Rules</td>
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<tr>
<td>IHS</td>
<td>Information Handling Services (a commercial component information provider)</td>
</tr>
<tr>
<td>IP</td>
<td>Intellectual Property implemented in HDL</td>
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<tr>
<td>ITRS</td>
<td>International Technology Roadmap for Semiconductors</td>
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<tr>
<td>LCC</td>
<td>Life Cycle Cost</td>
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<td>LOTE</td>
<td>Life of Type Evaluation</td>
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<tr>
<td>LLR</td>
<td>Low Level Requirements</td>
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<td>LRU</td>
<td>Line Replaceable Unit</td>
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<tr>
<td>LSD</td>
<td>Last Ship Date</td>
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<tr>
<td>LTB</td>
<td>Last Time Buy or Life Time Buy</td>
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<tr>
<td>MAB</td>
<td>Multi-Arm Bandit</td>
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<td>MOCA</td>
<td>Mitigation of Obsolescence Cost Analysis</td>
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<td>MRI</td>
<td>Material Risk Index</td>
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<td>MRO</td>
<td>Maintenance and Repair Organization</td>
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<tr>
<td>MSL</td>
<td>Moisture Sensitivity Level (of integrated circuits) or Mean Sea Level</td>
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<tr>
<td>NAS</td>
<td>National Airspace System</td>
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<td>NextGen</td>
<td>Next Generation Air Transportation System (U.S.)</td>
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<tr>
<td>NPRM</td>
<td>Notice of Proposed Rulemaking</td>
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<tr>
<td>NRE</td>
<td>Non-Recurring Engineering (Cost)</td>
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<tr>
<td>OEM</td>
<td>Original Equipment Manufacturer</td>
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<tr>
<td>PBL</td>
<td>Performance Based Logistics</td>
</tr>
<tr>
<td>PCN</td>
<td>Process or Product Change Notice</td>
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<tr>
<td>PD</td>
<td>Programmable Device</td>
</tr>
<tr>
<td>PLD</td>
<td>Programmable Logic Device (an electronic component whose function is defined by software HDL)</td>
</tr>
<tr>
<td>QA</td>
<td>Quality Assurance</td>
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<tr>
<td>QML</td>
<td>Qualified Manufacturer List (for military grade components)</td>
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<tr>
<td>RNAV</td>
<td>Area Navigation (originally random navigation)</td>
</tr>
<tr>
<td>RoHS</td>
<td>Restriction of (the Use of Certain) Hazardous Substances (in Electrical and Electronic Equipment)</td>
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<td>RTCA, Inc.</td>
<td>Radio Technical Commission for Aeronautics (former name)</td>
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<td>Abbreviation</td>
<td>Description</td>
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<td>SAC</td>
<td>Sn/Ag/Cu</td>
</tr>
<tr>
<td>SAE</td>
<td>Society of Automotive Engineers</td>
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<tr>
<td>SB</td>
<td>Service Bulletin</td>
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<tr>
<td>SBAS-LPV</td>
<td>Satellite Based Augmentation System - Localizer Performance with Vertical guidance</td>
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<tr>
<td>SESAR</td>
<td>Single European Sky ATM Research (E.U.)</td>
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<tr>
<td>SIL</td>
<td>Service Information Letter</td>
</tr>
<tr>
<td>SAIP</td>
<td>Single Aeronautical Information Publication</td>
</tr>
<tr>
<td>TC</td>
<td>Type Certificate</td>
</tr>
<tr>
<td>TOC</td>
<td>Total Ownership Cost</td>
</tr>
<tr>
<td>TSO</td>
<td>Technical Standard Order</td>
</tr>
<tr>
<td>UL</td>
<td>Underwriters Laboratory</td>
</tr>
<tr>
<td>U.S.</td>
<td>United States</td>
</tr>
<tr>
<td>VHDL</td>
<td>Very High Speed Integrated Circuit Hardware Description Language</td>
</tr>
<tr>
<td>YTEOL</td>
<td>Years to EOL</td>
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EXECUTIVE SUMMARY

The approach to the obsolescence and life cycle management problem should be multifaceted. It should contain both an engineering element and a business/cost element. There should be both a system-level approach with top-down analysis and a component-level approach with bottom-up analysis. Both of these should be supported by business and economic analyses of a range of alternative solutions with the objective of selecting a solution that is optimum. Module/subsystem-level design and analysis will work as a link between these two approaches. The analysis must include both technical and market forecasts from all sectors of the industry and the underlying supply chain. Any long-term planning for tackling obsolescence must recognize that ‘commercial off-the-shelf’ is now the normal business model for avionics systems in all markets, except space and specialized military, and the supply chain is no longer focused on aerospace as its principal market segment. Obsolescence management practices must recognize that technological advancement is a necessary and desirable feature of the aerospace business and cannot be sacrificed solely to maintain old systems.

The military specification system for components and the captive supply base that dominated aerospace for so many years is now redundant and ineffective for all practical purposes. The bulk of the supply chain has changed its focus and now focuses on serving other higher volume markets than aerospace. To minimize obsolescence resolution costs, the risk loss of configuration control, re-certification cost, customer dissatisfaction and other negative impacts of this revolutionary change, the avionics manufacturing industry is investing in obsolescence management infrastructure and practices, but these are largely reactive to notified obsolescence events. The next step on the obsolescence management capability ladder is to develop pro-active and predictive methods that take a holistic life cycle view in order to improve the product lifecycle planning capability.

The problem is highly complex and intimately tied to the business objectives of many stakeholders so there is no single answer and probably no simple answer. The solutions must include a comprehensive business, data and economics driven approach to selecting and managing parts and planning the life cycle of a product, recognition that some form of intra-industry and government-industry cooperation is necessary to promote best practices and complete acceptance of the transformation in engineering methods and product life cycle planning that this implies. Essentially the obsolescence and life cycle management problem is one of making use of available data and analytic tools to make predictions about future events and then pre-positioning activities that can respond quickly and at minimum cost to those events, if and when they occur.

Like any forecasting methodology, the pro-active, predictive approach does have its limitations. This approach cannot take into account future gluts and scarcities in the component market due to unforeseen market crises, natural disasters, disruptive technology innovations or mergers and acquisitions. Obsolescence can never be eliminated; it is a natural part of the continuing technology advancement needed to respond to customer and end user needs but manufacturers have much scope for improving the efficiency of their operations and providing a better experience for their customers.
1. INTRODUCTION

This research identifies ways to mitigate obsolescence-based risks and to provide related aviation safety input to the FAA. This report addresses the identification, mitigation and avoidance of issues related to obsolescence in systems, software, and airborne electronic hardware (AEH) development, design assurance, certification, life cycle maintenance and technical refreshment. This report also considers the ways in which avionics manufacturers can pro-actively manage the life cycle of their products. The outputs generated from this research will be used by the Federal Aviation Administration (FAA) as inputs for the development of FAA regulations, policy, guidance and training. This report details the investigations of the issues and causes of obsolescence in aircraft, systems, software and AEH, and the possible methods of mitigating these risks. This report identifies known and emerging obstacles, problems, issues and gaps in existing guidance and proposes standards and assurance techniques that may minimize the impact of obsolescence risks. This work was conducted in two phases.

Phase 1 focused on General Aviation (GA) aircraft. The objective of the first phase was to develop, execute, and complete a plan that addressed the following questions:

1. What are the causes and effects of GA parts obsolescence (e.g., changing operational environments, such as using GPS versus VOR, ADS-B versus Radar, NextGen, etc.)?
2. What issues (e.g., inability to address an unsafe condition during the Airworthiness Directive development process when engineering resources, development environments and tools, software and/or electronic parts are no longer available) and related costs (e.g., for new replacement parts) are incurred in aerospace applications due to GA parts obsolescence?
3. What trends in cost/savings can be achieved by resolving or improving the GA parts obsolescence issues, and what can practically be done (e.g., mandating that manufacturers make lifetime spares buys and/or provide free product recalls/updates; or else can the FAA take ownership of “orphaned” software or hardware)?
4. How does the evolution of electronic device interfaces and the associated standards result in GA parts obsolescence issues, including those associated with timing, power, thermal, environmental, and component/technology size characteristics?
5. How does the evolution of software standards, tools, languages, and on-aircraft applications affect GA parts obsolescence issues and cost?
6. How does the evolution of required skills and the perishable nature of these skills and changes in associated tools and processes result in GA parts obsolescence issues, including those associated with training, retraining, concurrent personnel requirements, personnel acquisition strategies and related GA parts obsolescence risks?
7. How does GA parts obsolescence in airborne systems, including displays, communications, local area networks (LANs), flight control, guidance and navigation, affect aircraft life cycle maintenance and requirements for technical refreshment?
8. How does the continuing trend toward larger, more complex systems on aircraft affect life cycle GA parts obsolescence at all aircraft levels from components to GA aircraft?
9. What approaches are being used by industry to minimize the impact of obsolescence on GA aircraft systems, software, and airborne electronic devices? What technologies can be used to mitigate the issues and costs of GA parts obsolescence (or should we limit technology or mandate strict standards for processors, languages, etc.)?

Phase 2 focused on the following questions:

1. Conduct literature searches, surveys, and/or other contact approaches to aid in identifying current and future GA parts obsolescence risks, mitigation practices, and related issue and cost information.
2. Identify current industry practices for GA parts obsolescence risk detection, mitigation, and metrics for the occurrence in avionics life cycle applications.
3. Identify known and emerging obstacles, problems, issues, and gaps in existing GA parts obsolescence guidance. Recommend mitigation techniques related to current and future GA parts obsolescence that equipment developers (component, subsystem, and system), government, and airlines face.
4. Determine existing R&D work in GA parts obsolescence related to these causes and issues, and propose approaches to mitigate these obstacles, problems, gaps, and issues.
5. Propose standards and assurance techniques that may minimize the impact of GA parts obsolescence risks.
6. Identify industry approaches that may require new or modified design assurance, certification, and/or airworthiness policies, standards, guidelines, and/or technologies to mitigate GA parts obsolescence risk.
2. LITERATURE SEARCH

Extended obsolescence and life cycle maintenance references are provided in APPENDIX C - LITERATURE SEARCH RESULTS with abstracts where available. They are listed in alphabetic order by first author. A separate reference list of those references listed in the text is also provided in section 13.

The references relate to hardware in the main, but a few do discuss software obsolescence. The literature is largely silent on obsolescence at the system level, e.g., that arising from changes in the operating environment or from regulatory action and on the problems associated with maintaining tools and platforms for long periods.

The majority of references are generated within the aerospace industry but some come from the nuclear/oil/gas/chemical industries that have many of the same concerns as aerospace, i.e., its’ regulated and safety critical nature.

The economic modeling references are generated predominantly by universities. They are a largely self-contained group and do not appear to have had significant take-up by industry since they are not cited in the other literature to any significant extent.

There are very few references that deal with the specifics of industry internal processes. We attribute that to a desire to protect proprietary information and competitive position.

The sources for these references fall into four main classes;

- Engineering journals and conference papers
- National and international standards and other guidance material e.g. military and regulatory documents
- MSc. and PhD. university theses and
- Economic modeling journals and conference papers
3. CURRENT INDUSTRY PRACTICE

Obsolescence Management is the sum of the methods, tools and processes for detecting and resolving obsolescence cases when they arise (the “reactive” process) and of the methods for taking active measures to avoid or reduce the impact of obsolescence (the “pro-active” process) [1]. Pro-active methods are, for example, identifying and ranking critical components according to their forecast risk of obsolescence prior to its occurrence or notification through predictive methods, quantitative methods for the selection of resolution options and imposing quantitative obsolescence risk assessment rules and restrictions within the design processes. Best-in-class industry maturity at present can best be described as being at the top end of reactive since many of the above techniques for pro-active obsolescence management are not available or are not widely implemented.

Recognition of obsolescence as a problem and the subsequent management of it has been an evolutionary process in most organizations. Consider the following hypothetical electronic systems manufacturing company. Initially, as a new company with a new product design, the company is unlikely to have any immediate experiences of component obsolescence and therefore will not develop formalized processes to deal with it until it becomes a regular occurrence. In the aviation industry, there is little or no public guidance to assist companies in setting the scope or content of obsolescence management processes. What usually develops first is a reactive process involving a few key players, such as Purchasing and Engineering. In a small firm with a limited product line, this may suffice indefinitely, but in companies having a broad and aging product line, priorities often begin to conflict and departmental boundaries reduce the level of communication. These factors, the cost of reactively resolving problems, the loss of revenues (through stalled production and sales) and downtime (through lack of available spares) eventually drive the firm to expand the scope of the reactive resolution process, often supplementing the process with an action-tracking tool that records the progress of resolution from notification to implementation. As obsolescence management in the organization matures, it will devote resources to the monitoring of the component lifecycle and use that information to take mitigating action prior to development of a critical situation (“pro-active” management). At this maturity level, the organization is willing to make tradeoffs such as devoting less engineering budget to new product development in favor of the rejuvenation of older products and deciding to stop production or support of aging products at the expense of potential revenue. The more time that is available in which to react to obsolescence, the better the solutions will be in terms of cost and ease of implementation. Ideally, an effective obsolescence management process addresses the product design, qualification, test and certification, supply chain, inventory and the manufacturing and repair implications of the solution and engages each affected business function at the optimum point. Nearly every business function from marketing to product support feels some impact from an obsolescence event.

The over-riding goal of obsolescence management is to minimize life cycle cost, i.e., enact the most cost-effective solution in terms of component cost, overhead, schedule impact, factory downtime labor consumption, support and operations cost that satisfies customer needs. It should be made clear that life cycle costs are borne by all the stakeholders, i.e., operators, aircraft and
avionics suppliers and so minimum life cycle cost can mean different things to different stakeholders.

In order to make these decisions, the participants must have access to all relevant information, e.g., the last time buy window, what second sources or equivalents can be found, what component stocks exist in distribution or can be sourced through brokers or aftermarket suppliers and what the demand forecast is, possibly across multiple programs. They must be granted the latitude to act decisively in the resolution of obsolescence cases. What must not be lost in the process is a focus on the needs of the customer.

Discontinuance by component manufacturers, resulting in obsolescence, is driven by several factors, for example, when a component manufacturer realizes that a given component or technology is no longer profitable, or is less profitable than others that could be produced using the same factory floor space and workforce or the manufacturing process is underutilized it may be declared obsolete. Alternatively, component manufacturers may discontinue a component because of market changes, legislation, corporate policy changes, product line rationalization after mergers and acquisitions and other external influences (see for example [2]).

In the semiconductor industry, there is an established process by which component manufacturers issue product change notices (PCNs). They communicate everything from minor manufacturing changes to component end-of-life (EOL) using the PCN vehicle. This practice builds an expectation that all component manufacturers should issue such notices with the same level of discipline, but the unfortunate truth is that the level of communication varies among manufacturers.

PCNs are distributed in text format by various means. These means, in general, require that avionics manufacturers manually review and process each one of them to determine if it is 1) relevant, and 2) if it is, open a case resolution record in their action tracking tool. Businesses-to-business (B2B) systems are not yet widely deployed to at least semi-automate PCN processing by the recipient.

For most component manufacturers, obsolescence is usually announced 6-12 months in advance of the last time buy (LTB) date, but can also occur instantaneously as the result of natural disasters or the demise of a key supplier of materials or technology and lesser notice periods are not uncommon. Note that LTB may mean either last time buy or lifetime buy. The distinction is one of context; a last time buy is enough to cover needs until a redesign removes the part from the product, a last time buy is enough last until the product is no longer produced or supported. A more formal definition of these terms is given in [3]. There may also be further 6-12 months later last ship date (LSD) by which the component manufacturer will have shipped all available product. A single PCN may include many different components from that manufacturer. A PCN may also announce that an EOL notice is withdrawn. PCNs may or may not identify alternative components. Automated manufacturing processes often need components to be supplied in packaging that is compatible with pick and place machines. This greatly improves productivity and reliability by avoiding manual handling. If the component manufacturer discontinues or changes the packaging, this may no longer be compatible, effectively making the component obsolete, even though it is still available.

An industry initiative called Aerospace Qualified Electronic Components (AQEC) has written a procurement specification for electronic components for avionics use [4]. One of the
requirements is that manufacturers supplying components to this specification should give 5 years notice of obsolescence, or if less provide information on how to obtain them from alternatives sources. This specification does not seem to have gained widespread adoption in the component supply industry since, there are only about 5 manufacturers using it and doing so on a limited basis.

Equipment manufacturers are increasingly finding that it is no longer economically feasible to purchase and operate the capital equipment and facilities required for the assembly of today’s high density interconnect and miniature electronic components, so they rely on contract manufacturers to provide circuit card assembly services. If the equipment manufacturer chooses to delegate component procurement to the subcontractor (as many do), then there is a risk that the equipment manufacturer may no longer receive critical PCNs associated with the components. Regardless of the components used or the product manufacturing process, it is incumbent on the equipment manufacturer to “detect” all obsolescence activities at the earliest possible time and direct them to the correct areas or individuals within their organization for prompt disposition.

Current industry practice covers a range of capability from being completely reactive to being to some degree pro-active and as mentioned above is largely a function of size and available resources, the larger companies being able to devote more resources to obsolescence management. A manufacturer that is only reactive is largely oblivious to the looming obsolescence problem until a realization is forced upon them by being unable to procure materials to fulfill additional production orders. Such manufacturers take no design measures to ease the resolution process or actively monitor the supply base for EOL announcements. As a consequence of this lack of preparedness, frequent production stoppages are experienced and customers are lost. At the other end of the spectrum, a manufacturer who is pro-active recognizes the inevitability of obsolescence and maintains an active surveillance of the supply base and all the components used and designs product to minimize the frequency, cost and time to make and field changes.

The U.S. Department of Defense (DoD) has developed a 4-level scale to characterize this maturity level [5] (reproduced below in Figure 1). The term diminishing manufacturing sources and material shortage (DMSMS) is the military term for obsolescence. This scale is analogous to the software capability maturity model (CMM) developed by Carnegie Mellon University and widely adopted by software writing organizations. This scale is useful for grading all types of aerospace manufacturers.

- **Level 1** - practices (largely reactive) sufficient to resolve known obsolescence problems.
- **Level 2** - practices (more proactive) sufficient to mitigate the risk of future obsolete items.
- **Level 3** - proactive practices sufficient to mitigate the risk of obsolescence when there is a high-probability/opportunity to enhance supportability or reduce total ownership cost (TOC) (these proactive activities may require additional program funding).
- **Level 4** - proactive practices implemented during the conceptual design of a new system and continued through its production and fielding.

In order to move through these maturity levels, the manufacturer must have an increasingly extensive set of mandatory internal process rules and documents that detail the process steps and
requirements along with mature quality assurance (QA) and oversight mechanisms and methods to assure that they are auditable and followed.

![Table 2. DMSMS Mitigation Practices for Each Intensity Level](image)

Current industry practice is very variable, but can best be described as reactive, i.e., Level 1-2 in the above scale though some avionics manufacturers can justifiably claim elements from Level 3. This is true for avionics manufacturers and more so for aircraft manufacturers. Information on the specific practices of manufacturers is generally subject to proprietary information restrictions or is not attributable. The summary here is what has been obtained through publically available information, e.g., papers, conferences and articles. In general, the processes described do not particularly distinguish GA obsolescence or treat it any differently than is done for other aircraft types. A questionnaire to assist manufacturers in a self-assessment of obsolescence management capability maturity is given in Appendix A - Obsolescence Capability Self-Assessment.

Airbus has introduced an supplement to its top level equipment requirements document ABD-100 [6] to outline the key characteristics and objectives of an obsolescence management processes that its suppliers should follow. The application of this supplement is dependent on specific contract language and to our knowledge has not yet been invoked on procurement contracts.

Boeing document D6-55583 [7] is the top level requirements document for a supplier Electronic Component Management Plan. This document is presently under revision to include obsolescence management.
In the military arena, Thompson-CSF describes a partially pro-active approach encompassing a preferred parts list, obsolescence recovery actions and life cycle analysis approaches to minimize future impact [8]. Raytheon has developed its own tool to track the life cycle status of the components in its approved parts database [9]. Alenia has reported on a pro-active obsolescence management process for military systems [10].

Honeywell implements a process which is documented through companywide procedures enforced by the QA system. This process is illustrated in Figure 2 below. Honeywell obtains notifications of impending obsolescence through various subscription services, operates an obsolescence management tracking tool to assign the resolution method implementation responsibilities and tracks each case through to completion. In addition, a tracking tool is used to manage and account for the various inventories of obsolete components located in multiple manufacturing sites, estimate and manage LTBs to control and allocate burn down of stocks on a global basis.

Figure 2 – Honeywell Obsolescence Management Process

3.1. RESPONSES TO OBsolescence

The types of obsolescence events mentioned above may occur at any time in the life cycle, or even before first production has begun. If any of these events occur, the avionics manufacturer has two basic options to choose from 1) declare the product is discontinued, i.e. end of life (EOL) either immediately or at some future date or 2) attempt some recovery action to extend the life. These options are not mutually exclusive; EOL can be postponed by a recovery action and the EOL decision can be revoked at any time in favor of rejuvenation.

An example of a product discontinuation notice is given in that [11] which arose from the area navigation (RNAV) rule change [12]. This may be either immediately or postponed to a defined future date by using up existing inventory or further postponed by the numerous recovery options
available (LTB, redesign etc.). This decision may be followed by a decision to develop a replacement product.

Depending on the type of initiating event, a recovery action may be required from either the product design authority or the manufacturing source to extend the product manufacturing life to an undefined future date when a further obsolescence event will again occur. The recovery action can be chosen from a number of options such as redesign or substitution. A full list with descriptions is given in two references [13, 14]. Recovery action may also be needed to stand-up the manufacturing process, manufacturing and design tools with their host platforms, so that the redesigned product can be designed, verified, re-certified, and produced.

These options need careful consideration of the business impacts and the use of decision support tools to arrive at a decision that is optimal in some sense. Many options may be satisfactory from a narrow technical viewpoint, but each option will carry with it a different cost. The decision is thus essentially to weigh the economics of the available options under conditions of considerable uncertainty. For example, uncertainty exists in the likelihood and timing of new airworthiness rules, legislation, planned product upgrades, new aircraft program launches and future obsolescence events.

Declaring EOL loses customer goodwill, driving them to competitors and loses future sales and support revenue. Recovery actions expense can range widely from minor as with substitutions, to major if the product needs to be re-certified or if substantial re-investment in design and manufacturing infrastructure is needed.

3.2. OBSOLESCENCE IN THE GENERAL AVIATION INDUSTRY

The nature and economics of the business and the relationship between the avionics supplier and the customer is significantly different between Part 23 and Part 25 avionics. There are a few large aircraft manufacturer customers for Part 25 avionics. Those customers in turn sell to operating cost conscious airlines, and thus both consider life cycle cost and negotiate long term support contracts. The general aviation (GA) market is much more fragmented with more Part 23 aircraft manufacturers and many more owner-operator customers.

There are 2 basic types of buyers of GA avionics; Part 23 aircraft manufacturers who in turn sell mainly to owner-operators and owner-operators who wish to add to the basic functionality provided as an original equipment manufacturer (OEM) fit. The GA avionics often have approved Technical Standards Order (TSO) alternatives from direct competitors that can easily be substituted. The GA avionics buyers are very price sensitive; for them, low initial cost to buy and install is a more important driver than long term life cycle cost. The downside of this fragmentation and the cost sensitivity of the business is that GA aircraft owner-operators can only hope for continued support and can only respond by selecting an alternative product if this is not forthcoming.

There is much that is common to obsolescence management between all aircraft types; however there are some features of the GA aircraft and avionics markets that are unique. Broadly, GA aircraft and the smaller business class aircraft (generally Part 23 aircraft) utilize federated architectures consisting of a broad array of panel and pedestal mounted instruments interconnected by a similarly broad array of interface and wiring standards. Newer GA aircraft
are tending to more integrated systems offerings with flat panel multi-purpose displays. This reduces weight and interfacing complexity at the cost of reduced flexibility to substitute competitor products.

Larger (Part 25) aircraft have integrated avionics suites that are certified for the particular type and are original equipment, though with some buyer furnished equipment (BFE) options. GA aircraft presently utilize mostly non-specific, off-the-shelf TSO products that are certified for a broad range of GA and low end business Part 23 aircraft. With the advent of integrated Part 23 avionics, similar unique certifications are beginning to apply to GA aircraft.

While none of this affects the overall procedures used by avionics manufacturers in managing obsolescence, it does affect the economics of the possible resolution solutions that could be adopted and hence the engineering and business solutions themselves. The underlying causes of obsolescence remain the same whatever the end market is. Obsolescence of avionics and aircraft is really no different to that of any other durable goods product; competitor products that have, for whatever reason, more buyer appeal that removes the market demand for the older ones, and buyers understand that as the natural order of things. It is the high capital cost and the expense of change or replacement that marks avionics as different, which behooves manufacturers to continually adjust offerings to remain competitive. This is the Nash equilibrium point in marketing theory. http://en.wikipedia.org/wiki/Nash_equilibrium.

Obsolescence is not simply a bottom-up supply chain issue causing lack of manufacturing and service capability. Obsolescence is also driven down from legislation, regulation and aircraft manufacturers and owner-operators choosing a competitor product. Avionics product obsolescence is either a consequence of the inability to produce for various reasons or a consequence of a lack of demand, again for various reasons. These consequences arise because of very different underlying causes.

3.3. MILITARY OBSOLESCENCE

Military programs suffer equally from obsolescence though the management approach is significantly different to that in commercial aviation companies. The source of the differences is in the contracting/commercial business model and thus the economics of the military business. The military program offices generally ‘own’ the obsolescence problem for the unique systems and vehicles they procure and deploy. Military programs must plan to set aside a sustainment funding pot for supplier contracts for the refreshment of their systems over the complete life cycle, often 25 years and up. The military usually does not have the option of substituting a competitor product. For these reasons, the military logistics organizations (e.g., Defense Logistics Agency (DLA), Defense Microelectronics Activity (DMEA) and various departments of the armed services) have invested heavily in obsolescence research [15, 16] and tools and sponsored the creation of several service-specific process guidelines (see section 3.10.3).

The military is beginning to address the uncertainties in the required logistics funding (of which obsolescence management is a part) by entering into Performance Based Logistics (PBL) contracts with platform and system suppliers. In PBL, the contractor assumes all the logistics risk and charges it back at a contractually agreed rate. Similar arrangements in the commercial market are called ‘power-by-the-hour’ support contracts, initially conceived for Part 25 aircraft engines,
but now also being used by fleet operators (mostly airlines) for all types of equipment. The supplier assumes all the logistics risk and charges it back to the customer at an agreed rate based on operating hours. Both of these approaches require that the supplier is able to price their overall risk at a profitable level, a somewhat difficult task given all the uncertainties that logistics entails.

This same kind of contractual approach could be applied in the GA market for all kinds of products, but has not been to our knowledge, probably because GA aircraft are not typically part of a large fleet with centralized maintenance. The same uncertainties in risk assessment and contract pricing models would apply. This is an economics research area that could leverage actuarial methods and models used in the financial services and insurance industries that have been pricing risk for many years.

3.4. THE CAUSES OF OBSOLESCENCE

The causes of obsolescence may be summarized in Figure 3 below. There are two major sources of obsolescence issues 1) supply side, bottom-up supply chain caused and 2) demand side, top-down airspace management and regulation caused. Legislative action in the U.S. or abroad has the potential for either of these which is discussed in section 3.5.1. An obsolescence issue may arise because of product deletions in the supply chain of components, sub-assemblies tools or platforms, legislation or standards and airworthiness rule changes. The fundamental cause of the supply chain issue is that the aviation industry is not vertically integrated and depends on an extensive commercial off-the-shelf (COTS) supply base so there is a gross technology life cycle mismatch between the supply base and avionics manufacturing. The components supply chain is on a commercially focused technology cycle of a few years (2-7 years) whereas the life cycle of aircraft and avionics is many times this, typically 20 years or more. A fuller discussion of the underlying causes is given in many sources e.g., [14, 17]. The underlying cause of legislation induced obsolescence is increasing societal demands for a less polluted environment. Regulatory induced obsolescence occurs along with the evolution of airspace management and their associated air and ground systems in response to increasing public demand for more capacity, fewer delays and continuous improvement of the safety record.
This diagram illustrates that there are many stakeholders causing or affected by obsolescence. The avionics industry depends primarily on a commercial supply base for components and for most of the supporting tools used in design and manufacturing and often uses contracted out manufacturing and repair process capability, yet is also driven by regulations and legislation.

3.5. OBSOLESCENCE OF SYSTEMS

Systems obsolescence refers to an entire line replaceable unit (LRU) being declared that it has reached EOL by its manufacturer because the manufacturer has taken a business decision that recovery action is either not technically feasible or is not economic from considerations of investment return or simply that the demand has declined to such an extent that the manufacturer decides that continued production is not economic. Demand decline can occur when a competitor product appears or the manufacturer introduces a new or upgraded product to maintain market share or occupy a new market niche. As with any product, the market ensures that supply and demand remain in balance.

Such cases may arise from either from top-down causes like legislative or regulatory action (e.g., lead free legislation and revised RNAV rules), from bottom-up causes like actions taken in the supply chain or lost manufacturing capability or from considerations of competitive position in the market.

Avionics suppliers generally notify customers and end users that a product has reached EOL by means of Service Information Letters (SIL) or Service Bulletins (SB). An example of a SIL arising from an RNAV regulatory rule change is given in section 3.5.2. This SIL was dated 14th
April 2010 and the last order date was 30th April 2010. In contrast to the obsolescence of components, continued support for repair is sometimes offered indefinitely which is not the case for components since these are non-repairable. Even so, continued support eventually becomes impossible.

There are presently no recommended or enforceable requirements on avionics or aircraft manufacturers to offer guarantees of continued support after product discontinuance has been declared or for minimum notice periods. This is an area where additional regulation could be applied, but the downside would be that manufacturers would have to price that additional risk into their products.

3.5.1. **Legislation Induced Obsolescence**

Legislation has the potential of drive either the demand side or the supply side. The major effect we have seen from legislation is on the supply side from lead free legislation. Lead-free legislation is causing the supply of non-compliant components to dry-up as the component suppliers transition their lines and obsolete the old components. The European Union (EU) lead-free legislation, Directive 2002/95/EC on the Restriction of Use of Certain Hazardous Substances in Electrical and Electronic Equipment (known as the “RoHS Directive” or “RoHS I”) restricts the use of lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyls and polybrominated diphenylethers in certain electrical and electronic equipment since 1st July 2006.

This legislation has caused component manufacturers to obsolete large numbers of components and to replace them with lead-free versions. These use a lead-free lead frame or contact plating material, for example pure tin or palladium. They may also make modifications to the packaging to allow for of the higher reflow temperature required by Sn/Ag/Cu (SAC) solders or to maintain the moisture sensitivity level (MSL) rating [18]. The MSL specifies time available between removing components from their dry-shipping containers and completion of reflow soldering. The MSL rating reduction arises because the higher SAC peak reflow temperature leads to a greater susceptibility to package and die damage (e.g., cracking, delamination) caused by explosive vaporization of absorbed moisture trapped in internal voids.

Some types of lead-free components (e.g., through hole and surface mount) can be successfully soldered using a Sn/Pb solder process and hence the lead-free alternates can readily be substituted. This is not true for lead-free ball grid array (BGA) packages. The BGA packages use SAC solder balls that are incompatible with a Sn/Pb solder process because the SAC solder has a higher melting point that does not adequately reflow at the lower temperature of a Sn/Pb solder process. Techniques for reliably soldering lead-free BGAs using Sn/Pb solder pastes are still an active research area.

The advent of tin finishes as a response to the lead free legislation has brought up tin whiskers as a new failure mechanism that was not present with the older components or soldering processes [19]. This is another assembly process aspect that avionics manufacturing companies need to address when substituting obsolete components.

Lead-free legislation may also make it an offense to continue to sell, lease or repair the product in its present configuration if it cannot be certified to RoHS. The avionics manufacturer must then discontinue the product or re-invest in the re-design of the product and the assembly process and
can no longer provide support or repair for fielded products. For now, various exemptions in the European legislation and the present lack of United States (U.S.) legislation make this a future risk, rather than a present risk. Even though similar legislation has not been passed in the U.S., the globalization of the component supply base and contract manufacturing services means that U.S. avionics manufacturers are nonetheless affected. There is a large body of literature on the manufacturing implications for the interested reader.

3.5.2. Regulation and Mandate Induced Obsolescence

Within the U.S. legislative framework, CFR Title 14 and its various sub-parts govern aviation. Regulatory bodies such as the FAA and the European Aviation Safety Agency (EASA) are charged with creating and implementing binding rules, requirements and standards to assure aircraft and operator airworthiness and safety. The implementing rules, requirements and guidance are subject to change and so an existing in-service product may no longer meet the new airworthiness requirements. New certification rules, airworthiness regulations and airspace operations rules may impose such a major restriction on usability or ban use entirely so that demand disappears. An example is the revised RNAV rules as in reference [12] which placed operational restrictions on the use of a particular piece of GA navigation avionics. In this case, the product remained manufacturable, but the manufacturer elected to declare that it had reached EOL since the extent of the change necessary to overcome the restrictions was deemed not economic [11]. The manufacturer elected to continue to provide support and repair for in-service products, but was under no obligation to do so.

Legislative and regulatory actions (e.g., mandates, advisory circulars, and airworthiness directives) are potential sources of both system functional (demand side) obsolescence and component (supply side) obsolescence. Where an LRU is not compliant with a new rule or mandate, it cannot continue to be used or is subject to significant usage restrictions. Rules and mandates are regulatory instruments that impose new operational requirements or procedures. They may therefore impose new functional requirements on aircraft, engines and avionics, GA and non-GA that cannot be accommodated by upgrades, but require new equipment and installation. Examples of mandate-induced obsolescence are found in references [11, 20]. It is therefore important to track such legislation and mandates, since the changes required by these are ideal opportunities to reset the obsolescence clock by introducing obsolescence resolutions that have been accommodated by LTBs.

Rules and mandates are the main governmental mechanisms for introducing air traffic control (ATC) system improvements, and are therefore a continuing factor that imposes continual upgrade requirements on aircraft operators. We may expect to see a continuing series of these as the U.S. National Airspace System (NAS) and European Union (E.U.) ATC System is upgraded through the U.S. Next Generation Air Transportation System (NextGen) and E.U. Single European Sky Air Traffic Management (ATM) Research (SESAR) [21-23] programs, respectively. These upgrades are typically major so that equipment upgrade through modification is often not economically or technically feasible. The existing installed equipment is rendered functionally obsolete and there is a complete collapse of the market for that obsolete equipment. A study of the NextGen equipage costs for the ground and air segments is given in references
3.5.2.1. **Avionics**

In early 2004, the E.U. SESAR Committee agreed on a first set of mandates to be given to EUROCONTROL [26]. This set covered flexible use of airspace, airspace design, functional airspace blocks and charging scheme. The Director General requested the Provisional Council and the Permanent Commission of EUROCONTROL to appoint a general delegation to accept and execute the mandates sent by the European Commission. Later in 2004, a second set of three mandates dealing with interoperability (Initial Flight Plan, Flight Message Transfer Protocol, and Coordination and transfer of flights between air traffic services) was examined by the SESAR Committee and sent to EUROCONTROL by the European Commission with expected work completion in 2005. In 2005, seven new mandates were received and accepted by EUROCONTROL. Four relate to the following areas:

- Air Traffic Flow Management
- European Upper Flight Information Region (EUIR)
- Single Aeronautical Information Publication (SAIP) for EUIR
- Performance Review

The other five are an extension of the scope of regulatory activities on interoperability:

- Mode S Interrogator Code Allocation
- Surveillance performance and interoperability requirements
- Aeronautical Data Integrity
- Data Link Services
- Air-Ground Voice Channel Spacing

A draft rule for E.U. Link 2000+ Data link services (DLS) mandate [27] has been issued in support of controller-pilot data link communications (CPDLC) requirements in E.U. airspace. This rule mandates CPDLC on new aircraft out of the factory from Jan. 1, 2011 and retrofits by February 15, 2015. The mandate impacts all aircraft operating under instrument flight rules (IFR) above Flight Level 285. Compliance will involve a data link utilizing a very high frequency (VHF) radio that will enable transmission of commands via a textual system [28].

In the U.S., the FAA has published new rules contained in 14 CFR §92.225 [29] and §91.227 [30] that mandate that by January 1, 2020, any aircraft operating in Class B or Class C airspace, or above 10,000 feet mean sea level (MSL), will be required to have Automatic Dependent Surveillance-Broadcast (ADS-B) Out equipment onboard. The FAA issued AC 90-114 requiring ADS-B OUT capability on December 2011 [31]. Advisory Circular AC 20-165 issued in May 2010 provides guidance for the installation and airworthiness approval of ADS-B OUT systems in aircraft. The FAA has not yet issued any rule requiring ADS-B IN operations so operators are free to decide if or when to equip themselves for it. The ADS-B rule mandates ADS-B Out avionics performance when operating within designated affected airspace and gives aircraft owners approximately 10 years to equip their aircraft. ADS-B is a fundamental part of the agency’s planned NextGen ATC system, and ADS-B OUT is projected to eventually supersede
the use of primary radar systems for tracking aircraft movements. The FAA has published a Final Rule in the Federal Register [32].

Other upcoming mandates include Satellite Based Augmentation System - Localizer Performance with Vertical guidance (SBAS-LPV) and required navigation performance. All of these mandates will require specific avionics capabilities and will render non-compliant avionics obsolete where they are unable to be suitably upgraded and operated in the affected airspace.

3.5.2.2. Engine Equipment

Engine mounted electronics is subject to the same obsolescence risks as other types of equipment and therefore the same approaches to obsolescence management are applicable. There is one additional functional obsolescence concern for engines arising from current and proposed legislative action, primarily in the E.U., around ‘green’ initiatives to reduce the environmental pollution caused by engines emissions, either by efficiency improvements or by the use of new fuels.

The E.U. has implemented new legislation for industrial emissions of all kinds and has recently included aircraft engines. The legislation was first enacted in 2006. It is a ‘cap and trade’ scheme that imposes fines on operators who exceed their allowances. The E.U. initially included aircraft using E.U. airspace in the emissions trading scheme, commencing in 2012. In response to intensive foreign lobbying, the E.U. suspended the application of these rules for aircraft operating to or from non-E.U. airports until at least after the November 2013 International Civil Aviation Organization (ICAO) meeting in the hope of negotiating an international agreement [33].

These regulations have the potential to drive obsolescence of engines in service today and hence the associated control electronics. The implications are not limited to engine electronics; ancillary functions such as auxiliary power unit (APU), environmental control system (ECS), thrust reversers and electrical power management could also be driven towards functional obsolescence.

Work is underway by the SESAR/FAA Joint Undertaking group Atlantic Interoperability Initiative to Reduce Emissions (AIRE) [34]. They are running numerous test flights to experiment with methods to reduce emissions using new operating procedures with currently installed engines and equipment. Any new procedures arising from this work may lead to new airspace rules and then to updated functional requirements for an extensive range of avionics equipment, such as flight management, cockpit displays, autothrottle, and flight guidance. The timescale for resulting new rules, if any, is not yet known, presenting a set of risks that cannot presently be reasonably assessed or mitigated.

3.6. OBSOLESCENCE OF SYSTEM SOFTWARE

While in-house software (and the hardware description language (HDL) used in application specific integrated circuits (ASICs) and field programmable gate arrays (FPGAs)) is perpetual and cannot go obsolete in the way hardware does, software and HDL can nevertheless become effectively obsolete because the requirements or airworthiness rules and standards change and can no longer perform its new intended function [35]. Processors, FPGAs and other execution
hardware can also become obsolete or unable to accommodate new software required to meet the new requirements because of throughput, memory space, interface protocol or other considerations. Some avionics items include a navigation database that is supplied by a third party. These have historically grown in size over time so that eventually the available storage becomes insufficient to accommodate it and the system cannot remain compliant with the required data standard unless additional storage can be added. Such a case arose with the Universal Avionics UNS-1 Flight Management System [20]. The decision was to EOL the product, also citing parts obsolescence as a contributing factor. Software obsolescence is a collateral consequence of all these other types of events. The same is true for COTS libraries compiled into software and HDL, provided perpetual licenses are purchased.

Frequently the only option available is the recompilation and re-certification of the system for a new underlying architecture. The use of high level languages is near universal, but the application of portable coding standards during initial software development can very much ease this transition [36, 37] by avoiding hardware specific constructs such as assembly level inserts or certain kinds of code optimizations that leverage architectural features of the underlying hardware.

One other option to preserve the usability of the original software in binary image form is the reconstruction of the obsolete processor in a custom integrated circuit, see section 3.10.2. This option may reduce the cost of re-certification since much of the existing DO-178B [38] certification artifacts can be reused.

3.7. OBSOLESCENCE OF HARDWARE COMPONENTS

Electronic components typically follow a life cycle curve where shipments increase from zero, plateau for a time, and then decline to zero. This curve is typically approximated by the Normal curve (after it’s functional similarity to the Normal probability distribution curve) and is described in [39, 40]. It is reproduced below in Figure 4.
Product deletion decisions made by the component suppliers may arise from commercial or legislative reasons. This results in supplies beyond LTB of some of the component parts of the product as listed on the bill of materials (BOM) being unobtainable, i.e., sub-assemblies and components. Product obsolescence then occurs when the avionics manufacturers stock, or his contract assemblers stock, of one or more of these obsolete parts has been exhausted. In this event, new copies cannot be manufactured and existing fielded copies cannot be repaired. Since a single component may be used in many products, this event may render several products obsolete simultaneously.

This is not confined only to components. Some avionics manufacturers have adopted modular design as an obsolescence mitigation strategy by buying complete sub-assemblies such as COTS electronic cards and power supplies. Unfortunately, this strategy is only partially effective since the manufacturers of these sub-assemblies are subject to the same obsolescence forces that result in the same obsolescence problems and alternate sources may not exist.

3.8. OBSOLESCENCE OF TOOLS AND PLATFORMS

The development and modification of system software, ASICs and FPGAs depends on the use of a wide variety of COTS tools and platforms such as compilers and libraries and platforms such as PCs and other types of workstations. These may have been scrapped or are no longer available or supported or have undergone changes that render them no longer qualified per the requirements of DO-254 [41] and DO-178B [38]. The lack of tool qualification then makes the tool unusable for the re-certification of a modified system. This requires a response, either tool re-qualification
or a new tool or product discontinuance. Some tools are in-house tools and thus largely immune to obsolescence, but some are often COTS items that can be removed from the market at any time or support can be terminated. Execution platforms carry no guarantee of continued availability beyond the warranty period.

Avionics manufacturers recognize these problems and some have developed processes to archive tools software and the supporting platforms until the all products they support are discontinued, i.e., will not require any further design changes. Since production may be for many years until redesign or discontinuance, this is a difficult and expensive task and subject to much uncertainty about when the required the tools and platforms will be needed or even if they will still work. Some avionics manufacturers use virtual machine software tools to emulate obsolete platforms on current workstations, similar to the emulation of Intel x86 microprocessor architectures on Mac platforms and vice versa so that the original tools can still be used. To our knowledge there is no established guidance or requirements on avionics manufacturers to implement these kinds software and HDL obsolescence protection measures, it is purely a manufacturer specific commercial judgment based on economic realities and a desire to support, so far as is reasonable, existing product and customers.

There are no known standards or channels for notification of obsolescence in COTS tools and platforms. The unavailability of these original tools and standing-up replacements then become a cost factor in deciding the resolution option to be pursued.

3.9. OBsolescence of Manufacturing and Repair Facilities

The manufacturing and repair capability may become defunct or unusable, e.g., because of RoHS legislation. The necessary manufacturing process materials may be obsolete (e.g., chemicals, solder) or the manufacturing equipment (e.g., reflow soldering, circuit card assembly (CCA) and LRU test) equipment may become non-functional and beyond economic repair. The product can then no longer be manufactured or repaired. Many avionics suppliers now contract-out manufacturing and also the procurement of the necessary components. Equipment manufacturers (and their subcontract manufacturers) have many customers and limited resources, so they may make a business decision that maintaining a capability for a low volume product is not viable or may wish to re-allocate those facilities to higher volume products. The avionics supplier then has to stand-up a new assembler or discontinue the product.

3.10. OBsolescence Management Tools and Resources

The existence of the problem of obsolescence has been well known for many years, it is a natural consequence of technological advancement. An industry has grown up to supply the demand for both obsolete components and for component life cycle information. The customers for these tools are mainly the avionics manufacturing companies and military program offices. The major ones are listed below in this section. These tools and services are only for components; no similar services are known that focus on tools or systems obsolescence.
3.10.1. **Component Obsolescence Information Services**

A number of commercial services are available on a subscription basis, which notify component users of impending obsolescence. The standard method by which component suppliers notify their customers that they intend to discontinue a component is via the product change notice (PCN), the same vehicle by which they notify customers that some aspect of the component design or manufacturing is changing, such as a change of manufacturing location, a lead frame plating material change, or a die shrink. These notices generally give users 6-12 months’ notice, so that they have the opportunity to make an LTB. Since the majority of avionics manufacturers buy components through authorized distributors, the component manufacturer may not be aware of all the customers, and therefore makes these notices available through their authorized distributors and third party PCN distribution services.

A commonly utilized service for PCN distribution is PCNAalert (owned by Information Handling Services (IHS), [http://www.pcnalert.com](http://www.pcnalert.com)) which provides a website and daily e-mail messages to registered users. Equipment suppliers are also able to access PCNs and check the current status of components through subscription BOM analysis tools such as:

- CAPSExpert (IHS) ([http://www.partminer.com](http://www.partminer.com))
- 4D-Online Parts Universe (IHS) ([http://www.4donline.com](http://www.4donline.com))
- TacTrac Comet (IHS) ([http://www.tactrac.com/comet](http://www.tactrac.com/comet))
- Silicon Expert ([http://www.siliconexpert.com](http://www.siliconexpert.com))
- QSTAR (QTEC Solutions) ([http://www.qtec.us](http://www.qtec.us))
- Total Parts Plus ([http://home.totalpartsplus.com](http://home.totalpartsplus.com))

IHS also provides a subscription component information service (CIS) data feed so that avionics manufacturers can populate their own database tools. The U.S. military operates the Government Industry Data Exchange Program ([http://www.gidep.org](http://www.gidep.org)), which is a collaborative organization that provides numerous resources to identify obsolete and soon-to-be obsolete components.

All of these services provide current status and some measure of future obsolescence risk by means of a life cycle coding scheme according to the scale of Figure 4 and a forecasted years to end of life (YTEOL). The algorithms that they use for these predictions are usually proprietary and therefore concealed. The typical scale is from 1-6 where 1 is introduction and 6 is obsolete (see reference [14] Chapter 1 and references [42] and [39]). FreeScale (a semiconductor manufacturer) uses an extended EIA scale (0-8) as shown in Figure 5 ([http://www.freescale.com/webapp/sps/site/eialink.jsp](http://www.freescale.com/webapp/sps/site/eialink.jsp)). Such services are primarily reactive tools, i.e., they provide warning that an obsolescence problem is coming in the short term, but are not presently capable of giving a forecast that is suitable for product life cycle planning decisions. For this purpose, a predicted obsolescence date with some confidence interval around it is needed (see section 4.1).
<table>
<thead>
<tr>
<th>Life Cycle Stage Codes</th>
<th>Life Cycle Description</th>
<th>Displayed Web Status</th>
<th>Meaning</th>
<th>Additional Information</th>
<th>Notes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>PRODUCT INTRODUCTION PENDING</td>
<td>Introduction Pending</td>
<td>Product is in planning or early design stage. Samples may or may not exist. Specification changes can occur and planned introduction dates may be delayed.</td>
<td>No orders or product shipments permitted.</td>
<td>This life cycle stage is not part of EIA-724 (Product Life Cycle Data Model).</td>
</tr>
<tr>
<td>1</td>
<td>PRODUCT NEWLY INTRO/D/RAMP-UP</td>
<td>Beginning to ramp up production. Can supply limited quantities.</td>
<td>Orders and shipments permitted.</td>
<td>Note: See EIA-724 (Product Life Cycle Data Model) for more information.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>PRODUCT RAPID GROWTH</td>
<td>Active</td>
<td>Product in rapid growth phase. Manufacturing capacity is being added.</td>
<td>Orders and shipments permitted.</td>
<td>Note: See EIA-724 (Product Life Cycle Data Model) for more information.</td>
</tr>
<tr>
<td>3</td>
<td>PRODUCT STABLE GROWTH/MATURITY</td>
<td>Product growth stabilizes and peaks. Product quality is very high.</td>
<td>Orders and shipments permitted. Product is highly recommended for use in new designs.</td>
<td>Note: See EIA-724 (Product Life Cycle Data Model) for more information.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>PRODUCT MATURITY/SATURATION</td>
<td>Sales and capacity have leveled out.</td>
<td>Orders and shipments permitted.</td>
<td>Note: See EIA-724 (Product Life Cycle Data Model) for more information.</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>NOT RECOMMENDED (DECLINING)</td>
<td>Not Recommended for New Design</td>
<td>Capacity beginning to decline. Product not recommended for new designs.</td>
<td>Orders and shipments permitted.</td>
<td>Note: See EIA-724 (Product Life Cycle Data Model) for more information.</td>
</tr>
<tr>
<td>6</td>
<td>PROD PHASE OUT/SEE LAST ORD DT</td>
<td>End of Life</td>
<td>Capacity declining rapidly. Formal discontinuance notice may be issued.</td>
<td>Limitations on shipments can occur, but orders are pressed toward final and last buy. Product should not be considered for new designs.</td>
<td>Note: See EIA-724 (Product Life Cycle Data Model) for more information.</td>
</tr>
<tr>
<td>7</td>
<td>PRODUCT LAST SHIPMENTS</td>
<td>No Longer Manufactured</td>
<td>Product in final stage of shipments after a formal Life Time Buy notice or product cancellation.</td>
<td>Shipments made to existing orders. Manufacturing capacity limitations may exist. New orders are limited to existing or residual inventory.</td>
<td>This life cycle stage is not part of EIA-724 (Product Life Cycle Data Model).</td>
</tr>
<tr>
<td>8</td>
<td>REMOVED FROM ACTIVE PORTFOLIO</td>
<td></td>
<td>Product is considered no longer available. Inventory is removed. All supporting hardware, software, and documentation for the product are removed.</td>
<td>No new orders, no shipments, and no inventory exist.</td>
<td>This life cycle stage is not part of EIA-724 (Product Life Cycle Data Model).</td>
</tr>
</tbody>
</table>

Figure 5 – FreeScale Life Cycle Coding Scheme [43]
3.10.2. Obsolete Component Sources

Manufacturers try to recover from obsolescence by taking the least cost solution. Generally this turns out to be alternate part substitution or LTB. These do not require re-design, do not affect software and require minimal re-qualification. Forecasting LTB quantities has inherent difficulties and limitations. When an LTB turns out later to have been too little and when the LTB option is no longer available, securing alternate components is needed. In this event, there may still be some options available before resorting to more expensive measures. Manufacturers sometimes transfer all the intellectual property and tooling of an obsolete component to a so-called aftermarket or sunset supplier with which they have an agreement. Examples of sunset suppliers include Rochester Electronics (http://www.rocelec.com) and Lansdale Electronics (http://www.lansdale.com). These companies are able to re-manufacture small batches of components for which they have the rights. The DMEA established the Advanced Reconfigurable Manufacturing for Semiconductors program (ARMS) (http://www.dmea.osd.mil/arms.html) facility to take over obsolete component manufacturing information and continue production through a public/private partnership with commercial foundries. The price is usually many times that of the original and is subject high minimum order quantity, but nonetheless these companies satisfy a market need, usually of interest only to military customers. Typically only low technology components are available this way, since they do not have the lines for submicron technology components.

A second approach is through reverse engineering and emulation. One company that specializes in this is the Generalized Emulation of Microcircuits (GEM) program operated by SRI (http://www.sarnoff.com/products/generalized-emulation-microcircuits), originally a spin-off from the DMEA [44]. Again this technique is largely for low technology components and mostly of interest to military customers since their product is qualified manufacturer list (QML) qualified. Some success has been reported on the use of emulation to execute the unchanged binary image on new hardware [45] and processors can be emulated using FPGAs, so maintaining the original code base [46-50].

There are some companies that specialize in reproducing cycle-accurate, binary reusable, obsolete processors e.g., Innovasic (http://www.innovasic.com). All of these emulation techniques incur substantial re-engineering cost and must be compared with the re-design option to establish both technical and economic feasibility.

A network of component brokers exists, mostly in China. They speculate by buying up stocks of soon to be obsolete components in the hope of selling them at a high profit. Equipment company buyers often trawl these brokers for additional parts when the LTB that was made on the original obsolescence has proved to be insufficient. This strategy is not without risk, since the provenance and location of origin and quality is often lacking, and many have been found to be used or counterfeit [51-55].

Although LTB or finding alternate sources often does turn out to be the lowest cost solution, it is difficult to be sure about that without at least some rudimentary cost analysis of the various options. Equipment suppliers must further bear in mind that obsolescence will eventually recur and necessitate further recovery.
3.10.3. Standards, Guides and Other Documents

The military (primarily within the U.S.) has sponsored the development of numerous guides on military obsolescence management [5, 56-65] and sponsored some study programs [15, 16, 66, 67]. Some more commercially relevant material has been developed by ARINC [68] (for aerospace, somewhat dated) and the British Standards Institute (BSI) [69-71].

The semiconductor trade body JEDEC provides a guidance document [72] that requires component suppliers to provide at least 6 months’ notice during which a LTB order can be placed and at least 12 months’ notice for final shipments. This is generally adhered to by the component suppliers, but it is not binding on them. There are no service information letter (SIL) or service bulletin (SB) guidelines known that indicate periods similar to those provided by component manufacturers.

The International Electrotechnical Commission (IEC) TC56 committee has published a guide to obsolescence management [73]. A revision of the IEC Electronics Component Management Plan (ECMP) [74] is presently in draft form being prepared by IEC TC107 (Process Management for Avionics). This draft currently provides a high-level skeleton for an obsolescence management plan that could form the basis for an obsolescence management section in a manufacturer’s component management plan [75]. The skeleton covers awareness (reactive), pro-active measures, and reporting requirements. The document recommends that all components be rated for risk of obsolescence that outlines factors for consideration, but does not provide a detailed methodology.

To our knowledge, this document has not yet been specified as applicable in any procurement contracts. It is probable that this ECMP document will eventually be incorporated by reference in Airbus and Boeing subcontractor general requirements documents and will appear in procurement contracts. TechAmerica (previously GEIA) has published a similar guide to the contents of an military DMSMS management plan [3].

The FAA has published Certification Authorities Software Team (CAST) Position Paper 3 [76], which discusses software certification considerations when equipment is modified to resolve an obsolescence issue. This document is concerned with ensuring that if software is affected by the change, then appropriate steps are taken to maintain the previously developed software design assurance. CAST papers do not set out any regulatory position and are only to be regarded as indicative of FAA thinking, which may inform future guidance and policy.
4. KNOWN AND EMERGING ISSUES

4.1. COMPONENTS OBsolescence Forecasting

Obsolescence forecasting is currently reactive, i.e., based on the receipt of a PCN. A PCN is the usual vehicle to notify the customer that a component has been declared obsolete. A PCN typically provides 6-12 months’ warning that a component is going obsolete with a further 6-12 months’ available for placing LTB orders. Component information services such as Information Handling Services’ (IHS) Parts Universe and PartMiner CAPS (now acquired by IHS) products provide lifecycle codes, but industry experience with these is that a life cycle code is not sufficient for decision making, since it cannot be used to predict an obsolescence date. Prediction of an obsolescence date requires that the shape of the curve (see Figure 4) and at least two points on it be known and that cannot be deduced from a life cycle code. Life cycle codes are self-reported by the component manufacturers and rarely show ‘decline’ until just before EOL is declared. This situation is to be expected, since a decline status declaration is a self-fulfilling prophecy that results in market collapse. Parts Universe also reports a YTEOL value, but the algorithmic basis of this forecast is proprietary to IHS. The YTEOL could possibly form the basis of a forecasting algorithm, if the date that a part was first introduced to the market could also be known. At present introduction date is not recorded in the available tools.

At present, techniques for projecting the component life cycle to future dates are not widely available. Some researchers report the outlines of possible methods [77-80], but these cannot yet be considered as mature and much further work needs to be done. This lack of forecasting ability is the basic cause of obsolescence management being presently reactive, i.e., reactive to EOL information provided by component manufacturers through PCNs. Significant steps forward need to made to progress to pro-active obsolescence management. Pro-active obsolescence management activities depend on the availability of component obsolescence forecasts.

4.1.1. Predictions Uncertainty

This report has previously discussed techniques to manage obsolescence based on quantitative economic modeling methods. All of these methods depend fundamentally on forecasts of future obsolescence events coming up from the components supply chain and forecasts of product demand. Demand forecasts come from the customer base via the avionics supplier marketing function and are ultimately derived from sales forecasts provided by aircraft manufacturers.

Commercial data services, such as IHS, offer a forecast value of years to end of life (YTEOL) for expected component obsolescence. The IHS values are based on proprietary data and algorithms. They do not provide any substantiation or confidence level.

Research is necessary to develop open, data driven predictive obsolescence modeling methods that are statistically sound. Section 5.2.1 describes some emerging approaches to this. This type of analysis is usually referred to as ‘predictive analytics’. Predictive analytics is widely used in diverse fields such as insurance underwriting, marketing science and financial options pricing. Predictive analytics attempts to predict a particular outcome for a given set of data and
assumptions, possibly with an associated confidence level, using an input data set whose
elements have associated uncertainty. Typical data items that seem likely to be relevant include
component demand forecasts for new production and repair, forecasts of trends in semiconductor
process technology (e.g., International Technology Roadmap for Semiconductors (ITRS) 2011)
[81], categories of components grouped by family sharing the same underlying technology, and
manufacturer specific historical data on obsolescence notices. The research objective is to gain
insight on predictive analytics tools and algorithms, how they could be used in the obsolescence
prediction domain and what data would be necessary. Predictive analytics methods can be used
to construct a product lifecycle plan.

It must be cautioned however that forecasts are beset with both epistemic and aleatoric
uncertainty. Epistemic uncertainty can be assessed by statistical methods, but aleatoric
uncertainty, exemplified in references [82, 83], is completely unpredictable. The latter resulted
from a business decision to reposition the company into the embedded computer market with
consequent obsolescence of many consumer oriented components. Events such as these cannot
realistically be forecast or planned for, but since they typically take some time to implement, it
gives the users some time to develop mitigations and recoveries. The only realistic option in
these cases is to reactively revise the product life cycle plan when they occur.

A third type of uncertainty arises from the demand side where existing aircraft programs depart
from the predicted demand profile. A decrease of demand leads to excess inventory and capacity
in suppliers, and an increase in demand leads to production shortages, extended lead times and
early exhaustion of last time buy stocks e.g., see reference [84].

The results from a predictive analytics process are necessarily probabilistic in nature due to the
uncertainties in the input data. It is therefore necessary to treat the results as an estimate of the
risk associated with a particular outcome and to make a judgment on what level of risk is
acceptable. The level of risk which is acceptable is a subjective decision.

4.2 LAST TIME BUY ESTIMATION AND INVENTORY MANAGEMENT

The estimation of an LTB or bridge buy (BB) lot size is problematical, since there are
uncertainties associated with calculating it. The uncertainties are the number of products to be
produced and maintained, the time period over which production will be required and the
component quantity required to support repair and maintenance. Future production depends on
future aircraft orders, the timings of aircraft discontinuance, major changes made to the avionics
lineup and any aircraft life extensions made by the aircraft manufacturer. Regulatory or
legislative action may force the early withdrawal of a product. The repair and maintenance
quantity depends on the equipment reliability so that estimating support needs is contingent on
having the data collection systems in place that track repair consumption and enable forecasting
of the expected failures.

The estimation of quantities and the timing of LTB and BB decisions cannot be made
independently for one component alone since a component may be used in multiple products. A
product marketing decision to EOL a product terminates the time horizon and hence affects the
LTB or BB decision. This time horizon may also be set by expected future obsolescence of other
components, regulatory actions or legislation.
The LTB and BB estimation problem is therefore a decision making under uncertainty problem involving repairable system reliability, market forecasting and obsolescence forecasting. Such problems are typically solved by the use of discrete event simulation models in a Monte Carlo framework. These models (such as those described in [85-87]) represent the input uncertainties with sampled distribution functions whose functional form (i.e., equation and parameters) are derived by empirical means based on historical data and a wide range of assumptions. The model output is then also a distribution function from which the mean and variance can be derived by distribution fitting. Such algorithms yield a probabilistic measure of the monetized risks of under or over provisioning associated with a given LTB or BB lot size. Recursive analysis then finds the lot size corresponding to the acceptable risk.

An added complication is that a particular component may be used for several products and therefore optimization must be done across the manufacturers' product range rather than stove-piped on a product by product basis. Having considered all these uncertainties and made an LTB or BB, the avionics manufacture must then ensure that the inventory is actively managed to allocate the available stock, such that no one product is prematurely starved by demand from another. This requires that the manufacturer has robust materials management infrastructure and manufacturing information systems that accurately track ordering, inventory and consumption.

4.3. OPTIMUM RESOLUTION METHOD SELECTION

Methods for the implementation of change in avionics equipment to recover from obsolescence are well known [14]; these are the standard engineering design processes subject to all the applicable airworthiness guidance and standards. All or many of the possible solutions may be technically feasible and achieve the desired aim of resolving the immediate obsolescence issue. These options will carry differing initial and recurring costs and time to implement so the optimum choice from among the technically feasible is arrived at by consideration of LCC and other less quantifiable considerations such as market position and reputation.

It is important to note that the real cost of an obsolescence recovery action decreases with time, since the real value of money usually decreases with time. The annual rate at which the value of money declines is termed the discount rate. The discount rate is the return on investment that could be obtained by investing the money rather than spending it immediately. This is an important modeling concept and the choice of discount rate has a strong influence on the selection decision. Most manufacturing organizations maintain a current rate within the corporate finance department, since this rate factors into many investment decisions.

The choice is not simply which option to choose, but which sequence and timing of options yield a result which is optimum in some sense. An optimum solution may be, for example, to purchase a BB lot to take production and repair to a fixed future date or an LTB to a planned EOL date or to when a re-design and upgrade is planned to be done. Thus, some possible sequences are LTB only, LTB → EOL, BB → redesign, BB → redesign → LTB (different component) → EOL, and many other possible sequences.

The modeling required to compare the costs involved in various options and sequences is non-trivial. As with LTB and BB estimation, there are many uncertainties involved and many possible scenarios to consider so a computer tool using algorithms, such as shown in reference [88] is
necessary. To date such tools are not widely available and those few that are available [89], are not widely deployed.

4.4. PERFORMANCE BASED LOGISTICS RISK ASSESSMENT

A supplier who writes a performance based logistics (PBL) (or power-by-the-hour) contract undertakes to maintain the equipment for a given period for a set price. Maintenance includes all steps necessary to maintain availability e.g., repairs, quick reaction spares pool, and obsolescence resolutions as required. All of these activities are subject to uncertainties and therefore risk, since exact needs cannot be predicted. To calculate a price for these services, the equipment supplier must estimate his risk for a whole range of contracts and arrive at a pricing model that produces an acceptable risk and return ratio that is consistent with its risk management policies. Modeling techniques for repair needs and spare provisioning are well established by the logistics community, but the techniques for LTB, BB and resolution selection are not typically part of those models. This an item suggested for future research listed in Table 7.

4.5. DESIGN PATTERNS

The propensity for obsolescence vulnerability is to some extent set by the design. Designers may choose components that are nearing EOL, though not yet the subject of a discontinuation notice. The design may lack change containment boundaries so that an obsolescence resolution requires consequential changes. To address these types of deficiencies, design patterns should include modular design patterns, or rules that incorporate change containment in both the hardware and software supported by design analysis of multiple design options to obtain a measure of the risk associated with those options. Examples of design patterns are modularity enforced by modifiable intellectual property (IP) blocks so that changes do not ripple out beyond the containing walls of the IP, and the use of a hardware abstraction layer (HAL) so that most hardware changes do not require changes to operational software and re-certification. The most serious effect of obsolescence relates to processors and a HAL is only partially effective in protecting against that. Some authors report specialized techniques for reducing the impact of processor obsolescence [45, 46, 48-50, 90-92] that depend on the use of IP.

The IP approach is attractive from an obsolescence protection viewpoint since IP is perpetual and can readily be ported to new underlying hardware subject to the design assurance safeguards required by DO-254 [41] and the forthcoming EASA certification memorandum [93]. However, custom IP has a much higher initial cost relative to the cost of buying electronic components or licensing COTS IP. It would be attractive to be able to use COTS IP for many of the common functions such as processor, memory controller, input, and output functions which are readily available and sold to the commercial market for many types of consumer devices. At the present time, such an approach cannot be used in avionics, because the current AEH design assurance guidance is process-based, requiring the applicant to develop a set of artifacts from each of the process steps. This makes it very difficult to use COTS IP due to the lack of these certification-process artifacts, or safety assurance artifacts. Such guidance would open up a wide range of design options and help to mitigate obsolescence risks. An outline of a possible approach to the design assurance of COTS IP is given in section 9. This would require changes to current DO-254 AEH guidance, a research topic suggested in Table 7.
4.6. CUSTOMER NOTIFICATION PERIOD OF SYSTEM EOL AND CONTINUED SUPPORT

Avionics manufacturers obsolete equipment for various reasons. Examples include regulatory and legislative action, declining market and loss of production capability and unavailability of material. At the present time manufacturers have no constraints on how much notice to give to customers so they may make a product LTB or whether to continue to offer support. Such notice periods are purely at the discretion of the manufacturer and driven by the normal competitive pressures. A code of practice would be of benefit to customers similar to the JEDEC code of practice largely followed by component manufacturers [72].

4.7. MAINTAINING SOFTWARE AND HDL TOOLS AND PLATFORMS

There is currently no guidance on retaining the capability to modify and re-qualify the software and HDL, which may be required as part of an obsolescence resolution. Software tools and platforms must be archived along with the source files; verification and test programs must be retained and maintained, and an alternative is to migrate the source code to new tools and platforms as the old ones are disposed of. The FAA CAST Position Paper CAST-3 [76] discusses the software implications of hardware obsolescence.

4.8. MAINTAINING MANUFACTURING AND REPAIR CAPABILITY

Sections 3.8 and 3.9 described the issues surrounding maintaining design, production and maintenance processes and tooling so that products can continue to be modified, produced and repaired throughout the life cycle. There is currently no guidance published on retaining these production capacity or facilities to continue production over a long period or for the continuation of repair capabilities beyond EOL. A recommendation that such guidance would be helpful and should be considered is given in section 12.

4.9. COMPLIANCE AUDITING

Some avionics manufacturers have developed internal obsolescence management processes that vary from informal to documented-reactive and also the supporting tools to manage individual cases. Emerging standards and guidance on best practice defines some minimum requirements for these processes [3, 75]. In order to claim that their processes are compliant with this guidance some kind of independent validation of that claim should be made. This is now the case with electronic component management (such as shown in reference [74]) where independent auditors (e.g., International ElectroTechnical Commission Quality Assessment System For Electronic Components (IECQ), BSI, Underwriters Laboratory (UL)) carry out an assessment to the standard and provide a certificate of conformance. This audit mechanism could be extended to include obsolescence management processes.
4.10. PCN PROCESSING

Component manufacturers send out PCNs in document format (usually pdf) to the PCN distribution services and to their known customers. Avionics manufacturers, who subscribe, receive many of these every day. Some of these are routine manufacturing changes and some are for EOL. Each one has to be assessed for importance and relevance, and identification of products that are affected. A single PCN often includes many different component part numbers, only some of which are relevant to the recipient. At the present time this is mostly a manual process of reviewing each one and creating a tracking tool entry for further actions. The labor intensive nature of this process could be reduced by the development of standardized B2B data items, fields and formats to directly place PCN information into the avionics manufacturers tracking tool by electronic transfer, thus eliminating much of the transcription effort and allowing the tool to automatically flag the products affected. An effort is underway by the Edifice non-profit organization (http://www.edifice.org/) to develop standards and guidance for electronic PCN delivery.

4.11. SECURITY

Currently avionics have not suffered significantly from cyber-attack since the networking has been limited to on-aircraft. The NextGen-enabled avionics will be more susceptible to cyber-attack than current systems because of the networking of ground and air segments. The networking enables an increased degree of control by the ground segment of the aircraft state and trajectory thereby introducing additional risk. This potential problem has been recognized for some time, and the development of new guidance began in 2007 by the Radio Technical Commission for Aeronautics (RTCA) Special Committee 216 on Aeronautical Systems Security. The NextGen systems will be designed to detect and protect against attacks from known threats, but will remain susceptible to new threats. The NextGen systems will therefore incorporate inoculation systems by means of firewalls, anti-virus capability and continual software upgrades in much the same way that PCs are. Whether or not such changes will also require hardware changes with consequent obsolescence of the old, is unknown at present. Current design assurance guidance requires extensive re-qualification following change that could become unsustainable. There is a need to design software so defensive upgrades can be incorporated without needing to re-qualify the entire software. Guidance on software architectures (i.e., design patterns) that implement such change containment would be very helpful. Cybersecurity is an area where regulation to require inoculation may induce systems, software and hardware obsolescence.
5. EXISTING R&D

This section describes obsolescence and related research that has been reported in the public domain literature. The main sources are journals, conference papers and some publicly released reports and student theses.

The current research canon for obsolescence primarily covers methods for the creation of stochastic models to; 1) estimate a future cost distribution function; and 2) compute the model parameters for constrained minimization of this function. Such methods can be used to estimate LTB/BB quantities, compare design and component choice alternatives, evaluate make/buy decisions, and derive an optimal redesign schedule. Such methods ultimately depend on methods for forecasting the obsolescence of components prior to the receipt of an obsolescence notice. Forecasting obsolescence is not well developed. Research that has investigated design patterns and methods that are compliant with the current airworthiness regulations is also very limited.

The majority of this research is concerned with numerical assessments of cost and risk under various scenarios using stochastic models. Stochastic cost models are necessary because many or most of the model inputs cannot be known precisely; they have a range of uncertainty that may be represented by a distribution function. The objective is generally to find the sequence and timing of actions and the model parameters that minimize either the total ownership cost (TOC) or the life cycle cost (LCC). Obsolescence of components or equipment is certain to occur at several unknown points in the life cycle of an equipment or aircraft thus exposing both the supplier and customer to risk of loss. Risk minimization has some present cost, so it devolves to optimizing the trade between present and future costs according to the chosen optimization criteria so as to minimize the chosen criteria; LCC or TOC.

We have divided the research into two broad categories; LCC/TOC modeling and design methods. The largest group is LCC modeling; design methods have received little attention. In practice, the TOC and LCC models are needed to assess the benefit that could be derived from the design methods and hence whether any extra expense arising from using those methods is justified according to some measure of return on investment.

5.1. ECONOMIC AND LIFE CYCLE MODELING

This category of research aims to find optimal strategies for obsolescence management in the sense of minimum LCC or TOC. Such methods depend on the creation of mathematical cost models. These can be used either as objective functions in classical function minimization algorithms or executed within a Monte Carlo framework to iteratively converge on a minimum cost solution. The common factor in all these models is a dependence on forecasts of future demand and obsolescence of components. Both LCC and TOC models incorporate all costs incurred from initial design and deployment to phase out at EOL. Such costs of course include those arising from engineering work and also the costs of the associated work to maintain the safety and design assurance of the product in accordance with the applicable regulations. The economic models can never be the only factor in decision making, since the continued assurance of safety remains paramount, but they can inform the debate and provide pointers in the right direction.
Obsolescence management devolves to repeatedly selecting the type and timing of product changes, i.e. the substitution of alternate components, LTB or some level of redesign. Product change is controlled by the approved, documented quality assurance standards within the avionics manufacturer that satisfy the airworthiness assurance regulations and guidance in the same way as for new product design. The safety risks associated with product change are therefore managed and mitigated in exactly the same way as for new product design; that is by conforming to the guidance in Title 14 CFR. There is however an opportunity to modulate the design assurance activities according to the degree of change (discussed in section 6.2) in order to reduce the cost of compliance while retaining assurance that safety is not degraded by the change.

5.1.1. **Estimating Life Time Buy Quantity**

A LTB or BB is made only after an obsolescence notice has been received and hence is a reactive strategy. Once the notice is received, a strategy must be determined to deal with it such as LTB/BB or redesign or some timed sequence of both. If an LTB or BB is the selected resolution option, the number of components to buy must be determined. Determination of the LTB/BB quantity depends on numerous factors, such as the expected production, the support demand profile, whether and when a redesign will be done, and whether the product will be declared obsolete (EOL) at some future time. Feng [85] describes the Life of Type Evaluation (LOTE) tool for estimating the LTB quantity that minimizes life cycle cost. The underlying model is derived from the Teunter and Fortin end of life model [94-96]. The LOTE model extends this to a multi-component assembly with a sequence of component EOL events and can include a redesign at some specified time.

Pourakbary [97] considers the case of the final stage of a product’s life where the product has a declining price, but repair cost remains constant or increases. There comes a point at which repair is no longer economical, and the manufacturer would be better advised to replace the failed product with a new one rather than repair and suffer warranty costs. This model does not consider the rising price of components in a shortage situation, as is often the case for recently obsolete components that are temporarily available from a few sources.

Bradley [87] considers the problem of an assembly of many components that sequentially become obsolete over the product lifetime using both stationary and non-stationary demand profiles. He concludes that manufacturers of long life, low growth products, as are typical in avionics, should attach more weight to lower manufacturing cost even if this requires increased initial design and sustainment costs.

5.1.2. **Life Cycle Cost Estimation**

Sandborn [98] describes the Mitigation of Obsolescence Cost Analysis (MOCA) tool to determine an optimum design refresh strategy based on life cycle cost. Prabhakar [99] provides a model for estimating the TOC associated with the selection of a particular component. Prabhakar [100] uses the obsolescence forecasting method of Sandborn [79] to develop a model for determining the value of second sourcing components that accounts for the set-up cost of
qualifying additional suppliers. The general principles of life cycle cost estimation are given in references \[101, 102\].

5.1.3. Selection and Timing of Resolution Options

When an obsolescence notification is received, the avionics manufacturer must initiate a resolution selection process to decide which of the available strategies is to be taken and when they should be implemented. These can range from simple part substitution to LTB/BB to redesign or some timed combination of them. The manufacturer may instead declare that the product has reached EOL provided that the contractual obligations originally agreed are satisfied. Even with an EOL declaration where no further upgrades or design changes will occur, there still remains the choice of whether or not to continue to provide repairs to products already fielded. It is common practice for equipment procurement contracts to specify that service will be maintained while 2 or more aircraft remain in service. This may prove to be an impossible condition to satisfy if all sources of supply are exhausted. In addition the timings and sequence of these activities must be decided.

One possible model for resolution selection is the multi-arm bandit (MAB) model. The available strategies are represented by arms on a slot machine that produces differing rewards when pulled. Arms may be pulled (i.e., strategies adopted) in any sequence and timing, and therefore the problem is to find the sequence and timing that produces the highest discounted reward. Rewards must be discounted since they occur at differing times. Kumar \[88\] illustrates MAB using a 2-arm MAB model where the 2 arms represent periodic component buy and redesign. When the component goes obsolete only an LTB can be made and redesign is the next choice. The technique is extensible to further resolution options.

Porter \[103\] describes a method for deciding the optimum time for redesign by considering the relative discounted costs of a BB and a redesign. He determines the optimum future time for redesign by comparing holding cost of a BB with discounted future redesign cost.

During the warranty period costs will be incurred for the provision of repair components. These may be obsolete by the time repair is needed so it is necessary to compute the required number when making a LTB \[104\].

Any LTB or BB must procure enough components needed to maintain fielded equipment in addition to new production. This may include beyond both the warranty period and EOL depending on the support policy of the equipment manufacturer. Karyagina \[105\] describes a point process life cycle model for repairable systems. Hong \[106\] describes a model for forecasting the demand for service (repair) components. These models have closed-form solutions for constant component failure rate, but require numerical evaluation if this assumption is not used. Constant failure rate is the common assumption, but other models can be used if there is validated failure data to support them.

Chiang \[107\] describes a model utilizing in part the newsvendor model that accounts for the numbers of equipment in service and the rate of replacement, which is dependent on equipment age. The newsvendor problem is an analogy with a newsvendor who must minimize his loss from buying too many papers when set against the loss of scrapping the perishable excess inventory (http://en.wikipedia.org/wiki/Newsvendor_model). Equipment or aircraft manufacturers face the
same problem, since they may have purchased more components or equipment than they eventually use by the time the product is at EOL, resulting in surplus inventory for which there is no remaining market. This inventory may of course be continued to be drawn-on by service needs, if the manufacturer elects to continue support until an EOS date is declared.

5.2. COMPONENT OBsolescence Forecasting

The research on obsolescence forecasting may be split into demand side and supply side forecasting. Demand side forecasting attempts to forecast the future obsolescence date of a component using a prediction model such as one based on historical sales data or past obsolescence history of similar components. Supply side forecasting views the problem from the point of view of the supplier who attempts to maximize his profit by discontinuing products with declining sales. Obsolescence forecasting is the central component of the economic modeling methods. In order to be pro-active it is not sufficient to wait for an obsolescence notice, and therefore, some forecasting is required to predict the future costs of a range of present actions.

5.2.1. Demand Side Methods

These methods forecast a future obsolescence date using historical data such as sales profile, manufacturer product deletion history and technology forecasts. Solomon [40] presents a model based on the observation that sales of a particular type of component or component family typically follow an approximation to a Gaussian growth curve, where sales increase to a peak and then decline towards eventual obsolescence. Fitting the curve to sales data enables predicting when sales will fall sufficiently low that obsolescence is imminent. The model is refined by separating the sales data of a component family by secondary attributes. Secondary attributes are specific to component families such as operating voltage, memory size or databus width. Huang [78] applies this model to ASICs using secondary attributes that are the various types of ASICs on the market.

Sandborn [79, 80] presents a model for forecasting obsolescence based on historical procurement lifetimes (the duration from introduction to EOL) for classes of components. Such models are useful where sales data is not available. Josias [108] describes a similar methodology based on fitting a linear regression equation to observed lifetime data for obsolete components using component attributes as regression terms. The lifetime of a non-obsolete component can then be predicted by inserting the new component attributes into the regression equation. This methodology allows for dimensionality reduction in the regression equation by computing a significance value for each attribute, so that insignificant ones can be disregarded.

Clay in U.S. patent [109] describes a tool and method to calculate a material risk index (MRI) for a component. This method was originally described in reference [110]. The methodology combines supplier risk, alternate source risk, individual component risk and risk arising from semiconductor process technology evolution to produce an overall MRI. At present information on the underlying process technology for individual components is not widely available from the component information sources (CIS), therefore technology/process risk is currently difficult to assess. The index can be used to score a bill of materials, identify high risk choices and
discriminate between alternative designs based on a rolled up risk as reflected in a LCC/TOC model at the product level.

5.2.2. Supply Side Methods

A manufacturer discontinues production of a product (makes it obsolete) because he perceives that the profit stream is soon expected to fall below a level that justifies employing the capital resources necessary for its manufacture. This is true for manufacturers of components, equipment and aircraft. Manufacturing cost may increase or decrease depending on volume and realized manufacturing efficiencies, but the main driver of obsolescence is declining customer demand and hence volume and income. Manufacturers of durable goods of all types use market forecasting models to predict sales over some chosen planning horizon and hence inform their product end of life decisions. Such models are usually referred to in the literature as growth or technology diffusion models and have found wide application in diverse durable goods manufacturing industries, such as washing machines and TVs. Component consumers could use the same type of models to give some insight into the future obsolescence risk associated with a particular component MRI and use that in a product risk assessment process. Meixell [111] describes a model that is based on the observation that the future demand for a particular product can be predicted using to-date sales data for a class of similar products. A class is a group of items that share some characteristic such as the underlying manufacturing technology employed. Such a characteristic is referred to as a leading indicator. The example given is for a semiconductor technology node (i.e., the basic feature size for that node) as a leading indicator. Since new sales data is continually being collected, the model uses standard Bayesian updating to update the forecast. There are many underlying technology growth models reported in the literature and a summary is provided in Meade [112] with some discussion of their applicability bounds. One of the growth models often proposed is the Bass model [113] or one of several variations given in [114-118]. All of these models depend on fitting the model to observed data. Srinivasan [119] describes a non-linear least-squares fitting algorithm and Schmittlein [120] describes a maximum likelihood technique. These models are fairly computationally complex and require data that is not readily available to component consumers. To our knowledge these have not been used by component consumers to estimate their risk of obsolescence because of the difficulty of obtaining the needed data.

5.3. DESIGN METHODS FOR OBSOLESCENCE AND MITIGATION

This category of research aims to develop design and design analysis techniques that drive down the risk of obsolescence occurring and making it easier (i.e., cheaper and quicker) to recover from the event when it does occur. Many architectural and detailed designs could satisfy the functional requirements. A requirement can be implemented in hardware, software or IP combinations. All of these alternatives will experience differing TOC over the equipment lifetime due to differences in the manufacturing cost, the warranty and support cost and the repeated costs associated with resolving the inevitable occurrences of obsolescence. An economic analysis of multiple design options and top level architectural schemes at an early stage of design can select the most promising to go forward. In support of these multiple options, Singh [89] provides a methodology to compare the obsolescence impact of multiple design
options using the MOCA tool. Bradley [121] provides a similar model. The use of purchased or licensed commercial COTS IP in avionics is presently problematical since it is, unless alternate means are proposed, subject to the design assurance requirements of DO-254 [41]. These requirements cannot readily be satisfied due to the unavailability of the necessary certification artifacts except in a few particular cases. A suggested approach to solving this problem is given in section 9, but cannot yet be considered mature.

5.3.1. Mitigating Software Obsolescence

Obsolescence of components may impact the airborne system software and require some change or update to accommodate the airborne electronic hardware (AEH) changes necessary to resolve the obsolescence issue [35]. Airborne software changes carry a cost to re-qualify and re-certify the system and must be factored in when considering both initial design choices and the optimum strategy for obsolescence resolution. Goswami [122] provides an extension to the MOCA model that accounts for the impact of obsolescence on embedded software.

Airborne software obsolescence most often occurs when the processor becomes obsolete. Several authors [45, 46, 48-50, 91, 123, 124] describe a design approach using processor IP based on the proposition that the processor HDL code can readily be retargeted to a substitute host device. This approach can retain software object code compatibility and cycle accurate timing, and so avoids, or reduces requalification and recertification cost.

Airborne COTS software is not frequently used in avionics, because of the certification-process requirements, except in case where the software manufacturer has undertaken to qualify the software product per DO-178B/C [38, 125]. This is rarely the case for design and manufacturing tooling software. This is most often purely COTS. Avionics manufacturers therefore must take steps to preserve such software and the associated platforms over the equipment life cycle in order to be able to continue to maintain product and service capability.
6. **STANDARDS AND ASSURANCE**

This report provides some suggested topics that the FAA could provide guidance on for setting standardized approaches and minimum requirements for the management of obsolescence-induced change and ensure that existing airworthiness is maintained as products evolve through many changes.

These suggestions are those that pertain to: 1) the interface between the customer and supplier of avionics equipment; 2) continued airworthiness after modifications are made to resolve an obsolescence issue; and 3) the procedures to be followed by the FAA in adopting new rules, regulations, or guidance so that the economic consequences to owners and operators with installed equipment are fully considered.

Avionics companies may want to manage their internal obsolescence management processes, tools, models, design rules and their supplier relationships in customized ways. The details of the processes are closely help proprietary information and therefore cannot be constrained by or disclosed in standards documents. Aircraft manufacturers may similarly want to establish unique and confidential working relationships with suppliers, though some guidance on EOL visibility may be useful.

The FAA sponsors organizations such as RTCA and the Society of Automotive Engineers (SAE) to publish standards that are ultimately incorporated into guidance material such as advisory circulars. The guidance assists applicants in meeting airworthiness requirements by providing detailed acceptable means of compliance to Title 14 CFR and a common understanding for the FAA and industry.

Because of the short market life of many of the components used in avionics equipment, avionics manufacturers constantly make design and construction modifications to retain production and support capability. This continues until they conclude that the continued investment is no longer technically or economically feasible. Such changes can vary from minor substitution of an exactly equivalent component to major re-design and software re-certification.

The material presented below is intended to assist the FAA in scoping the task and writing charter documents for standards and rulemaking bodies, but does not provide detailed language since this must be the result of FAA/industry consensus that is not subject to legal challenge.

### 6.1. PRODUCT SUNSET NOTIFICATION

Avionics manufacturers may declare that a product will be obsolete after a certain time. There are several possible causes of this, e.g., inability to procure further production components and material, because the demand has declined to the point where continued production lacks sufficient business justification or the production process capability is no longer available. There are many underlying reasons for these basic causes so we see obsolescence problems cascade throughout the supply chain.

Avionics product EOL notification is typically given in a SIL or SB that is sent out to all known customers and authorized service centers. In such cases, the manufacturer should provide a
minimum set of information in the notification. The recommended minimum information content is provided in section 12 and Appendix B - Generic Product Life Cycle Plan.

6.2. MODIFICATIONS AND CONTINUED AIRWORTHINESS

In resolving an obsolescence event, the original design assurance (DA) must be maintained in order to provide assurance of continued airworthiness to the type certificate holder and certification authorities. Current guidance, in the advisory circulars and the associated standards, defines new product design assurance and safety assurance procedures, but does not adequately address how that guidance should be applied to modifications. A recommendation on this is given in section 12.

While changes only for the resolution of obsolescence mostly will not result in a change of function, there exists the possibility that the changes could have unintended safety effects, particularly for critical systems, unless precautions are taken against that possibility. Such changes can vary in complexity from very low (e.g., equivalent or exact component substitution) to very large (e.g., processor change, software change and re-certification). Safety may be affected if, for example, the replacement components have lower reliability, are more susceptible to or generate more electromagnetic interference (EMI), require consequential software change or have additional unused functions or modes that are not forcibly disabled. The application of current design assurance standards may detect these possible safety effects (but are not guaranteed to do so) if applied in full, but often are not because the change is not expected to compromise or negate the original design assurance.

The FAA issued a Final Rule (Docket No. FAA-2001-8994; Amendment Nos. 21-77A, 25-99A) in May 2001. This rule interprets CFR Title 14 Part 21 Subpart D (Changes to Type Certificates) requirements. The FAA subsequently developed associated guidance material [126]. This rule and guidance discusses the applicability of, and requirements for changes to aircraft type certificates following changes to the aircraft. The regulation classifies aircraft changes as major or minor and a definition of major and minor is provided in CFR Title 14 Part 21 Subpart D section 21.93. This regulation appears to apply to the aircraft as a whole, and does not cover how the impact of the equipment change should be assessed. Changes to avionics equipment, from whatever cause, can potentially have consequences to aircraft performance or safety, and therefore should be assessed in a modification program.

The FAA has not provided any guidance on how avionics manufacturers should assess the airworthiness impact of changes to avionics systems or the circumstances under which changes would require an amendment to the type certificate (TC) or TSO. Additional guidance on avionics equipment changes is desirable to ensure that such possibilities are considered and mitigated so that the original design assurance is not lost. A recommendation to this effect is given in section 12.

Major changes would require the application of current design assurance guidance as for a new design with the corresponding artifacts presented to the FAA in a modification project request. Minor changes would require a smaller subset to be performed with minimal FAA oversight. The FAA has developed a document that describes these considerations in the CAST Position Paper CAST-3 outline [76]. This document is primarily concerned with assessing the impact on
software arising from obsolescence induced hardware change. It recommends that a change impact analysis be performed, categorizing the change as significant/insignificant software impact. This document, though old, provides a good starting point for more formalized guidance.

There appears to be no formalized measure of complexity, so change classification must be a result of engineering judgment, agreed with the FAA. This classification would also define the artifacts to be provided to the FAA and those which should be developed for inspection on request.

6.3. RULEMAKING PROCEDURES

The rollout of NextGen will probably see a considerable number of new procedural rules being promulgated such as those listed the NextGen Concept of Operations [21]. Such rule changes may render an equipment-installed base inadequate to the new task, and thus either unusable or only usable under limited operational circumstances. The rulemaking activities of the FAA should consider the economic impact on the installed base of equipment when new operational rules are introduced. Ideally new rules should maintain backwards compatibility of existing equipage for some period of time to allow users a reasonable period to re-equip. Recognizing that some incentive is needed to persuade operators to re-equip to conform to the new rules, the ‘best-equipped – best-served’ principle could be applied in which operators with compliant equipage may retain access to existing services or utilize additional services and capabilities. Guidance on the Notice of Proposed Rulemaking (NPRM) process should be written that gives due weight to economic impact on operators bearing in mind the inherent limitations arising from the FAA mandate to consider the safety, security and lastly the efficiency of the NAS.

The evolution of airspace rules and the effects on installed aircraft equipment are the normal evolution of aircraft and NAS capability. The effect of rulemaking goes beyond obsolescence and life cycle maintenance and encroaches into new avionics product development in response to the imperative of improving the aircraft capability and the NAS capacity and efficiency. Because of the statutory need for public review, comment and consensus, the rulemaking process is necessarily on a slow timescale that is commensurate with the typical lifecycle of aircraft equipment. Modification of equipment to comply with new and revised rules is therefore less likely than avionics manufacturers declaring equipment EOL and developing entirely new products. Operators must necessarily continue to replace equipment that is non-compliant, a burden which falls most harshly on GA owner-operators.
7. **HIGH VALUE APPROACHES**

This section presents in summary form in Table 1, the methods that have been previously described. These approaches are referenced back to the previous sections. The table has the following headings:

- **Approach**
- **Type**
  - Economic analysis (E)
  - Design methods (D)
  - Forecasting (F)
  - Regulation and standards (R)
- **Description**
- **Value**\(^1\)
- **Cost**

Value and cost are coded with qualitative 3-valued categories, High (H), Medium (M), and Low (L). These are merely the author’s opinion and are not derived from any verifiable sources.

Although the items below are presented as discrete items, they are interdependent. For example:

- A product plan requires analysis of component obsolescence forecasts, future product demand and anticipated regulatory actions in order to schedule redesigns, align them with customer roadmaps and decide the eventual EOL date.
- An optimum redesign schedule and resolution methods at discrete intervals depend on the product plan.
- The product plan may need to be adjusted and optimized according to the results of LCC analysis and the design decisions finally adopted.

In short, life cycle planning is an iterative process with many feedback loops and with no clear stopping criteria. Furthermore, any such plans are subject to disruption by external events and invalid assumptions requiring re-planning on a continuous basis.

As headed by “Approach”, general descriptions of the methods and specific references are given in column 1 of the table. Recommendations on additional and changed guidance to implement these methods are given in section 12.

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\(^1\) Note that by value, we mean value to the equipment supplier, since it is expected that value to the supplier would be manifested as value to the customer through pricing and supportability, but this is difficult to quantify. Recurring (i.e., operating) cost is used as a measure of cost, but it should be understood that there are substantial (but not yet quantifiable) non-recurring costs and technical and organizational hurdles to overcome associated with implementing these processes.
Table 1 – High Value Approaches

<table>
<thead>
<tr>
<th>Approach</th>
<th>Type</th>
<th>Process Description</th>
<th>Value</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTB forecasting (section 4.2)</td>
<td>E</td>
<td>Calculating the number of components that should be bought in response to an LTB notification. This calculation includes those needed for continued production, repair requirements until the next redesign point or product EOL for all affected products</td>
<td>H</td>
<td>M</td>
</tr>
<tr>
<td>LCC estimation (section 5.1.2)</td>
<td>E</td>
<td>Calculating the profile of the expected discounted cost of manufacturing and supporting the product to EOL. This calculation includes manufacturer costs of production, warranty, support and obsolescence management</td>
<td>H</td>
<td>M</td>
</tr>
<tr>
<td>Optimum resolution selection (section 4.3)</td>
<td>E</td>
<td>Calculating the optimum choice of which of the available resolution options (e.g., substitution, redesign, product sunset etc.) based on some measure of optimality, e.g., LCC</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Optimum redesign schedule (section 5.1.3)</td>
<td>E</td>
<td>Calculating the optimum timing and content of multiple redesigns through the product life cycle based on some measure of optimality, e.g., LCC</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Product life cycle plan (Appendix B - Generic Product Life Cycle Plan)</td>
<td>E</td>
<td>The expected production profile, timing and content of redesigns and upgrades and the expected final EOL date</td>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>Obsolescence forecasting (section 4.1)</td>
<td>F</td>
<td>Estimation of the probability or risk of obsolescence as a function of future time for components that have not yet been declared obsolete by the manufacturer</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>MRI (section 5.2.1)</td>
<td>F</td>
<td>Calculation of a dimensionless and scaleless index number for an individual component representing the probability or risk that the component will become obsolete at some fixed future time. This calculation is a special case of obsolescence forecasting based on a fixed time horizon</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>Product scorecard (section 5.2.1)</td>
<td>D</td>
<td>A product BOM annotated with 1) an obsolescence risk measure for each component, e.g., MRI, YTEOL and 2) a mitigation plan for components that fall below a documented and agreed threshold. The card would be used as a decision tool for production managers to accept or reject the design definition and transition to the manufacturing phase</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>Approach</td>
<td>Type</td>
<td>Process Description</td>
<td>Value</td>
<td>Cost</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>Design patterns (section 4.5)</td>
<td>D</td>
<td>Design methods that seek to minimize the cost of resolving future obsolescence cases, e.g., design partitioning and change containment boundaries. This minimization of cost also includes strategic use of custom and COTS IP and the certification and design assurance methods necessary to permit their use</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design selection (section 5.3)</td>
<td>D</td>
<td>Performance of a trade study to select from a set of alternative designs and select the one that minimizes future obsolescence management costs according to some selected optimality criteria, e.g., LCC. This minimization of cost also includes decision criteria for Make/Buy determination</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product EOL notification (section 4.6)</td>
<td>R</td>
<td>Recommended minimum information content for a product EOL notice</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continued airworthiness (section 6.2)</td>
<td>R</td>
<td>Recommendations and guidance defining the design assurance artifacts required for equipment modification modulated according to change significance, extent and complexity and in accordance with the applicable airworthiness regulations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rulemaking (section 6.3)</td>
<td>R</td>
<td>Recommendations and guidance for the Aviation Rulemaking Advisory Committee for 1) consideration of the cost impact of proposed rules on the installed base and 2) allowing adequate time for the user community to comply by provision of a transition plan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacturing and design tooling (sections 4.7, 4.8)</td>
<td>D</td>
<td>Ensuring that required tooling is available to support manufacturing until product EOL and repair until the support end date declared in the product EOL notice</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
8. **SHARED ISSUES**

Obsolescence issues, caused by the obsolescence of electronic components, touch on all those who make, buy, use and certify avionics equipment. These and other peripheral entities may generally be described as electronic device organizations, i.e., those whose business depends on electronic components in a direct or indirect way. Electronic components exist as either piece parts for manufacturing and repair material or incorporated within finished equipment. In one form or the other, they flow around the entire aerospace ecosystem, originating with the part manufacturer and ending at disposal. The flow of parts between these electronic device organizations is illustrated in Figure 6. Each arrow represents a flow of parts from one entity to another and, since each entity is a business, thus also represents that a commercial relationship exists between them. In addition to the physical parts flow, there is also an information flow of data about parts, e.g., part properties, characteristics, life cycle stage, qualification data and standards for proper application in equipment.
Figure 6 – The Flow of Components between Electronic Device Organizations
8.1. ELECTRONIC COMPONENT MARKET SEGMENTS

We characterize the electronic component market (i.e., buyers and users) into two broad segments. Segment 1 (which includes the aerospace industry) is characterized by:

- Long (20+ years) product life cycle and slow technology turnover
- High product complexity
- Low volume, high cost
- Severe environment
- Safety critical
- Strict regulation of design, production and operation

These are characteristics that are shared to varying degrees by other industry segments such as nuclear power generation, outdoor telecommunications, oil and gas exploration/extraction, industrial process control, automotive and railways. Even when taken as a whole, in 2011 this segment account for less than 15% of the $300B (2011) annual semiconductor sales ([127]. Military/aerospace is 1.1% and declining. This is the single most important factor for the obsolescence problem in aerospace.

Segment 2 (which includes consumer, computer and communications) is characterized by:

- Short product life cycle and rapid technology turnover
- High volume, low cost and price sensitivity
- Benign environment
- Non safety critical
- Little regulation

Both segments share concerns about reliability and availability, since these have a direct influence on safety and profitability. The 2011 market shares by industry segment is shown in Figure 7 and the growth forecast by market segment Table 2.

---

2 Network infrastructure and data center computing typically has a long life cycle
Figure 7 – Global Semiconductor Market Share, 2011 (Military includes aerospace) [127]

Table 2 – Global Market Forecast for Semiconductors ($Billions) [127]

<table>
<thead>
<tr>
<th>Market Sector</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer</td>
<td>28.1</td>
</tr>
<tr>
<td>Communications</td>
<td>22.0</td>
</tr>
<tr>
<td>Consumer products</td>
<td>19.2</td>
</tr>
<tr>
<td>Automotive</td>
<td>7.3</td>
</tr>
<tr>
<td>Industrial/medical</td>
<td>6.8</td>
</tr>
<tr>
<td>Military</td>
<td>1.1</td>
</tr>
<tr>
<td>Other/not classified</td>
<td>15.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

Note: CAGR% – compound annual growth rate
8.2. ELECTRONIC DEVICE ORGANIZATIONS

The obsolescence problem is particularly intractable because there are many electronic device organizations involved, each of which, with the exception of regulators, are commercial self-supporting entities with differing concerns and motivating factors. In Table 3 [127], electronic device organizations are categorized by type (the industry segment they primarily serve) and their primary concerns from an obsolescence perspective are listed in Table 3.

Table 3 – Electronic Device Organizations Primary Concerns

<table>
<thead>
<tr>
<th>Electronic Device Organization Type</th>
<th>Primarily Serving Segment</th>
<th>Primary Concerns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parts manufacturers&lt;br&gt;Semiconductor fabricators and packagers</td>
<td>2</td>
<td>Manufacturing cost&lt;br&gt;Technology cycle time&lt;br&gt;Environmental legislation&lt;br&gt;Raw material supply continuity</td>
</tr>
<tr>
<td>Parts distributors and brokers</td>
<td>2</td>
<td>Inventory cost</td>
</tr>
<tr>
<td>Aftermarket part suppliers</td>
<td>1,2</td>
<td>Inventory cost</td>
</tr>
<tr>
<td>U.S. DoD Defense Supply Center</td>
<td>1</td>
<td>Technology cycle time&lt;br&gt;Inventory cost</td>
</tr>
<tr>
<td>Avionics manufacturers&lt;br&gt;Aircraft manufacturers</td>
<td>1</td>
<td>Regulation&lt;br&gt;Design assurance&lt;br&gt;Long life cycle</td>
</tr>
<tr>
<td>Operators (e.g., Bizjet, Airlines, DoD)</td>
<td>1</td>
<td>Long life cycle&lt;br&gt;Operating cost&lt;br&gt;Support cost&lt;br&gt;Operational environment&lt;br&gt;Regulation</td>
</tr>
<tr>
<td>GA owner-operators</td>
<td>1</td>
<td>Long life cycle&lt;br&gt;Acquisition cost&lt;br&gt;Support cost&lt;br&gt;Operational environment</td>
</tr>
<tr>
<td>Contract manufacturers</td>
<td>2</td>
<td>Line startup cost&lt;br&gt;Recurring cost&lt;br&gt;Production rate&lt;br&gt;Material supply continuity&lt;br&gt;Inventory cost&lt;br&gt;Environmental legislation</td>
</tr>
<tr>
<td>Aircraft and avionics maintenance and repair organizations</td>
<td>1</td>
<td>Regulations&lt;br&gt;Long life cycle</td>
</tr>
<tr>
<td>Regulators (e.g., FAA, EASA)</td>
<td>1</td>
<td>Aircraft, airspace safety&lt;br&gt;Continued airworthiness&lt;br&gt;Airspace usage efficiency</td>
</tr>
</tbody>
</table>
| Parts test, screening and qualification houses | 1 | Technology cycle time  
Part testability, observability |
| Parts information services (e.g., IHS, GIDEP) | 1,2 | Technology cycle time  
Source data feeds |
| Standards organizations (e.g., IECQ, IEC, UL, BSI, RTCA, SAE) | 1,2 | None |

Table 3 shows that the common concern among parts users in aerospace (segment 1) is the long life cycle requirement. For the supply side (part distributors and manufacturers) this is of no concern since they are motivated primarily by consumer demand (85% of total demand). This forces a high rate of technology turnover and hence obsolescence.

This variety of concerns leads to differing views and incentivizing factors among electronic device organizations on how the costs of obsolescence should equitably be distributed. Each organization will naturally seek to minimize its own cost. In commercial GA, regional and large transport aerospace, the primary bearers of obsolescence cost are presently the avionics manufacturers, though ultimately all obsolescence costs must find their way to the end users through purchase price and support cost. For military and space products, the end user is almost exclusively a government organization, who bears the cost of obsolescence recovery directly.
9. USING COTS IP

Aircraft safety is not simply a matter of ensuring that the electronic components used are safe. Safety a COTS electronic component or COTS IP has no meaning since safety, like reliability, of an electronic component (including those that contain IP) depends entirely on the use context and the extent to which a design error or failure can contribute to a system hazard. Safety is a system property that must be assured by applying best practice at multiple levels.

This section suggests some approaches, methods and processes by which an adequate measure of design assurance can be associated with COTS IP, when used in airborne applications. This design assurance is one, but not the only, contributory measure to system safety. The intent is to outline methods and processes that can be modulated according to the criticality level of the airborne equipment.

COTS IP is widely available from many vendors implementing a wide variety of functions. It is incorporated in a programmable device (PD) such as an ASIC or FPGA and used to provide many differing functions that have traditionally been implemented as COTS hardware components. Examples include processors, memory and peripherals. COTS IP is delivered in various formats e.g., source code HDL or as a pre-compiled and hardened macro targeted to a unique implementation process. It may also be encrypted to protect the underlying HDL source code.

This topic is important and relevant to obsolescence management since IP has some inherent technical and commercial advantages compared with hardware components. The advantages with respect to obsolescence are 1) COTS IP can be bought or perpetually licensed, and it does not suffer from obsolescence directly, 2) if the target PD becomes obsolete the IP can be ported to an alternative that need not be identical and 3) IP modules can be linked by design tools to other IP to add and change functionality. These advantages are offset by increased difficulty in showing that adequate design assurance is provided to satisfy certification standards. In the remainder of this section, questions posed in reference [128] are addressed and a framework for future certification guidance on the use of COTS IP are developed.

In considering the use of COTS IP, avionics manufacturers must be cognizant of the product liability aspects, since a majority of COTS IP, in common with COTS components, is sold with a disclaimer that the buyer absolves the seller from any product liability when they are used in safety critical applications. A typical statement quoting from Texas Instruments is shown below. This is taken from the data sheet for a Texas Instruments 54/74AHC00 Quad 2-input Positive NAND gate but is a generic disclaimer.

“Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that
might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have not been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.


Statements such as this need not be inhibitors to the use of COTS IP and components since the avionics manufacturer and the aircraft manufacturer automatically assume the product liability risk when they choose to use such items and mitigate the risk through the verification and validation processes.

9.1. DEFINITION OF COTS IP

While no single and generally accepted or common usage definition of COTS IP is known, this report considers COTS IP to be any IP with the following characteristics; 1) is widely available for general sale or licensing, and 2) high level requirements (HLR), low level requirements (LLR), detailed design, validation and verification artifacts and documentation is not accessible to the avionics product designer and certification applicant. These characteristics have exact parallels in COTS electronic components.

This definition thus covers purchased hard, firm and soft³ format COTS IP that can be loaded by the applicant into a PD. This definition explicitly excludes any unique IP developed by the certification applicant since the applicant has complete design knowledge and control over all

³ Hard: technology specific physical layout format; firm: technology independent netlist format; soft: technology independent register transfer level (RTL) or HDL format.
requirements and certification artifacts. Unique IP can thus be assured using the existing DO-254 processes. The assessment process proposed is the same whatever the method of delivery though there are differences in the mechanics of loading the COTS IP into the PD.

The basic characteristic of COTS IP is that the user only knows the functional properties and has no knowledge of, or access to, the HLR, LLR, design or verification. Functional properties are specified in manufacturer documentation (e.g., data sheet, application notes, user/programmers guide) that provides constraints that the user must observe in the application and the input/output relationships. Mostly unspecified are the consequences of stepping outside those bounds. A further and important characteristic of COTS IP is that there is often a substantial user base that can contribute to confidence, but this is often difficult to quantify or discern what fraction of the usage base is actually relevant. Determining a relevancy metric is one of the tasks to be accomplished by the recommended updates to design assurance guidance in section 12.

9.2. SIMILARITIES BETWEEN COTS IP ASSURANCE AND ASSURANCE OF COTS ELECTRONIC COMPONENTS

The approach presently used for COTS electronic components and modules, is to determine whether the vendor has adequate processes in place for the qualification and quality assurance of the component and to claim credit for wide usage. This approach is that recommended in DO-254 [41]. Wide usage and service history are strong selection criteria and can typically be claimed for COTS components, since they are developed for a wider market, often of much higher volume than aerospace. DO-254 section 11.3 provides some guidance on assessing and using product service experience to provide some degree of design assurance. The current guidance [129, 130] for acceptable means of compliance to Title 14 CFR is built on the premise that no single failure can lead to a catastrophic system failure.

A review of the problems associated with COTS hardware use in safety critical systems, but not the solutions, is provided in [131]. Particular attention has been given to graphics processor devices [132, 133] because of their potential to display hazardless misleading information (HMI) to the crew. The difficulty of assuring the safety of COTS IP is not in any way objectively different to that of assuring the safety of a complex COTS electronic component. Complex COTS component assurance is a topic of current research, e.g. microprocessors [134-138].

Aerospace vendors generally have an Electronic Components Management Plan (ECMP) to describe the process followed for component selection and use that is in accordance with an international standard for preparing a ECMP such as IEC TS-62239 or EIA-4899 [74, 75, 139]. For electronic components, compliance with the ECMP is usually accomplished by audit of the vendor’s component qualification process and results. It should be noted however that the audit process rarely extends to the design and verification of the component; i.e., design errors may be present and there have been some notable cases where this has occurred [140]. In most cases, a vendor audit is performed using the STACK S-0001 specification [141] to determine the baseline quality requirements. This specification details the same general requirements for initial component qualification and ongoing quality assurance of commercial integrated circuits that MIL-STD-883J provides for military components [142]. The second and equally important part of the ECMP is the requirement for the user to document the processes by which the components are used. The user’s design and verification processes that fully account for the declared
capabilities of the purchased component should be documented in the users design and verification procedures system and documentation.

Acceptable means of compliance to current regulations and guidance for the selection and use complex COTS electronic components is typically provided through a combined strategy of 1) use of the ECMP, 2) system safety analysis, 3) assurance developed throughout the system hardware/software verification processes, and 4) architectural provisions to mitigate the possibility of common cause design errors. This methodology has been in use across the industry for more than 10 years and has proved to have been very successful.

This report suggests that a similar process can be applied to the use of COTS IP and that the ECMP process offers a good model to extend to the COTS IP arena and that much of the ECMP for COTS components related process is applicable.

9.3. COTS IP USAGE

Many companies have well established processes to develop programmable devices (ASIC, PLD, FPGA hereinafter referred to as PDs) that is compliant to DO-254 [41]. This process typically depends on the availability of complete design information for the IP, e.g., requirements, code, plans, verification results, traceability matrix etc. Since this is not generally available for purchased or licensed COTS IP, avionics vendors are not able to apply these processes and therefore are not able to use any of the wide variety of COTS IP available from vendors thus 1) pushing up cost and time by developing custom IP and 2) bringing additional risk from developing “one-of-a-kind” IP that does not benefit from a wide usage base.

The make-buy decision, being essentially an economic one, is altered by the availability of COTS IP and thus design decisions that are not currently economically feasible become possible. This factor alone will help to drive down non-recurring and recurring cost and also reduce life cycle cost from the avoidance of obsolescence. The economic aspect drives the decision process on how to deal with an obsolescence event.

The only known COTS IPs that have an available DO-254 DAL A package provided are the Altera NIOS-SC processor IP, the TTECH ARINC 664 controller in Xilinx FPGAs and ARINC-429 interface IP from BARCO and Ultra Electronics. The NIOS-SC is a relatively low end processor with limited application areas. The small market size and high cost of developing a DO-254 support package is likely to discourage IP suppliers from entering the market to any significant degree, so the availability of functions is expected to remain very low for the foreseeable future.

This section proposes how we might define selection criteria and a process for assessing COTS IP and vendors for suitability for use in certified aerospace products of all design assurance levels. Suitability here means not only that the COTS IP/PD combination performs its required functions under all the expected normal and abnormal operating conditions, but also that it has been developed within a structured and controlled process of assured quality that is consistent with the DO-254 process-based design assurance philosophy. This process will provide high confidence that the IP is functionally correct and error free and that the target end-use equipment can be certified.
There exists the possibility that any electronic component, whether containing IP or not, will contain design errors. This possibility is recognized by the current guidance; however the current Title 14 CFR guidance also recognizes that such errors should be mitigated by system design measures such as redundancy and dissimilarity developed through the processes of ARP-4754A and ARP-4761 augmented through the process-based design assurance processes of DO-178C and DO-254.

DO-254 sets out a complete process for the specification, design, verification and documentation of complex electronic hardware, of which PD’s are an example. Currently DO-254 only applies to PD’s that are programmed with avionics manufacturer developed IP. This restriction is due to the limitations, guidance and policy imposed by the FAA [143-148] since the impracticality of applying it to COTS hardware is recognized. DO-254 also defines the supporting infrastructure that all the design activities must be accomplished within, such as quality assurance, requirements traceability, configuration management, and design and coding standards. This collection of design, verification and infrastructure documentation is collectively referred to as life cycle data. DO-254 is generic enough that user defined data formats are quite acceptable provided they meet the content requirements and are properly cross-referenced to the DO-254 hardware life cycle data item descriptions as described in section 9.3.2.

Since COTS IP is developed for wide usage in a range of applications, there are often multiple operating modes and features. When used in a particular application, some of these modes and features may never be invoked and therefore represent the hardware equivalent of dead code. Dead code can be a hazard since there are no corresponding requirements, and thus may not be tested. Guarding against erroneous invocation of dead code must be one of the objectives of verification, however this assumes that the user knows what dead code there is in the COTS IP and this may not be the case. This issue is not confined to IP; a similar concern arises for software and for electronic components and modules where modes are controlled by a configuration register or pin programming. This is a difficult problem, but some of the advanced verification techniques discussed in section 9.4.1 may be able to address this issue.

The major markets for COTS IP are in telecommunications, computers and other non-aero sectors. Here, there is no requirement to demonstrate design assurance to a certification authority such as the FAA or EASA. In these markets, cost and time to market are the principal drivers rather than safety.

Aerospace application of COTS IP is constrained by the requirement to demonstrate design assurance. In the civil aircraft market, the FAA invokes design assurance requirements through AC 20-152 [143] associated policy [148] which in turn references DO-254 as an acceptable (but not the only) means of compliance. For military equipment, similar requirements are often levied by the customer on a contract by contract basis. AC 20-152 currently restricts the application of DO-254 to PDs, largely due to the recognized impracticability of obtaining the life cycle data for COTS electronic components.

There is little experience of regulatory approval of systems that contain COTS IP and therefore there is no well-established process for doing so. Recent, but unofficial, guidance for the FAA certification-process staff in conducting DO-254 reviews of PDs is provided in draft Order 8110.CEH [147, 149] and in a more general DO-254 Job Aid [146]. These do not explicitly
mention COTS IP. In addition, CAST position papers [145] provide some additional guidance, but also does not specifically address how COTS IP should be certified.

9.3.1. A Suggested Approach to COTS IP Assurance

The demonstration of DO-254 compliance is difficult for COTS IP. The life cycle data that is required by DO-254 is not generally provided. The proposition in this section is that much of the data exists in a well-managed COTS IP vendor, but may not be organized in the way consistent with DO-254. To what extent this is true is a research question suggested in sections 9.4.1.4 and 11. This section expands on the approach developed in [150]. The initial assumption is that high quality, well managed COTS IP vendors have an interest in developing products that are free from design errors and correctly implement the design requirements set out for the product at the start of the development program. This assumption is based on the expectation that vendors who supply large volumes will not be prepared to risk that design errors will slip through the validation and verification processes, which cause defects in the products of their customers and a corresponding loss of confidence. COTS IP vendors have a strong incentive (commercially, not safety driven) to eliminate design errors from their products, since these errors lead to costly rework, recalls and product liability penalties. They also have a broad customer and application base so that problem reports are quickly fed back to the vendor. The IEEE Draft Standard P1734 [151] is intended to provide a unified view of quality measures for IP to facilitate the use and integration of this IP in electronic systems.

There is a strong similarity between the hardware design process defined in DO-254 and the ISO-9001 philosophy of “say what you do -- do what you say”. That is to say, avionics vendors must define their IP processes in great detail, show that these processes satisfy the objectives of DO-254 and support the processes with a QA function to ensure they are followed and can be demonstrated to have been followed. There is, therefore, an expectation that a pre-requisite for vendors to be able to supply COTS IP of adequate quality is that they carry an ISO-9001 or equivalent approval. This approval is intended to assure that the vendor follows a well-defined and documented development process extending from requirements capture through to validation and verification, with supporting process for quality assurance, configuration management, problem reporting, and resolution. For these types of vendors there will likely be a strong correlation between vendor process and documents, and DO-254 process and life cycle data items.

The general approach proposed is to set out a discovery process to map DO-254 life cycle data items to the corresponding items of vendor data. This discovery process is a type of gap analysis in the vendor’s processes, and thus highlights the additional costs to the user of creating the missing life cycle data or developing mitigations in higher-level assemblies or software.

This process-oriented approach is based on a structured examination (through an audit) of whether the COTS IP vendor has established and followed a rigorous and structured approach to the specification, design, and verification of the COTS IP, and that it has been used in multiple applications with no unresolved problem reports outstanding. Furthermore, the process validates that the vendor operates adequate process assurance and quality assurance controls that are able to assure configuration management of the delivered product, the supporting application documents and the necessary supporting tools. That these processes are in place and operating
correctly will be verified by an independent external certification body performing periodic audits to the top-level quality certificate (e.g., ISO-9001).

The intent is to gain assurance that the necessary processes exist, are followed and are adequate rather than reviewing the artifacts of each and every COTS IP. The vendor will be expected (as they typically do) to provide minimum deliverable documentation sufficient for successful application, with references into the qualification documentation.

A suggested map of the proposed process is shown in Figure 8. The audit elements may be based on the VSIA QIP tool [152].
Figure 8 - Process Map
**9.3.2. Representative Mapping of RTCA/DO-254 Data Items and Supplier Documents**

The tables below are excerpted from DO-254 Appendix A [41] as an example of templates to be used during the discovery process involved in selecting a COTS IP and supplier. These example templates are for a COTS IP that is intended for use in a Design Assurance Level A (DAL-A) product. Lesser configuration management (CM) categories apply to lower DAL assignments though this would imply that an assessment performed at a lower level could not later be used to establish approval of the IP for use in a product with a higher DAL.

During this assessment process, a cross-reference map linking DO-254 objectives to supplier process evidence would be completed either by prior submission or during an on-site supplier audit/review. This will involve substantial time and effort initially by both the customer and supplier, but is likely to be substantially repetitive during subsequent selections from the same supplier, since the requirements validation, IP design and verification processes are largely independent of the actual product. The intent is to minimize the number of documents that need to be submitted, while ensuring that the supplier-processes closely follow the requirements-based verification paradigm of DO-254.

Should the audit process highlight deficiencies, then the choices are for the COTS IP supplier to correct the deficiency (e.g., design data, verification results, and documentation), or for the user to provide additional design and architectural mitigations, or for the supplier to be disapproved.

**Table 4 – DO-254 [41] Appendix A Objectives/Supplier Evidence**

<table>
<thead>
<tr>
<th>Data section</th>
<th>DO-254 Hardware Life Cycle Data</th>
<th>DO-254 Objectives</th>
<th>Submit</th>
<th>CM Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.1.2</td>
<td>Hardware Design Plan</td>
<td>4.1(1, 2, 3, 4)</td>
<td>HC2</td>
<td></td>
</tr>
<tr>
<td>10.1.3</td>
<td>Hardware Validation Plan</td>
<td>4.1(1, 2, 3); 6.1.1</td>
<td>HC2</td>
<td></td>
</tr>
<tr>
<td>10.1.4</td>
<td>Hardware Verification Plan</td>
<td>4.1(1, 2, 3, 4); 6.2.1(1)</td>
<td>HC2</td>
<td></td>
</tr>
<tr>
<td>10.1.5</td>
<td>Hardware Configuration Management Plan</td>
<td>4.1(5); 7.1(3)</td>
<td>HC1</td>
<td></td>
</tr>
<tr>
<td>10.1.6</td>
<td>Hardware Process Assurance Plan</td>
<td>4.1(4); 8.1(1, 2, 3)</td>
<td>HC2</td>
<td></td>
</tr>
<tr>
<td>10.2.1</td>
<td>Requirements Standards</td>
<td>4.1(2)</td>
<td>HC2</td>
<td></td>
</tr>
<tr>
<td>10.2.2</td>
<td>Hardware Design Standards</td>
<td>4.1(2)</td>
<td>HC2</td>
<td></td>
</tr>
<tr>
<td>10.2.3</td>
<td>Validation and Verification Standards</td>
<td>4.1(2)</td>
<td>HC2</td>
<td></td>
</tr>
<tr>
<td>10.2.4</td>
<td>Hardware Archive Standards</td>
<td>5.5.1(1); 7.1(1, 2)</td>
<td>HC2</td>
<td></td>
</tr>
<tr>
<td>10.3.1</td>
<td>Hardware Requirements</td>
<td>5.1.1(1, 2); 5.2.1(2); 5.3.1(2); 5.4.1(3); 5.5.1(1, 2, 3); 6.1.1; 6.2.1(1)</td>
<td>HC1</td>
<td></td>
</tr>
<tr>
<td>10.3.2.1</td>
<td>Conceptual Design Data</td>
<td>5.2.1(1)</td>
<td>HC2</td>
<td></td>
</tr>
<tr>
<td>10.3.2.2</td>
<td>Detailed Design Data</td>
<td>5.3.1(1); 5.4.1(2)</td>
<td>HC1</td>
<td></td>
</tr>
<tr>
<td>10.3.2.2.2</td>
<td>Assembly Drawings</td>
<td>5.3.1(1); 5.4.1(2); 5.5.1(1)</td>
<td>S</td>
<td>HC1</td>
</tr>
<tr>
<td>10.3.2.2.4</td>
<td>Hardware/Software Interface Data</td>
<td>5.3.1(1); 5.5.1(1)</td>
<td>S</td>
<td>HC1</td>
</tr>
<tr>
<td>10.4.1</td>
<td>Hardware Traceability Data</td>
<td>6.1.1; 6.2.1(1, 3)</td>
<td></td>
<td>HC2</td>
</tr>
<tr>
<td>10.4.2</td>
<td>Hardware Review and Analysis Procedures</td>
<td>6.1.1; 6.2.1(1)</td>
<td></td>
<td>HC1</td>
</tr>
<tr>
<td>10.4.3</td>
<td>Hardware Review and Analysis Results</td>
<td>6.1.1; 6.2.1(1)</td>
<td></td>
<td>HC2</td>
</tr>
<tr>
<td>10.4.4</td>
<td>Hardware Test Procedures</td>
<td>6.1.1; 6.2.1(1)</td>
<td></td>
<td>HC1</td>
</tr>
<tr>
<td>10.4.5</td>
<td>Hardware Test Results</td>
<td>6.1.1; 6.2.1(1)</td>
<td></td>
<td>HC2</td>
</tr>
<tr>
<td>10.5</td>
<td>Hardware Acceptance Test Criteria</td>
<td>5.5.1(3)</td>
<td></td>
<td>HC2</td>
</tr>
<tr>
<td>10.6</td>
<td>Problem Reports</td>
<td>5.1.1(3); 5.2.1(3); 5.3.1(3); 5.4.1(4); 5.5.1(4); 6.2.1(2)</td>
<td></td>
<td>HC2</td>
</tr>
<tr>
<td>10.7</td>
<td>Hardware Configuration Management Records</td>
<td>5.5.1(1); 7.1(1)</td>
<td></td>
<td>HC2</td>
</tr>
<tr>
<td>10.8</td>
<td>Hardware Process Assurance Records</td>
<td>7.1(2); 8.1(1, 2, 3)</td>
<td></td>
<td>HC2</td>
</tr>
</tbody>
</table>

Requirements for configuration management of the data items by the IP supplier and the definitions of HC1/2 are excerpted from DO-254 [41] Table 7-1 and reproduced below in Table 5.
9.4. ADDITIONAL CONSIDERATIONS

There are no data items listed for DO-254 section 11 [41]. The additional data items listed in Table 6 should be part of the documentation provided by the COTS IP supplier.

Table 6 – Additional DO-254 Objectives [41]

<table>
<thead>
<tr>
<th>Hardware Life Cycle Data</th>
<th>DO-254 Objectives</th>
<th>CM Category</th>
<th>Submit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Service Experience Data Acceptability Criteria</td>
<td>11.3.1(1, 2, 3)</td>
<td>HC2</td>
<td>S</td>
</tr>
<tr>
<td>Assessment of Product Service Experience Data</td>
<td>11.3.2(1, 2, 3, 4)</td>
<td>HC2</td>
<td>S</td>
</tr>
<tr>
<td>Product Service Experience Assessment Data</td>
<td>11.3.3(1, 2, 3, 4)</td>
<td>HC2</td>
<td>S</td>
</tr>
</tbody>
</table>

9.4.1. Advanced Methods

The COTS IP assurance methods in section 9.3 are essentially process-based methods that replace user processes with vendor processes of demonstrably equivalent rigor. While these are a minimum requirement, additional assurance methods could be used which operate at the functional level and do not require knowledge of the internals of the COTS IP. These methods depend on a formalized representation of the functional properties of the item that can be verified...
using conventional directed (requirements based) test or randomized testing [153]. Functional properties can be captured in tools such as System Verilog.

9.4.1.1. Run-Time Methods

Run-time methods are architectural mitigations that add independent observer elements to monitor the IP function at run time and provide error detection. An error is any function output that results in a deviation from the output expected by the monitor or a hazardous situation. Expected outputs are developed from the functional properties of the hardware or software, expressed as a functional model and hazardous situations are developed from the functional hazard and system safety assessments. In order for this to be effective, common cause (design) errors between the function and monitor must be eliminated by techniques such as hardware and software dissimilarity. Some work on this approach has been reported in [154, 155]. Functional hazard and system safety assessment in conventional practice today typically considers only hardware failures as contributors to hazards. Recent work that derives hazards based on functional failures is exemplified in references [156, 157]. A new field of research called Software Health Management (see for example reference [158]) offers some promising new techniques to detect hazards at run time. These techniques bear some resemblances to model-based techniques.

9.4.1.2. Model-Based Verification

Model-based design first creates executable, high-level functional models that can be stimulated in a simulation environment. These types of tools are useful for exploring rare events (or corner cases) and developing high-level requirements that can be tested for during verification. One example of this type of tool is the Honeywell Integrated Lifecycle Tools and Environment (HiLiTE) [159], which is a proprietary Honeywell tool that generates test cases from a functional model of the function under test. The model is generated from the functional specification, and therefore is implementation independent. Commercial tools such as Simulink, System Verilog, or SCADE can be used to generate the high-level models. In the context of COTS IP, model generation can only be performed according to the information provided by the supplier, i.e., the user guide, application notes, and data sheet. Test cases provided by this tool can be used for testing the IP in a simulator and the final FPGA. A subset of these tests may also inform the equipment verification plan.

9.4.1.3. Functional Failure Path Analysis

Functional failure path analysis (FFPA) [160] was introduced in DO-254 Appendix B. The FFPA decomposes a design into paths of hardware elements that cause or contribute to the loss of a function identified by a functional hazard assessment. This process allows a correspondence between hardware elements, functional failures and system hazards to be established so that the hardware as a whole need not be classified according to the highest level of design assurance required by any one function.
This method may be used to identify hardware elements (and thus COTS IP) that do not contribute to identified hazards, and therefore elements for which design assurance is not required. The method does not offer any assurance for COTS IP elements that do contribute to hazards, since the foregoing limitations on the ability to analyze the design remain.

9.4.1.4. COTS IP Research Questions

The development of a process to assure the safety of equipment using COTS IP is partly a technical problem and partly a consensus building process. Design errors cannot be provably eliminated in any software, IP, hardware or operating procedure design process (except in a small subset of cases that are amenable to formal methods), and therefore the exercise is to some degree about establishing a set of ‘rules’ and ‘best practices’ (i.e. acceptable means of compliance) that are adjudged by the industry and regulators to adequately assure safety.

The following are suggested as research questions:

- How can the COTS IP usage base be discerned and filtered for relevant usage?
- Do those COTS IP vendors that are willing and able to demonstrate their quality standards and internal design controls represent a sufficiently large class of applications and functions, which prove to be useful?
- How should vendor standards and controls be assessed, both initially (for a new COTS IP product) and for update through to declared EOL?
- What are the current constraints of DO-254 that constrain or prevent the use of COTS IP?
- What, if any, amendments should be made to current guidance and standards to establish an industry/regulator consensus (i.e. revised acceptable means of compliance) on safe use practices?
- What architectural, design or verification measures can be applied to mitigate the safety hazards that COTS IP might produce?
- Is it practicable to develop a set of metrics against which COTS IP could be scored?
- What would be the approval threshold for the metrics within the certification process?
- How can COTS IP unused functionality (dead code) be identified and shown to be permanently disabled or deactivated?
- What classes of functions and implementations are amenable to model-based verification?
- What is the effectiveness of the DO-254 advanced methods and to what classes of COTS IP are they applicable?
10. FINDINGS

Obsolescence is caused by both top-down regulatory and legal pressures and bottom-up supply chain pressures. GA owner-operators and manufacturers of all types of avionics and aircraft have no control over either, but are nonetheless required to respond.

The present state of obsolescence management in commercial and military aerospace in general, and in the GA industry in particular, is at best, focused on getting the maximum forewarning of obsolescence and reacting to that.

The obsolescence problem has been around for many years, but because of its difficulty and changing market dynamics it has been, and continues to be, an evolutionary process to develop mitigation methods. The Part 25 aircraft manufacturers are taking the lead in developing and promoting standardized requirements through bodies such as the IEC with the support of the avionics manufacturers. Part 23 aircraft manufacturers have, so far, not been evident to any large extent in these activities. Avionics manufacturers are moving steadily to improve their internal mitigation processes and these experiences are being incorporated in the standardization activities. This is necessarily a slow process because the underlying business problem is that of the equitable distribution of obsolescence costs in an open, competitive market. Consequently, mutually agreeable and acceptable policies between suppliers and customers have to be pursued.

The internal processes for obsolescence management used by avionics manufacturers are largely the same for all types of products, GA or otherwise. The differences arise mostly in the resolution option selection, which is driven mostly by the differing economics of the target markets.

The rate of progress on process development and maturity level is constrained by the high costs involved in setting up and operating the infrastructure, just to keep-up with the blizzard of new obsolescence issues, lack of obsolescence aware design patterns, and lack of economic analysis and forecasting tools to select the resolution option that is most likely to be the most cost effective. The costs of obsolescence management efforts must eventually find their way into product price, so the problem is essentially an economic one that rests on an ability to provide a compelling value proposition to the customer that long term savings can be realized in return for short term cost. The further progression of obsolescence management maturity is likely to be through the development of obsolescence-aware design patterns and economic modeling and forecasting methods, from which product life cycle plans and customer value propositions can be derived.

Obsolescence has marginal safety or security impact since 1) the airworthiness regulations governing AEH apply to obsolescence driven change as much as to the original design and also to change for any other reason, and 2) the regulations are technically adequate for assuring initial and continued airworthiness. Whilst poorly controlled obsolescence resolutions or redesign or aviation rule changes could potentially lead to a risk of some aircraft operating with obsolete or non-conforming equipment, that is an enforcement issue that cannot be easily mitigated through technical means.

There are numerous areas where obsolescence management practices and guidance could be improved. Most of these areas are ultimately dependent on methods for forecasting component obsolescence, market demand, and regulatory actions, which would enable methods and
algorithms for decision making under uncertainty. Obsolescence management must be seen as a holistic risk minimization activity, since obsolescence will always exist and is subject to factors with a high degree of uncertainty.

11. **FUTURE WORK**

Several potential and promising research topics have been identified in this report. These are summarized in Table 7 below. The suggested participants are categorized as:

- **Industry** – Avionics, aircraft manufacturers, industry trade associations, consultants
- **Universities** - University-based collaborative research centers
- **Government** – DoD, DoE, FAA, EASA, NASA, Federally Funded Research Centers

**Table 7 – Possibilities for Combined Research Topics**

<table>
<thead>
<tr>
<th>Research Topic</th>
<th>Industry</th>
<th>Universities</th>
<th>Government</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decision support tools to aid management in selecting from the available choices of responses to an obsolescence event of either an electronic component or complete equipment EOL. Such tools will draw from research on economics and optimization algorithms.</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>The feasibility, cost/benefit tradeoff and market acceptability of establishing a code of practice or enforceable regulations and contract terms to guarantee a minimum period of support for avionics equipment after discontinuance</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Development of auditable standards for obsolescence management processes and capabilities of equipment and aircraft manufacturers</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Develop new design assurance techniques and regulatory guidance language that would permit the use of COTS IP. The IP can be perpetually licensed, and thus is immune to obsolescence. This solution is attractive to avoid the obsolescence of processors and other complex hardware, but is presently impossible because the lack of DO-254 support artifacts, except in a few limited cases. A promising research avenue is to investigate whether adequate design assurance can be given by DO-254 to manufacturer process mapping</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
Development of a means to calculate a probabilistic measure of obsolescence risk or forecast EOL for components that have not yet been reported as soon-to-be obsolete. This would provide a real time obsolescence health index for currently used components. A health index could incorporate a variety of metrics, such as the present known state, indices produced by the obsolescence status tools, technology class or grouping, component technology roadmap forecasts such as International Technology Roadmap for Semiconductors (ITRS) and National Electronics Manufacturers Initiative (NEMI), manufacturer product deletion history, the probability and timing of mergers and acquisitions, and fiscal health measures from business information sources.  

<table>
<thead>
<tr>
<th>Task Description</th>
<th>Completion Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop a probabilistic LTB/BB estimation method. This is a difficult and unresolved problem, since it depends on what future orders can be expected and over what timescale, and also on how many will be needed to support existing items in repair. These factors carry considerable uncertainty because market forecasts are inherently unreliable and future spares needs depend on both the number of items in service and in-service failure rate.</td>
<td>X X</td>
</tr>
<tr>
<td>Develop standards, guides and best practice for the preservation of manufacturing tools/processes and software/HDL tools and platforms.</td>
<td>X X</td>
</tr>
<tr>
<td>Extend LCC models in the literature to TOC models for aircraft manufacturers (and possibly fleet owners) to enhance the fidelity of the construction of aircraft roadmaps and technology refresh plans.</td>
<td>X X</td>
</tr>
<tr>
<td>Develop a modulated list of the minimum artifacts needed to show continued airworthiness after equipment modification of varying degrees of complexity.</td>
<td>X X</td>
</tr>
<tr>
<td>Develop reference material describing the principal components and structure of a product life cycle plan. This material would serve as a guide to the evaluation of product life cycle plan.</td>
<td>X X</td>
</tr>
<tr>
<td>Develop proposed modifications to the guidance for the NPRM processes to provide adequate response time to users who are affected by system obsolescence induced by rulemaking.</td>
<td>X X</td>
</tr>
</tbody>
</table>
12. **RECOMMENDATIONS**

The FAA is recommended to give consideration to providing guidance to industry in the following areas.

- **Recommended practices to assure continued airworthiness following changes to the design of avionics, whether from obsolescence resolution or any other cause.** The required level of design assurance should be tailored to the extent of the change and its probable impact on continued airworthiness (see section 6.2). It is recommended that the FAA should develop general equipment change guidance to complement the existing aircraft level change guidance. This would define the steps required to 1) assess the impact of the changes on the aircraft type certificate and 2) maintain the original equipment design assurance and airworthiness under various degrees of modification. We recommend the following steps:
  - Determine the change(s) to be made to hardware and any consequential changes to software.
  - Classify the whole change package according to complexity as major or minor.
  - Document the changes and classification in a Change Impact Analysis (CIA).
  - From the classification, determine the steps necessary for continued airworthiness of software and hardware and determine whether a type certificate amendment is required.
  - Open a modification project with the FAA if necessary to amend the Instructions for Continued Airworthiness (ICA).

- **Expand FAA internal ICA working guidance (Orders and Notices) to define the degree of involvement with the applicant when changes are made or a revised certification application submitted.**

- **Existing design assurance guidance gives some guidance on modification procedures and requirements, but this should be expanded to provide a more detailed set of steps and considerations according to the classification of the modification and provide explicit requirements for artifacts.**

- **Control of the aviation policy, guidance, regulation, and order-making process to allow adequate time for operators to spread the cost of upgrades (see section 6.3).**

- **Provide guidance on the minimum contents of a product life cycle plan.** See Appendix B - Generic Product Life Cycle Plan for a proposed template.

- **Provide updated guidance for methods and processes for the selection and use of COTS IP to assure that adequate design assurance is obtained (see section 9).**

- **Recommended practices for manufacturers of avionics to notify customers of product end of life.** These practices are not considered to impact safety assurance or certification. The intent of these guidelines is to ensure that avionics equipment users have adequate information and a reasonable amount of time to adapt their operations and procure alternative products where necessary. The recommended information should be at least the following:
  - The latest date for LTB order (After this date no further orders can be accepted).
  - The latest date for shipment of LTB orders (After this date no further shipments will be made).
- If design authority, design approval holder, manufacturing rights or support has been licensed or transferred to a third party, the name and address of the licensee.
- A list of approved alternative products and approvals (if any) for each affected aircraft type.
- The period of continued support after the warranty expires. During this period, maintenance support will be provided, possibly by a licensee.
- The extent of continued support e.g., provision of repair services by the manufacturer, licensee or approved repair stations, incorporation of airworthiness directives (AD) as required by the FAA and updates to technical publications.

• Recommended practices to assure that design, manufacturing and support tooling is maintained and supported through to the end of service life.
13. REFERENCES


Bastia, S., "Next generation technologies to combat counterfeiting of electronic," *Components and Packaging Technologies, IEEE Transactions on [see also Components,*


JEDEC, "PRODUCT DISCONTINUANCE," JESD48B, May 2005


APPENDIX A - OBSOLESCENCE CAPABILITY SELF-ASSESSMENT

The following questionnaire is intended to assist avionics and aircraft manufacturers in self-assessing their obsolescence and life cycle management maturity level.

1. Does obsolescence have a net negative impact on profitability (consider not just cost, but also new market opportunities created by obsolescence of own and competitor older products?)
2. Do you devote engineering and other financial resources to obsolescence management?
3. Do you incorporate terms in procurement contracts for product obsolescence?
4. How much notice of product discontinuance (i.e., no further order acceptance) do you typically provide to customers?
   a. Is this a formalized company policy?
   b. What notification mechanism do you use?
5. Do you ever discontinue maintenance and support for obsolete products?
6. Have you experienced cases where regulation, rulemaking or legislation has forced you to obsolete a product?
7. Do your customers expect you to manage obsolescence transparently and at no direct cost?
8. Do your design processes consider obsolescence risk or susceptibility as a discriminator between design choices (e.g., make/buy, software/hardware implementation)?
9. Do you use decision support tools and processes to assist in choosing between resolution options (e.g., last time buy, re-design, emulation etc.)?
10. Do you have a defined, formalized obsolescence management plan?
   a. Is this a general plan, several product specific plans, or both?
11. Do you create and maintain product life cycle plans for each product?
12. Do your product life cycle plans include planning for
   a. Expected obsolescence of supplies?
   b. Demand variation?
   c. Support needs?
   d. Product upgrades?
   e. Product end of life?
13. Do you regard obsolescence as a shared problem, a problem you expect your suppliers to take care of, or entirely your problem?
14. What is the customer value proposition for obsolescence management?
   a. Are you willing to pay a premium on the product price or on a support contract to assure that fleet procurement, repair and upgrade are managed for you transparently for a given period?
   b. Are such arrangements contractually feasible?
   c. How should such contracts be priced?
15. Do you get adequate notice that a supplier has obsoleted a product you need?
   a. How do you get that notification?
   b. What tools are used to track it through to a resolution?
16. Have you bought fake components or otherwise unapproved parts?
   a. Do you have formalized controls to detect/prevent that?
17. Do you maintain an approved parts and supplier list?
   a. Is component selection outside of that subject to special controls or approvals?
18. What metrics do you use for obsolescence health status?
19. Is obsolescence health status used as a selection criterion during design?
20. Is an obsolescence health assessment of a BOM required prior to and as a condition of transition to production?
21. Do you archive the design tools and platforms required to update hardware or software throughout the life cycle?
22. Do you have a defined, formalized process to classify changes (for obsolescence or any other reason) as major/minor from a continued airworthiness perspective?
23. From your answers above, where would you grade your obsolescence management capability/maturity in the scale in the figure below (1-3+) [5].

![Intensity Levels Table]

Notes: 1. VHDL: Very High Speed Integrated Circuit (VHSIC) Hardware Definition Language 2. EDI: Electronic Data Interchange
APPENDIX B - GENERIC PRODUCT LIFE CYCLE PLAN

This Appendix sets out a generic product life cycle plan template (hereinafter ‘the template’) to guide the development of a product specific product life cycle plan (hereinafter ‘the plan’). The manufacturer of an avionics product in series production is expected to maintain a plan for each product and to maintain the plan current throughout the life cycle as the hardware design evolves for any reason. Modifications may occur for a variety of reasons, e.g., functional upgrade, obsolescence recovery, and reliability improvement. Given the dynamic nature of both the product market and the supply base, it may be advantageous for the plan owner to implement it as a data or web-based computer application utilizing live data feeds from various engineering and manufacturing IT infrastructure assets, but this is not a requirement.

1. PURPOSE

Avionics products are in a constant state of evolution as the availability of manufacturing facilities, materiel and customer demand changes over time. Current life cycle management processes mostly react to changes in order backlog or to EOL notices issued by component suppliers. One of a number of available actions (e.g., BB, LTB, redesign, and EOL) is then selected and the process repeats until EOL. The reactive approach typically provides only 6-12 months of reaction time. This is insufficient for the longer term planning that is necessary to implement and certify complex design change and to efficiently manage the wider portfolio of multiple product life cycles that share common components. Efficient management of the life cycles requires that a product plan be established for each product early on so that investment and recurring cost optimized decision points can be planned for and the necessary materiel, budget and staffing can be prioritized among competing demands. A product life cycle plan shows the expected substance and timing of life cycle events that would impact the avionics supplier’s ability or willingness to continue with production and support of a particular product and what actions are to be taken at those events.

It is assumed that product design and modification will be accomplished in satisfaction of the, as from time to time amended, currently applicable Title 14 CFR airworthiness assurance regulations, standards and guidance and that the supplier will maintain documented processes and procedures to accomplish this.

The template defines a set of objectives to be met by the plan, categorized under various headings. The template does not specify or define how those objectives will be satisfied; activities to satisfy the objectives and the resulting artifacts will be defined in the plan, or incorporated by reference to managed and documented standards and procedures.

It is expected that;

- The referenced internal company standards and procedures will be controlled under the manufacturer’s approved configuration management and quality system.
- This template will be available to regulators and customers to guide their evaluation of a plan offered or proposed by an avionics supplier.
- The avionics product manufacturer will develop, for internal use only, a plan according to the provisions of this template.
• The plan is not required to be (but may be) publicly available since it may contain proprietary information.
• Disclosure of the plan may be subject to the terms of a proprietary information agreement if so desired by the manufacturer.
• The avionics product manufacturer will provide regular evidence of continued plan compliance.

There is no expectation that the plan will be provided to regulators or customers, since it may include confidential, proprietary or competition sensitive information. For plan compliance, see section 6 of this Appendix.

The manufacturer may choose to minimize product life cycle costs by using optimization methods for the selection and timing of upgrades, obsolescence recoveries and EOL or end of support (EOS) notification. Manufacturers are free to optimize a product plan atomically or globally across a portfolio of products.

Explanatory notes are given in italicized text. These are intended for guidance only; they are not intended to be plan objectives. The plan owner may use any suitable, documented methods and processes to accomplish the objectives.

2. SCOPE

This template is applicable to a product life cycle plan for any avionics product.

3. REFERENCES

For dated references, the issue of the given date shall be applicable; otherwise the latest issue is applicable.


No other references are provided. It is expected that all activities associated with life cycle management will satisfy the current and applicable Title 14 CFR Regulations, Guidance, Policy and Standards as from time to time amended.

4. DEFINITIONS

First we provide some definitions of terms used in this appendix.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product</td>
<td>An avionics product whose design authority is held by the plan owner</td>
</tr>
<tr>
<td>Plan owner</td>
<td>The holder of the product design authority</td>
</tr>
<tr>
<td><strong>Component</strong></td>
<td>A COTS electronic component, material, non-repairable sub-assembly, software code version, software license, IP version, or IP license listed in the product BOM. A component carries a unique component manufacturer part number recorded in the users component information database that is linked to the AEH product manufacturer’s internal unique part number</td>
</tr>
<tr>
<td><strong>LTB date</strong></td>
<td>Date by which a LTB of a product should be made. No further orders can be entered after this date.</td>
</tr>
<tr>
<td><strong>BOM</strong></td>
<td>Bill of Materials for a product comprising a list of components used for product manufacture, test and release</td>
</tr>
<tr>
<td><strong>EOL</strong></td>
<td>End of Life of a component or product. The product will no longer be manufactured</td>
</tr>
</tbody>
</table>
| **EOS** | End of Support  
- of a product – will no longer be maintained or supported by the plan owner  
- of a repairable sub-assembly – will no longer be maintained or supported by the sub-assembly manufacturer or his licensed designees |
| **EOL Notice** | A document detailing any or all of a product EOL date, EOS date or LTB date |
| **Functionally obsolete** | Forecast demand is zero or small |
| **Obsolete** | A component is not manufactured by any source. Diminishing stock may continue to be available from holdings or the market |
| **Licensing** | Transfer of product design authority, production drawings, tooling, test procedures, test software and technical documentation to a third party |
| **Product life cycle** | Extends from initial product type sale to the later of EOL or EOS date |
| **Product life cycle plan template** | A document detailing the contents of a product life cycle plan (this document) |
| **Product life cycle plan** | A detailed plan for the management of a product life cycle in accordance with the provisions of this template |
| **Regulator** | Internationally recognized aviation safety organization that approves certification applications, e.g., FAA, EASA |

5. **PLAN OBJECTIVES**
In the sub-sections that follow, 25 plan objectives in 7 groups are defined. A product plan shall show how each of these objectives is satisfied. Mandatory requirements are indicated by “shall”.

NOTE: MANUFACTURERS MAY SHOW SATISFACTION BY ANY SUITABLE MEANS INCLUDING BY REFERENCE TO OTHER CONTROLLED COMPANY DOCUMENTS OR DATA SOURCES.

A. PLAN SCOPE AND MAINTENANCE

Objective-01: Each certified avionics product currently in production, maintained or supported by the plan owner shall have a plan

Objective-02: The plan shall be revised on significant events to reflect new or updated information

NOTE: MANUFACTURERS SHOULD DEFINE APPROPRIATE SIGNIFICANT EVENTS, E.G. COMPONENT EOL NOTICES, CHANGE IN PRODUCT DEMAND, PRODUCT UPGRADES.

Objective-03: The plan shall cover the planned life cycle up to the later of EOL or EOS

Objective-04: The plan owner shall manage the plan under an approved configuration control system

Objective-05: The plan shall identify the plan owner organization responsible for maintenance of the plan

Objective-06: The plan shall identify the documented implementation procedures that assure conformance to this template

Objective-07: The plan shall identify exceptions to this template

NOTE: IT IS EXPECTED THAT PRODUCTS WILL BE IN A CONTINUAL STATE OF EVOLUTION THROUGH FUNCTIONAL UPGRADES AND OBSOLESCENCE RECOVERY ACTIONS THROUGHOUT THE LIFE CYCLE. THE PLAN WILL LIKewise BE IN A CONSTANT STATE OF EVOLUTION

B. PRODUCT DEMAND

Objective-08: The plan shall identify the expected product demand profile showing the expected volume for each planning period over the planned product life cycle

NOTE: MANUFACTURERS MAY USE ANY PLANNING PERIOD, TYPICALLY 1 YEAR HOWEVER SIGNIFICANT EVENTS MAY PROMPT A PLAN REVISION

NOTE: MANUFACTURERS MAY ELECT TO EOL A PRODUCT IF THE FORECAST DEMAND FALLS BELOW AN ECONOMIC RATE OF PRODUCTION

C. PRODUCT REPAIR
Objective-09: The plan shall identify the expected repair component demand profile over the product life cycle for each component on the BOM for each planning period

NOTE: MANUFACTURERS MAY USE ANY PLANNING PERIOD, TYPICALLY 1 YEAR

D. PRODUCT MODIFICATION

Objective-10: The plan shall identify the dates when product modifications are intended to be performed

Objective-11: The plan shall identify the manufacturers documented procedures and processes applicable to modifications

NOTE: PRODUCT MODIFICATIONS MAY OCCUR WHEN PERFORMING OBSOLESCENCE RECOVERY OR FOR A VARIETY OF OTHER REASONS

E. PRODUCT EOL OR EOS

Objective-12: The plan shall identify planned product EOL and EOS dates, if any

Objective-13: The plan shall identify if and when the product is planned to be licensed

Objective-14: Plan ownership shall be transferred to the licensee when the product is licensed

Objective-15: An SB or SIL shall be issued to known users and customers within a reasonable amount of time identifying the announced product EOL or EOS dates

NOTE: THE PRODUCT MANUFACTURER MAY OPT TO LICENSE THE PRODUCT AT ANY TIME

NOTE: IT IS NORMALLY EXPECTED THAT EOL WILL PRECEDE EOS, BUT THIS IS NOT NECESSARILY TRUE

NOTE: PRODUCT MANUFACTURERS MAY ELECT TO OBSOLETE A PRODUCT THROUGH AN EOL NOTICE IF THE NECESSARY MODIFICATIONS WOULD BE TECHNICALLY OR ECONOMICALLY INFEASIBLE

F. COMPONENT OBSOLESCENCE, SELECTION AND USE

Objective-16: The plan shall maintain a current estimate of the expected obsolescence date of all components on the BOM

Objective-17: The plan shall forecast the dates and quantity of component LTBs

Objective-18: The plan shall forecast the expected timing for the obsolescence of each component

Objective-19: The plan shall identify the expected recovery action(s) for each forecast obsolescence event
Objective-20: The forecast component obsolescence date shall be updated in the plan if a new or alternate component is added or substituted in the BOM

Objective-21: The plan shall maintain a current forecast of run out dates for LTB/BB stock holdings

NOTE: COMPONENTS WILL BE SELECTED AND USED ACCORDING TO THE SUPPLIERS DOCUMENTED PROCESSES. TYPICALLY THESE INCLUDE AN APPROVED ELECTRONIC COMPONENT MANAGEMENT PLAN (ECMP) COMPLIANT TO IEC TS 62239 (REFERENCE [1] IN THIS APPENDIX)

NOTE: WHEN THE FUTURE OBSOLESCENCE DATE IS NOT KNOWN, AS IS THE CASE PRIOR TO THE ISSUE OF A COMPONENT EOL NOTICE, THE OBSOLESCENCE DATE MAY BE ESTIMATED BY THE PLAN OWNER’S OWN METHODS OR BY USING AN ESTIMATED VALUE PROVIDED BY A COMMERCIAL COMPONENT INFORMATION SERVICE

NOTE: MANUFACTURERS MAY CHOOSE TO CONSOLIDATE AND ALIGN OBSOLESCENCE RECOVERIES BY THE USE OF BBs

G. DESIGN AND MANUFACTURING TOOLS AND FACILITIES

Objective-22: The plan shall identify the tools and facilities necessary to design, modify and verify product hardware and software

Objective-23: The plan shall identify the procedures and processes used to preserve the availability of product hardware and software design facilities and tools until the later of the EOL or EOS dates

Objective-24: The plan shall specify the actions necessary to preserve the availability of product manufacturing process, materials, facilities and tooling until the later of the EOL or EOS dates

Objective-25: The plan shall identify the expected obsolescence date of the product manufacturing process, materials, facilities or tooling

NOTE: MANUFACTURERS MAY ELECT TO REPEATEDLY SUB-CONTRACT MANUFACTURING TO APPROVED SUPPLIER WHILE RETAINING DESIGN AUTHORITY

NOTE: DOCUMENTATION ON THE INSTRUCTIONS FOR USE OF TOOLS AND FACILITIES WILL NORMALLY BE MANAGED WITHIN THE NORMAL PRODUCT OR PROCESS DOCUMENTATION

6. PLAN COMPLIANCE

The plan shall be deemed accepted when the plan owner and the type certificate holder agree that the plan is acceptable to both parties, if the type certificate holder chooses to exercise the right of plan acceptance. Certification by a mutually acceptable and internationally recognized assessment body may be used as evidence that the plan satisfies the objectives of this document.
APPENDIX C - LITERATURE SEARCH RESULTS


Critical applications are more and more relying on electronic components to provide the services they are designed for. The obsolescence of such electronic components has already been recognized as a critical issue that must be properly addressed. Among the different possibilities, FPGA-based emulation of obsolete digital components seems particularly interesting. This paper proposes an automatic approach for customizing the processor cores before they are implemented on the FPGA of choice, by removing the unnecessary instructions. The benefits stemming from this approach are cost savings thanks to the possibility of adopting smaller, less expensive, FPGA devices, the possibility of integrating both the processor and its companion chip on the same FPGA device, and the possibility of adopting hardware redundancy without incurring in high overheads. The approach has been evaluated on a case study, showing that a customized and hardened processor obtained from our design flow requires the nearly the same area of the original, un-hardened, processor.


Selecting an appropriate FMS requires consideration of many factors for successful implementation and operation. Primary factors are the system's flexibility, lifecycle cost, and competitive ability over time. This paper proposes a quantitative measure for comparing alternative FMS designs with respect to these three criteria. The model captures the effect of these three factors in a single measure.


Questions about the readiness of U.S. military forces to go into battle have received widespread attention in recent years, and the issue was hotly debated in the 2000 U.S. presidential campaign. Partly as a result of a slowdown in purchasing of new materiel in the 1990s, many weapon systems are showing their age, and their lifetimes are being extended beyond their original design lifetimes. This has led to increased maintenance costs and reduced mission-capable rates. The problem is especially severe with electronics systems, such as aircraft avionics, which increasingly depend on commercially available components that have a technology refresh cycle as short as 18 months and an availability cycle of less than a decade.

No abstract available


Commercial off the Shelf (COTS) has become a byword for acquisition reform, but there are significant risks associated with the use of COTS products in military systems. These risks are especially acute for aviation systems. This paper explains how COTS can negatively affect military acquisitions and gives ideas on how to plan and resolve COTS caused problems


This paper presents the experience and lessons learned in the development and implementation of an electrical equipment obsolescence management program at a large oil gas company. A methodology was developed to identify obsolete equipment by a rational application of obsolescence criteria and ranking mechanisms. Major investment in replacing aging electrical equipment is required to ensure operational continuity and reliability, and to assure the continued viability and cost-effectiveness of existing Company's assets. Key strategies to develop successful strategic planning for capital investments in existing facilities are outlined. The obsolescence management program is contributing to minimizing or deferring capital expenditures in replacements by cost-effective alternatives that will extend the economic life of electrical equipment, while maintaining the required operational safety and availability. 2010 IEEE.


A broad view of the usage spectrum is taken. Speculation as to whether the concept of the discrete micro-processor may soon be outdated and whether a definitive assessment of the thing will ever be feasible is studied. In the light of these considerations future development trends are discussed


The actual operating life time for many electronic systems turned out to be much longer than originally foreseen, leading to the use of obsolete components in critical projects. To skip microprocessor obsolescence problems, companies should have bought larger stocks of components when still available, or are forced to find parts in secondary markets later. Alternatively, a suitable low-cost solution could be replacing the obsolete component by emulating its functionalities with a programmable logic device. However, design verification of microprocessors is well known as a challenging task. This paper proposes a coupled methodology to generate test-programs, using complementary techniques: one pseudoexhaustive and one driven by an evolutionary optimizer. As a case study, the Motorola 6800 was targeted.

Processor obsolescence is a big concern affecting most equipment involved in safely critical applications (automotive, aerospace, nuclear plants, military applications...). Indeed, such applications are active years longer than was originally anticipated. A method for validating the solution consisting in the replacement of a processor, not available any more in the market, by its emulated version by means of an FPGA is presented in this paper. The Motorola 6800 processor is used as a test vehicle to illustrate the key aspects of the explored validation plan. Significant experimental results and their impact on the HDL description are discussed.


One of the biggest challenges faced by the nuclear power industry is obsolescence of C&I equipment. A lot of equipment used in many of the nuclear power stations has been designed as one-of-a-kind and replacement of such control systems is a real challenge. Engineering Division at British Energy's HQ in Gloucester is in the process of replacing one such system at the Hinkley Point B Power Station supported by SIEMENS PG. The first part presents an example of a control system replacement project of a boiler feed control system, the half unit valve control system. It highlights typical challenges faced by British Energy from producing specification to commissioning. The second part is presentation by SIEMENS PG, which focuses on SIEMENS experience of working with British Energy on this particular project and the choice of the particular solution offered to British Energy.


The purpose of this paper is to develop a retailer's profit-maximizing myopic inventory policy for an item recognized as subject to gradual obsolescence. Demand is assumed to be a decreasing function of both the retailer's sale price and of time, up to a certain stochastic time point when obsolescence occurs and, as a result, the demand suddenly drops to zero. For each ordering cycle, the decision variables are the retailer's selling price and the order size. A stop-ordering rule is developed on the basis of finding the time point beyond which it is profitable to stop ordering, even if there is still some demand for the item. In addition, the sudden obsolescence problem is shown to be a limiting and non-trivial case of its gradual counterpart. The numerical example illustrates the main features of the model, including the importance of the vendor dropping the price charged to retailers, so as to provide the needed incentives for the retailers to drop the price charged to their own customers and thereby palliate as much as possible to negative effects of obsolescence. This paper develops a myopic policy to evaluate a retailer's decision.
process, when an item is recognized as subject to gradual obsolescence. The model considers demand to be a decreasing function of both the retailer's sale price and of time, up to a certain stochastic time point when obsolescence occurs and, as a result, the demand suddenly drops to zero. The retailer's profit-maximizing policy consists of an optimal selling price and an order size for each ordering cycle, as well as the time point beyond which it is profitable to stop ordering, even if there is still some demand for the item. This is in contrast to alternate formulations, where the stopping rule is based upon minimizing the cost of obsolescence, rather than evaluating the profitability of the item in question. Finally, the numerical example illustrates the need for vendor/retailer collaboration in the development of the pricing policies. Otherwise, the retailer has no incentive to keep prices low and thus counteract the normal decreases in demand that occur as time passes by and the probability of obsolescence increases. Crown Copyright 2002 Published by Elsevier Science Ltd. All rights reserved.


This paper develops ordering policies for a retailer confronted with a product subject to instant obsolescence, as a result of the imminent end to its economic lifetime, usually for technological, economic or change-in-fashion reasons. The retailer's objective function exhibits a profit maximizing rather than a cost minimizing optimization objective to better reflect the profit-generating role of the retailer's merchandise. There is also a price-induced demand function to provide the retailer an additional profitability tool to handle the sudden loss of the product's income generating potential. Due to the highly complex nature of the model needed to solve the instant obsolescence problem, three heuristic solutions are proposed. The first exhibits orders of equal size. Such a feature is highly coveted in practice, but produces optimal solutions only under rather restrictive assumptions about the probability distribution of the product's economic lifetime. The second yields approximated solutions, valid for any probability distribution, regardless of whether an optimal solution can be derived. The third includes both features. A numerical example highlights the nature of the various heuristic solutions. This example also brings forward an important supply-chain characteristic, namely without any price incentive when purchasing the item in question, a profit-maximizing retailer may find it rational to discourage sales of the item or even to refuse to stock it at all.

ARINC (1999), STRATEGIES TO ADDRESS ELECTRONIC COMPONENT OBSOLESCENCE IN COMMERCIAL AIRCRAFT, 2551 Riva Road, Annapolis, MD, 24101-7465.

The purpose of this document is to establish guidelines that should be observed during initial design, production and maintenance of avionics LRUs, and to present short term and long-term strategies to minimize the costs and impacts associated with decreasing availability of electronic components


Embedded computer systems often remain in service long after part or all of the hardware has become obsolete, due to the high cost of replacement. This cost occurs as often software has to be rewritten for the new hardware. Portable code allows compiled software to be executed on any platform without change. This enables hardware to be replaced when it is obsolete, but software to be moved to the new hardware unchanged - so reducing the cost of obsolescence.

AVIONIC SYSTEMS STANDARDISATION COMMITTEE SYSTEMS ENGINEERING SUBCOMMITTEE (1999), PROCESSOR OBSOLESCENCE IN AVIONICS.

This paper was written in response to a request to prepare a discussion paper on processor obsolescence issues. It reviews the reasons for processor obsolescence and the subsequent consequences. The paper considers briefly guidelines, which already exist, and how these fall short of the ideal. It then considers some of the techniques, which could be used to assist in mitigating against processor obsolescence. The report concludes that guidance is needed in two contexts, one associated with existing systems where processor obsolescence is likely to become an issue and the other in the context of making systems more proof against future changes.


Despite a flurry of attention during the early 1980s and the occasional article thereafter, product deletion continues to suffer from neglect, which is surprising given its role in aiding processes of innovation and change that are central to competitive survival. The aim of this article is to rejuvenate research interest in this field. In doing so, we review and organize the relevant literature in three key sets of factors and postulate that their interplay delineates the product deletion scenarios followed by a company. On the basis of this argument, we develop a typology of product deletions and outline how it increases our knowledge of this critical issue and leads to useful research directions.


This paper recommends that the reliability, obsolescence and integrity management processes related to subsea fields should be integrated into a single process, here termed 'life cycle management', because they all treat in a similar way with the same systems, the overall aim being to maintain system integrity and availability throughout field life. This paper asserts that all three processes should commence early in the design phase of a project and be carried through to decommissioning. It also discusses failure modes, effects and criticality analysis (FMECA) which, it is proposed, should be developed into an integrated system in support of life cycle management, reflecting the root causes of failure as a means of identifying effective and measurable mitigation activities.

This report documents a procedure for forecasting digital microcircuit Obsolescence at the Defense Electronics Supply Center, Dayton, OH. Obsolescence is caused by rapid advancement in digital technology and decrease in commercial demand while military demand still continues. In logistics parlance, parts obsolescence is known as a Diminishing Manufacturing Source (DMS) problem. Continued supply of an obsolete DMS item is assured via substitution, alternate sourcing or a one time buy equal to the lifetime requirements of the item. Emulation is a recent alternative which explores the possibility of replacing obsolete digital microcircuits with state of the art devices which can be manufactured and supplied on demand. The report recommends use of a statistical model which forecasts DMS items from a population of presently non-DMS items belonging to obsolete digital microcircuit technologies. The items forecast by the model should be evaluated for their emulation potential.


A methodology and a set of tools that can tremendously decrease the cost of complex system design and verification are proposed. Both the methodology and the tools are based on the SLDL Rosetta, which provides a semantic base to work with.


In an uncertain economic decision environment, an expert's knowledge about the defender's remaining life and its cash flow information usually consist of a lot of vagueness instead of randomness. To describe a planning horizon which may be implicitly forecasted from past incomplete information, a linguistic description like 'approximately between 10 and 14 years' is often used. A fuzzy replacement analysis for a defender is examined in the paper. The life of the defender is given by a membership function that is an intersection of the membership functions regarding the physical impairment of the defender, its obsolescence, and external economic conditions. A fuzzy economic analysis for a replacement decision is also given.


A growth model for the timing of initial purchase of new products is developed and tested empirically against data for eleven consumer durables. The basic assumption of the model is that the timing of a consumer's initial purchase is related to the number of previous buyers. A behavioral rationale for the model is offered in terms of innovative and imitative behavior. The model yields good predictions of the sales peak and the timing of the peak when applied to historical data. A long-range forecast is developed for the sales of color television sets


Growth model for timing of initial purchase of new products was tested empirically against data for eleven consumer durables; basic assumption of model was that timing of
consumer's initial purchase is related to number of previous buyers; behavioral rationale
for model is offered; model yields good predictions of sales peak and timing of peak
when applied to historical data; long-range forecast is developed for sales of color
television sets. (13972)

Bayruns, T., B. J. Glusman, et al. (2003), The feasibility of applying safety certifiable software
standards to Comanche mission processing, Digital Avionics Systems Conference, 22nd

The RAH-66 Comanche helicopter represents state of the art technology that provides
interoperable reconnaissance and attack capabilities for the battlefield of the future. The
program is currently in the Engineering Manufacture and Development (EMD) phase
with first low rate initial production delivery scheduled for summer 2008. The current
trend toward Integrated Modular Avionics (IMA) for mission processing in military
programs has long been the fundamental enabling concept of the Comanche Mission
Equipment Package (MEP). Operational requirements and aggressive performance
specifications relative to weight size, processing power, and IO throughput necessitated
use of IMA as well as many unique design and integrations solutions resulting in an early
instance of Open System Architecture technologies and approaches. As work continues
on the program, typical problems associated with component obsolescence and a desire to
reduce total ownership costs have meant evaluation of new technology and its application
for argumentation as well as replacement of components in the current MEP. As in the
past, the program continues to maximize incorporation of Commercial-Off-the-Shelf
(COTS) products and the use of standards-based solutions as development cost reduction
measures. New capabilities, just now being incorporated into commercial real-time
operating systems, offer the potential of considering a COTS replacement for the
Comanche MEP OS. Over the last few years, advancements in COTS computer and
telecommunications technologies are enabling broader acceptance of COTS OSA
concepts. These concepts leverage commercial designs more closely, incorporate more
modern commercial standards, and offer less costly obsolescence mitigation while
meeting military rotorcraft integration challenges. This paper will give an overview of
those unique MEP architectural considerations and highlight the recent advances in
embedded partitioned processing driven by safety certifiable Operating Systems as
potential solutions for these issues while preserving a large investment in legacy code. It
will also discuss how insertion of these technologies can position the Comanche MEP to
successfully deal with future requirements such as Global Air Traffic Management
(GATM) compatibility and Multiple Independent Level Security.

Bayruns, T. and J. R. Koenig (2002), Proactive open system architecture design concepts for the
V-22 Osprey tiltrotor. Digital Avionics Systems Conference, 21st DASC. 1: 5C1-1-5C1-
10 vol.11.

The V-22 Osprey tiltrotor is in low rate initial production with an avionics architecture
designed in the late 1980's using state-of-the-art military designs. Even before full rate
production begins, the aircraft has faced vendor hardware and software obsolescence
issues compounded by rapidly growing interest in satisfying new requirements such as
FAA DO-178B certification. This paper describes how open system architecture design
concepts used by other military aircraft, such as the F-15, F/A-18, and other military
transports, maximizing off-the-shelf technology can be applied to the V-22 Osprey to consolidate avionics, mitigate obsolescence, reduce life cycle cost and support growth requirements. The approach presented focuses on the mission processing, display processing, and sensor processing subsystems and shows potential space, weight, cost, and power reductions with minimal deviation from any current aircraft requirements. Technology and standards for placing all three subsystems into a single unit are examined to determine the feasibility of the open systems approach. Being proactive today by applying open system concepts to the V-22 Osprey will allow future development of affordable new mission variants with reduced total ownership cost.


The conventional wisdom that product lifetimes are shrinking has important implications for technology management and product planning. However, very limited empirical information on this topic is available. In this paper, product lifetimes are directly measured as the time between product introduction and withdrawal. Statistical analyses of desktop personal computer models introduced between 1974 and 1992 are conducted at various product market levels. Results indicate that (1) product technology and product model lifetimes have not accelerated, and (2) manufacturers have not systematically reduced the life-cycles of products within their lines. Instead, the products of firms that have entered this industry in the more recent years tend to be based on previously existing technology, and, not surprisingly, these products have lifetimes that are shorter than those of established firms. Implications of these findings are discussed.


The ability of the Department of Defense to execute its mission is directly dependent on the capability to produce and maintain weapon systems. Rapid advances in technology have been instrumental to the development of highly efficient and capable systems. However, they have also increased the rate electronic part manufacturers change product lines resulting in the Department of Defense's increasing dependence on obsolete electronic components. The objective of this thesis is to provide a viable tool for managers to eliminate, mitigate, and proactively manage the growing obsolescence problem. The thesis will define obsolescence, provide a comprehensive discussion of ongoing obsolescence initiatives, and provide a systematic approach to manage microelectronic obsolescence. The thesis will also explore and provide recommendations to address the increasingly common scenario where an ongoing weapon system production program receives little or no notification of a part going out of production.


The United States Air Force (USAF) has an inventory of over 24,000 aircraft with over 47,000 gas turbine engines. Aircraft systems are expensive and must be periodically modernized or upgraded to keep pace with changing threats, missions, and advancing
technology. Controls and accessories comprise approximately 1/5 of the total cost of an engine. The main component of the controls system is the Full Authority Digital Engine Control (FADEC). Legacy FADEC systems are both unique and dedicated to a specific weapon system. Today, each FADEC design is unique within its application class. Developing a universal or common standard for engine controls and accessories which includes FADECs would significantly reduce development and support costs across DoD platforms. With engines representing up to 60% of the platform operating costs, modernizing them could provide significant return on investment and avoid the high cost of full system replacement. Obsolescence issues consume considerable funds and manpower and increase the risk to operational missions and the supply pipeline. To minimize the impact obsolesce, technology insertion can provide alternatives that leverage state-of-the art hardware and software to resolve the unavailability of critical parts, enhance performance and decrease cost. These alternatives will be developed through open system architectures with common or "universal" standardized inputs and outputs with improved reliability (reduce failures), common and advanced materials, reusable software, decreased number of components, high-reliability modules and improved manufacturing processes. The universal FADEC system for DoD engines will involve a family of common components. It will consist of a real-time operating system and partitioned application software (AS) structure. These components will significantly ease the strain on the supply and maintenance infrastructure. The universal FADEC vision is to develop a common input/output scheme, open hardware and software architecture, and generic circuit modules. A systems approach will be employed, considering sensors, cabling, connectors, and interface standards, as well as the FADEC electronic hardware and software.


This methodology has been applied to several Prairie Island IC systems and subsystems, and is being used to substantiate resource allocations and priorities in planning. The methodology has been valuable in fostering a systematic approach and removing bias in the evaluation process. The methodology will be raised to incorporate experience gained at Prairie Island and other participating plants.


The aviation system that is part of the life-blood of our economy is poised to face rising demand with limited additional capacity and outdated technology. This could put considerable stress on the system in terms of congestion and efficiency. The Next Generation Air Transportation System (NextGen) represents a series of incremental policies, procedures, and technological changes to modernize the air traffic control (ATC) system into a more efficient, state-of-the-art satellite-based system. On the technology side, NextGen is composed of two main components: aircraft based equipment that records and transmits the exact location of the aircraft using Global Positioning System (GPS), and ground based infrastructure that can receive and analyze the GPS data.
Infrastructural improvements also entail devising more direct and fuel-efficient routes, and upgrading the computer and backup system used at 20 Federal Aviation Administration (FAA) air traffic control centers nationwide. The infrastructure implementation is currently in the hands of the FAA and funded by the Airport and Airway Trust Fund (AATF), while aircraft equipage is expected to be paid for by the operators.

Boeing (2004), Supplier Obsolescence Management Program, D6-82983, Boeing.

The intent of the Supplier Obsolescence Management Program (SOMP) is for the supplier to define, document and implement an obsolescence program throughout the lifecycle of electronic and Avionic Products subject to obsolescence. Although elements of suppliers’ obsolescence program are subject to review by Boeing, the supplier is expected to establish internal management processes that address potential obsolescence events beginning with initial design, production and maintenance of electronic and avionic LRUs, and establish short term and long term strategies to minimize the customers cost of ownership associated with decreasing availability of electronic components through occurrences of obsolescence.

BCA encourages all suppliers participating in the SOMP to be flexible in developing and implementing internal processes to accomplish these objectives. Each supplier is responsible to define, document and implement a SOMP that is tailored to their overall operation. BCA will expect the supplier to provide timely and credible data associated with obsolescence as defined above and in the body of this document.


In this paper we present a Monte Carlo approach for the evaluation of plant maintenance strategies and operating procedures under economic constraints. The proposed Monte Carlo simulation model provides a flexible tool which enables one to describe many of the relevant aspects for plant management and operation such as aging, repair, obsolescence, renovation, which are not easily captured by analytical models. The maintenance periods are varied with the age of the components. Aging is described by means of a modified Brown-Proschan model of imperfect (deteriorating) repair which accounts for the increased proneness to failure of a component after it has been repaired. A model of obsolescence is introduced to evaluate the convenience of substituting a failed component with a new, improved one. The economic constraint is formalized in terms of an energy, or cost, function; optimization studies are then performed using the maintenance period as the control parameter.


In this paper, an endogenous growth model is built up incorporating Schumpeterian creative destruction and embodied technological progress. Under embodiment, long run growth is affected by two opposite effects: (i) obsolescence costs add to the user cost of capital, which have a negative effect on research efforts; and (ii) the modernization of
capital increases the demand for investment goods, raising the incentives to undertake research activities. Applied to the understanding of the growth enhancing role of both capital and R&D subsidies, we conclude that the positive effect of modernization generally more than compensates the negative effect of obsolescence.


Life-cycle mismatch occurs when the life cycle of a product does not coincide with the life cycles of the parts used in that product. This is particularly a problem with products that contain electronic components that sometimes have life spans of only two years. The cost of mitigating component obsolescence, which may require redesigning the product, is often considerable. Thus, prudent product design necessitates the selection of electronic components and product architecture, considering the cost of mitigating an obsolete design and other costs related to the design and manufacture of a product. Accordingly, we develop and analyze a model that shows how a product design can be effectively tailored to a particular product's life cycle.


Life-cycle mismatch occurs when the life cycles of parts end before the life cycles of the products in which those parts are used. Lifetime buys are one tactic for mitigating the effect of part obsolescence, where a quantity of parts is purchased for the remaining life of a product. We extend prior work that determines optimal lifetime buy quantities for one product with one obsolete part by providing an analytic solution and two simple heuristic policies for the optimal lifetime buy quantities when many parts become obsolete over a product's life-cycle. We determine which of our two heuristics is most accurate for different product life cycles, which yields a metaheuristic with increased accuracy. That analysis also reveals critical perspectives in making lifetime buy decisions with nonstationary life-cycle demand patterns.


Technology planning is becoming critical with the rapid development and obsolescence of technologies. Technology roadmapping provides a tool for selecting which technologies to pursue in what timeframes. This paper provides a framework for technology roadmaps, describes the roadmapping process, and reviews its application

Broadbent, M. (2005), Use of FPGA for Emulation of Obsolete Processors in Safety Systems, QinetiQ.

No abstract available

BSI (2000), Obsolescence Management - Code of Practice for Obsolescence Notification and Support from Suppliers of Electronic Components, BSI.

No abstract available
Parts obsolescence problems are prevalent in fielded and developmental systems where the service life or development cycle is longer than the manufacturing life of one or more of its components. With the typical manufacturing life of most electronic components today being two to four years it is expected that most defense systems will have obsolescence problems before fielding and certainly experience obsolescence during service life. The Manufacturing Technology Division has implemented a five year, 21 Million dollar initiative in parts obsolescence. The contractors are proving an additional 11 Million in cost share. Request for proposals were published in the Commerce Business Daily under the titles 'Parts Obsolescence Tools' BAA-97-11-MLKT, and 'Parts Obsolescence and the Application of Commercially Manufactured Electronics' BAA-98-14-MLKT. The resulting initiative consists of programs in the following areas: a) Commercially available obsolescence management decision and reverse engineering tools: The objectives are to take the most cost effective management decision and reduce the cost of re-engineering. b) Application of Commercially Manufactured Electronics (ACME): The objective is to address key technology driven issues required to increase effective use of commercially manufactured electronics at the chip, board, and box level. This area includes efforts addressing Physics of Failure (PoF) reliability approaches and Application Specific Integrated Circuits (ASIC) availability. c) Pilot Programs: These programs will establish improved business policies and obsolescence management processes utilizing the tools and technologies of the other areas. They will demonstrate and document the cost effectiveness of implementing the technology and processes into weapon systems.

Parts obsolescence was affecting all Alenia products/programs so that we had to identify a robust strategy to prevent uncontrolled effects. The design of products family has taken the obsolescence management issue as key basic requirement. The basic ideas on the back of our pro-active approach for obsolescence issues are: All products (in terms of equipment subsystem or systems) design shall offer a flexible open architecture which permits to change a specific functional block maintaining unchanged the overall architecture. The 'Open architecture' used shall facilitate any design changes into the defined functional blocks (caused by obsolescence issues) because of the high level of interface standardization. A product configuration for a pre-determined period of time
shall be maintained by performing components buy for all expected production batches including logistic support, allowance and spares. There will be a defined periodic product enhancement which permits a pre-planned obsolescence removal activities and relevant design changes. There will be a high level of backward compatibility between the updated system configuration and the previous one. Technologies which support the Product enhancement will be consolidated and introduced at a point where the level of risk is considered acceptable (or obsolescence became a major issue).


The paper talks about the history of computing that explored obsolescence. Computer technology had undergone the most dramatic progress of any technology in the second half of the 20th century, and thus also the most dramatic rate of obsolescence. At the root, obsolescence is a process that occurs when users chose to replace one technology with another, either because they need to. That newer technology is also better is almost an aphorism of the last few centuries.


Our Space projects often use specific radiation tolerant processors for executing flight software. The flight software represents a huge investment in design, coding and validation. When a processor becomes obsolete, and when instructions set is to be changed, this leads to port software to the new target and to validate it again on a new computer. This is a time and cost consuming task. A huge effort was undertaken by space agencies like ESA and CNES to standardize the SPARC instruction set and make technological advances on several chips from ATMEL or VHDL-IP cores, with an increasing processing power. The paper describes the approach taken at CNES for the replacement of the Transputer T805 used for Myriade OBC computer, before migrating for a new instructions set (SPARC for example) for a new line of micro and minisatellites common avionics.


No abstract available


Technological change is examined in a model of capital production to show that "creative destruction" can occur as an outcome of firm's optimizing behaviour, regardless of market structure. Capital systems are made up of components that are all necessary for each system to operate and each component has uncertainty with respect to its durability. For different types of technological change agents make a corresponding decision about whether to continue to use the original capital system (if it is still alive) or to scrap it and build a new capital system which embodies the new technology. Each system has transitional probabilities for scrapping that depend on the size of the present value of the vintage. As technology improves, the optimizing level of durability, and thus the optimal stock of embodied services increases for the new capital system. Yet simultaneously the
probability of scrapping an old system over any given time interval increases. Thus, the larger is the improvement in technology, the greater is the chance of scrapping the old system before its physical service life has ended. Over some time horizon of unforeseen and rapid technological change investment in new capital systems could be increasing while at the same time old capital systems are scrapped at a faster rate. 2005 IMACS. Published by Elsevier B.V. All rights reserved.


As the nation's nuclear power plants age, the need to consider upgrading of their electronic protection and control systems becomes more urgent. Hardware obsolescence and mechanical wear out resulting from frequent calibration and surveillance play a major role in defining their useful life. At Cook Nuclear plant, a decision was made to replace a major portion of the plant's protection and control systems with newer technology. This paper describes the engineering processes involved in this successful upgrade and explains the basis for many decisions made while performing the digital upgrade


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No abstract available


We study the effects of delaying an end-of-life buy. Manufacturers sometimes are required to place a final, end-of-life buy for a component that the supplier will no longer provide. The manufacturer performs a newsvendor analysis with the possible result of significant expected underage and overage costs. If the decision can be delayed, the expected overage and underage costs can be reduced. We model the effects of a delay of the final purchase under various scenarios of remaining demand. We contrast the manufacturing benefits with the costs incurred by the supplier and show that the supplier, who benefits greatly from the end-of-life buy, likely will require an incentive to enact a delay. Our results provide an insight to the observation of increasing numbers of end-of-
life buys and provides a framework for analysis as manufacturers strive to cope with the issue.


Rapid advances in electronics technology with resultant obsolescence and nonavailability of currently used electronics components and devices force systems managers to continuously upgrade and modernize existing systems in order to ensure equipment supportability. This paper examines the requisite attributes of Life-cycle Cost (LCC) analysis methods needed to effectively and flexibly project long term cost requirements, perform LCC versus performance tradeoff analyses, and accurately calculate time phased cost profiles during the planning and design of system upgrades. To be effective, an LCC analysis tool must facilitate modernization and upgrade planning by allowing the decision makers to rapidly analyze life-cycle economic impacts caused by front end technical and logistic decisions. Required accuracy of the estimate and the time and resources available to complete the analysis are important factors in selecting the analytical methods to be employed. When used as an integral part of the planning process, LCC analysis provides a tool for the systematic balancing of overall cost of systems ownership with system technical and schedule requirements.


System Life Sustainment of electronic systems, especially Military Legacy Systems, have traditionally been a sequential set of processes and plans that are applied to the system based on what point of the life cycle curve the system happens to be in at any point in time. With Military systems, these processes are stretched to the limit as the life of the systems is artificially extended by the services (to as much as 30 years). Critical elements of proper life cycle management of Military systems and their associated product implementations are system integration, product replacements, upgrades, and technology insertions. Reduced Government funding and manpower levels have further emphasized the need to improve life cycle management processes. As legacy systems age, their associated sustainment costs can rise dramatically due to obsolescence, reliability and supportability problems while at the same time the performance of the system, as compared to state of the market or technology, decreases. Key decision points occur during the life cycle that will impact long term funding and performance profiles. Early detection of sustainment problems provides sufficient time for the decision making process to implement an analysis of viable alternatives and solutions. To be complete the analysis must include an evaluation of alternative sources and support concepts, technology infusion, re-engineering, commercial technology insertions and comparisons of life cycle costs. To be successful in the support and evolution of systems, programs must have a well defined approach and tool set to aid in the decision making process.

The importance of service parts is much emphasized as the competition in the market becomes severe. These service parts are not only providing product after-sale service, but also playing one of the important rules as competing with competitors in the future. Especially, the supplier of service parts may no longer manufacture the parts after certain period of time before the end of service period for considering economic production quantity. Therefore, the after service providers must place a final order to meet future demand before the production of service parts is stopped. In this paper, we first combine an effective demand forecasting model by considering product sales and the rate of return with newsboy problem to determine the optimal final order quantity by a tradeoff of deadstock cost and lost sale cost. Next, we use the real data provided by a local auto company to construct a simulation model to compare our model with current practices of this auto company. Results show that our model reduces the total cost significantly, and the auto company is suggested to apply the newly developed model to placing its final order and controlling its inventory policy more effectively.


Due to obsolescence, increasing maintenance costs, and the lack of qualified spare parts for the equipment and components of the analog instrumentation and control (I&C) systems in operating domestic nuclear power plants, nuclear utilities are replacing equipment and upgrading certain I&C systems. These activities generally involve changing from analog to digital technology. In many cases commercial products offer practical solutions. Digital I&C systems have the potential to enhance safety, reliability, and availability of the plant systems and improve plant operation. However, the use of digital software-based equipment presents challenges and concerns to the U.S. nuclear industry and the Nuclear Regulatory Commission (NRC). The NRC’s approach to the review and acceptance of design qualification for digital systems largely focuses on confirming that the applicant or licensee has employed a high-quality development process that incorporated disciplined specification and implementation of design requirements. Inspection and testing is used to verify correct implementation and to validate the desired functionality of the final product.


The technological obsolescence of a unit is characterized by the existence of challenger units displaying identical functionalities, but with higher performances. This paper aims to define and model in a realistic way, possible maintenance policies of a system including replacement strategies when one type of challenger unit is available. The comparison of these possible strategies is performed based on a Monte Carlo estimation of the costs they incur. 2008 Elsevier Ltd. All rights reserved.

The technological obsolescence of a unit is characterised by the existence of challenger units displaying identical functionalities, but with higher performances. Though this issue is commonly encountered in practice, it has received little consideration in the literature. Previous exploratory works have treated the problem of replacing old-technology items by new ones, for identical components facing a unique new generation of items. This paper aims to define, in a realistic way, possible replacement policies when several types of challenger units are available and when the performances of these newly available units improve with time. Since no fully generic model can exist in maintenance optimisation, a modular modelling of the problem, allowing easy adaptations to features corresponding to specific applications is highly desirable. This work therefore proposes a modular Petri net model for this problem, underlying a Monte Carlo (MC) estimation of the costs incurred by the different possible replacement strategies under consideration. 2008 Elsevier Ltd. All rights reserved.

Clay, S. (2007), Material Risk Index (MRI) and Methods for Calculating an MRI for Electronic Components.

No abstract available


The invention relates to a system and methodology for facilitating managing product life cycle. A component that determines relevance of components to a product; an analyzing component that determines, infers or predicts obsolescence, level of risk to EOL of a subset of the components. A substitution component that identifies replacement components and suppliers for the subset of components. A cost analysis component that determines material/components cost savings, and redesign cost implementation and/or redesign cost avoidance. A viability component that measures reliability of a component. A transition component that identifies components that require updating or replacement. A profitability component that determines the expected revenue derived from a component over its projected remaining life.


Simple inventory models are developed for fast moving spare parts subject to the risk of unexpected, immediate obsolescence. The approach does not require a precise knowledge of the probability distribution of the moment of obsolescence, as is the case for models discussed in the literature. A rough estimate of the obsolescence risk for the next order cycle is sufficient. The models can be seen as extensions of the EOQ-formula. Following cases are studied: 1. Constant obsolescence risk; no shortages allowed2. Varying obsolescence risk; no shortages allowed3. Varying obsolescence risk; shortages allowed It appears that the models are practicable and, in the proper circumstances, lead to a substantial reduction of cost.

The safe and efficient operation of the reactor within nuclear power stations is determined largely by the measurement and control of neutron flux and core temperature. These parameters are measured using complex sophisticated electronics, located throughout the station, which has to be replaced due to component obsolescence and more onerous operating requirements. The author discusses the problems associated with the replacement of these equipments against a background of the dual requirements of satisfying the Nuclear Installations Inspectorate (NII) on safety matters while achieving successful installation during the very limited reactor shut down periods


Information systems are critical assets for modern enterprises and incorporate key knowledge acquired over the life of an organization. These systems must be updated continuously to reflect evolving business practices. Unfortunately, repeated modification has a cumulative effect on system complexity, and the rapid evolution of technology quickly renders existing technologies obsolete. Eventually, the existing information systems become too fragile to modify and too important to discard. For this reason, organizations must consider modernizing these legacy systems to remain viable. The commercial market provides a variety of solutions to this increasingly common problem of legacy system modernization. Understanding the strengths and weaknesses of each modernization technique is paramount to select the correct solution and the overall success of a modernization effort. This paper provides a survey of modernization techniques, including screen scraping, database gateways, XML integration, CGI integration, object-oriented wrapping and componentization of legacy systems. This general overview enables engineers performing legacy system modernization to pre-select a subset of applicable modernization techniques for further evaluation

Component Obsolescence Group (UK) (2005), "Obsolescence - (993) Companies must face up to a growing problem, states COG", Jane's Defence Industry.

The Component Obsolescence Group (COG) reports that the UK industry could avoid likely costs through effective obsolescence management. This ranges from more than 300,000 for a major component redesign to 13,500 to find a substitute component and 100 for a solution involving the use of existing stockpiled parts. The early identification of an obsolescence problem can lead to avoid more expensive solutions. COG advises organizations to take pro-active steps to predict where potential problems might arise and to monitor the availability of components that have a high risk of becoming obsolete.


To sustain the operation of major plant items in a power station during its proposed lifetime requires a planned programme of overhaul and maintenance. This is likely to include the replacement or refurbishment of components due to general 'wear and tear',

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obsolescence, unavailability of spare parts or as a result of modifications elsewhere on the
plant. Control and instrumentation (C and I) systems are particularly prominent in these
respects usually having a life expectancy less than that expected for major items of
mechanical and electrical plant. To offset this however, it is shown that some of the
greatest returns on investment can result from the replacement, upgrading or
refurbishment of power station C and I systems

Condra, L. (1999), Combating Electronic Component Obsolescence by Using Common
Processes for Defense and Commercial Aerospace Electronics, NDIA.

No abstract available

Condra, L., A. Anissipour, et al. (1997), "Electronic Components Obsolescence" IEEE
Transactions on Components, Packaging, and Manufacturing Technology - Part A, 20(3):
368-371.

Until recently, permanence was an underlying assumption of aerospace electronic
equipment. The intent was to design electronic equipment once, and the design was
assumed to be static, producible and maintainable for the lifetime of the airframe, which
was, and still is, often several decades. Furthermore, the aerospace-oriented culture that
 pervaded the avionics equipment industry, allowed each equipment design to be
optimized independently, with little regard for commonality, modularity, reuse,
scalability, or extendibility to other applications. Provisions for design and production
changes were minimal or nonexistent and suppliers focused on producing spares, rather
than developing more competitive products. This situation was abetted by the lack of any
significant competition and the long-term availability of military grade electronic
components. In recent years, several major electronic component manufacturers have
ceased production of military-grade components which were once considered immune to
obsolescence [1]. The reasons are associated mostly with global competitiveness and the
financial benefits of manufacturing components for the high volume electronics industries
(e.g., computers, consumer products, and telecommunications), rather than for the low
volume complex systems industries (see Fig. 1). The pullout of many of the leading
component manufacturers from the military market has had mixed effects on the
aerospace industry. The use of commercial electronic components has already provided
such advantages as availability of more and advanced functions, availability of state-of-
the art technology, extremely reliable components, and significantly lower costs than
traditional military (and QML) components [1]. On the other hand, the decline of the
military components industry and the fast pace of the commercial components industry
have both lead to shortened component availability and thus concerns about component
obsolescence. Some aspects of the current challenges and “costs” associated with the
phenomenon of component obsolescence are described below to illustrate the problems
and the demand for urgent attention

Condra, L., D. Followell, et al. (2000), Minimizing the Effects of Electronic Component
Obsolescence, Boeing Aero Magazine, 10.

The ongoing revolution in the electronics industry has created a significant challenge for
the aerospace industry. Manufacturers of aerospace electronic components such as
integrated circuits, diodes, resistors, and transistors are leaving the aerospace market to
pursue the rapidly expanding computer, consumer electronics, and telecommunications markets. Boeing continues to lead the aerospace industry in developing new approaches for adapting to the changing electronics market and ensuring access to a supply of suitable components.


The ongoing revolution in the electronics industry has created a significant challenge for the aerospace industry. Manufacturers of aerospace electronic components are pursuing the rapidly expanding computer, consumer electronics, and telecommunications markets. To successfully adapt to this changing environment, both designers and users of aerospace systems must understand and address several issues which are as follows: a). scope of the component obsolescence problem, b). selection and management of electronic components, c). design of electronic systems and equipment, d). operation, maintenance, and support of electronic equipment, e). qualification and certification of electronic equipment.


Competition among product manufacturers is intensifying in many industries. The nature of this competition forces firms to manage the product supply process for speed to avoid product obsolescence and decreased competitiveness. Rene Cordero describes a number of time-saving techniques and develops a framework for managing the product supply process for speed: making speed a central objective of the firm, selecting faster product strategies, managing for the speedy implementation of these product strategies, and managing human resources for speed. Although speeding the product supply process requires significant changes in the traditional management of product development, managing for speed can bring benefits such as faster response to market needs, reduced product cost, and increased product quality.


Advances in commercial technologies have sparked an evolution in the military marketplace. Parts obsolescence driven by rapid advances in technology and acquisition reform are two key drivers that are causing military platforms to rapidly incorporate commercial technologies. Improvements to military platforms based on commercial technology are targeted at increased safety, asset availability, lower cost of ownership, and overall operating efficiency. Recognizing that they cannot build an infrastructure independent from the commercial sector and that they can benefit from recent technological strides, the military has embraced commercial technology in their upgrade programs. This paper explores the US government's desired migration to a more commercial-like procurement model and the challenges associated with that shift. It also attempts to provide some insight for government agencies and defense contractors as they shift to this new paradigm and make the appropriate strategic adjustments.

The rapid growth of technology over the last twenty years is providing vastly improved capabilities for both avionics and avionics test systems. Unfortunately, an environment of rapid technological growth breeds a corresponding environment of rapid technological obsolescence. Test systems developed fifteen years ago are becoming increasingly more difficult to support due to obsolescence issues and, additionally, such a test system does not reflect the current state-of-the-art for automatic test equipment. The ability of a test system to evolve is essential to providing cost-effective support systems for electronic systems. The F-15 Tactical Electronic Warfare System (TEWS) Intermediate Support System (TISS) was developed under the Modular Automatic Test Equipment (MATE) guidelines to support the suite of F-15 electronic warfare LRUs. MATE imposed hardware architecture constraints, which were factors that contributed to its abandonment. However, the modular aspect of MATE has provided a system that can easily evolve with technological advancements. Modularity is the cornerstone of modern software systems and this is the aspect that has been exploited in the evolution of the TISS

Cruickshank, D., S. Daughtridge, et al. (2007), Proven method to eliminate ground system obsolescence, 7th International Symposium Reducing the Costs of Spacecraft Ground Systems and Operations (RCSGSO), Moscow, Russia, European Space Agency; Space Research Institute (IKI); Federal Space Agency of the Russian Federation (Roscosmos); European Space Agency (ESA).

Satellite operators select hardware and software for a ground control system that they will rely on to monitor and control their spacecraft effectively throughout a 15+-year lifetime. However, evolving technology can render equipment provided at the beginning of the mission obsolete. Using a true COTS (Commercial Off-the-Shelf) software approach, ISI (Integral Systems, Inc.), addresses this issue by implementing and supporting a long-term product maintenance program and by providing the same software system to all users. For the satellite industry, this proven approach eliminates ground system obsolescence problems and enables operators to leverage the latest product improvements and enhancements. Therefore, operators are guaranteed a system that is fully supported and cost effective for the entire satellite lifetime. For this model to work, the ground system software must provide to a large customer base a comprehensive set of evolving COTS products, such as IST s EPOCH IPS (Integrated Product Suite). Then, a maintenance program and new license sales can economically make advanced capabilities and new features available to all operators and manufacturers using the product suite. In addition, new hardware with the latest operating system version can be added to replace aging equipment without adding capital costs beyond the relatively low cost of standard COTS hardware. Under this program, existing and prospective customers benefit from the same enhancements and updates. Each release is tested and guaranteed to be compatible with each customer's satellite fleet. Thus, operators are never abandoned to rely on obsolete, unsupported systems. As an independent systems integrator, ISI has successfully supported satellite operators worldwide for over 10 years using this model. One such customer, Loral Skynet, currently operates a mixed fleet of ten GEO (Geostationary Earth Orbiting) spacecraft. In 1996, Loral Skynet decided to replace multiple, manufacturer-
proprietary ground systems with a common ISI ground system. This was an important
decision for Loral Skynet; because it provided a common operator interface, provided
scalability for future expansion, and reduced long-term operating costs by simplifying
ground system maintenance, administration, and training. Loral Skynet has participated in
the ISI maintenance program since its inception and has benefited from the various
updates and improvements over the years.

Darling, D. R., T. Cirillo, et al. (2004), Parts Obsolescence Management Technology Transition
(POMTT);, 383p.

Obsolescence impacts everything, especially in the Defense industry. The reduction of
sources and availability affects component parts, assemblies, software, and even complete
systems. Changes in the commercial and military marketplace have also resulted in
military-grade parts becoming less available. These obsolete high-reliability components
are now too expensive to reproduce, and often less reliable than new commercial parts
that perform the same function. As a result, manufacturers of high reliability weapon
systems must now use commercial parts for their military applications. The Air Force
established the Electronic Parts Obsolescence Initiative (EPOI) in 1998 to help address
these problems, and specifically support the mitigation of obsolescence. Tools,
technologies, and methodologies were established and funded; and follow-on pilot
demonstration programs were also established to evaluate the performance and
commercial viability of these tools.

David, I. and E. Greenshtein (1996), "Brownian analysis of a buffered-flow system in the face of

We consider a stochastic flow system with an intermediate storage buffer. When the
buffer is depleted of stock, orders from outside are placed. It is assumed that there is a
risk of failure (which is referred to as obsolescence) that wipes out existing inventory, and
that the time to obsolescence is exponentially distributed. The problem is to determine
order quantities so as to minimize expected inventory costs when faced with
obsolescence. The underlying input-output (production-demand) process is not
controllable and the resulting inventory level is modeled by a Brownian motion. We
develop an exact expression for the expected total cost until obsolescence, dependent on
the order-quantity decision-variable. Numerical results which center around one specific
application are examined to gain insight into the problem. The work is a generalization of
recent research on the EOQ in the face of obsolescence in that it studies the influence of
randomness in the inventory level process.

David, I., E. Greenshtein, et al. (1997), "Dynamic-programming approach to continuous-review
obsolescent inventory problems", Naval Research Logistics, 44: 757-774.

Inventory models of modern production and service operations should take into
consideration possible exogenous failures or the abrupt decline of demand resulting from
obsolescence. This article analyzes continuous-review versions of the classical
obsolescence problem in inventory theory. We assume a deterministic demand model and
general continuous random times to obsolescence ('failure'). Using continuous dynamic
programming, we investigate structural properties of the problem and propose explicit
and workable solution techniques. These techniques apply to two fairly wide (and
sometimes overlapping) classes of failure distributions: those which are increasing in failure rate and those which have finite support. Consequently, several specific failure processes in continuous time are given exact solutions.


The growing complexity of modern avionics systems, together with the relevant enabling hardware and software technologies, have conspired to produce avionics systems in which a significant proportion of the total life cycle costs are incurred in designing, writing and maintaining the operational flight programmes (OFPs). This paper presents processor design techniques for containing these software costs, using both post- and pre-planned product obsolescence, whilst simultaneously enabling advances in processor technology to be utilised with no impact on the software costs.


The increased speed with which new technologies are being introduced into the modern aviation operating environment has made it necessary to find new ways of evaluating certification, human factors, operational and safety issues. We no longer have the luxury of an extended development program, followed by an evolutionary period of products maturing into more complex forms, with an extended useful life. Modern technology delivers fully formed products to the marketplace with rapid wide distribution and, in many cases, a limited operating life due to forced obsolescence caused by new advances and technologies. Aviation has always been a technology leader, and this hasn't changed, so the introduction of new communication, navigation, surveillance and display technology is moving forward at a fast pace. Aviation is also a very competitive business, and maximum benefit comes from the early implementation of innovative new products and applications. While some time elements of the product life cycle have changed, critical requirements for validating safety, reliability and system integrity in civil aviation have not. The process of operationally integrating a new technology into an existing, highly complex, costly and potentially hazardous domain, such as airports and aircraft cockpits, demands an exhaustive evaluation of their effects on the existing system, while maintaining safety and performance standards, support logistics and affordability. To shorten the time required for equipment and procedural development, and operational implementation, the use of simulation has grown in importance. Simulation can consist of virtual modeling on a computer workstation, part task devices with actual system hardware and software, or full-mission man-in-the-loop simulators with visual systems and motion. All have their place in the process, and all play a role in shortening development time and cost. We will be looking at the use of full-mission simulators for piloted operational evaluations.

Obsolescence of embedded parts is a serious concern for managers of complex systems where the design life of the system typically exceeds 20 years. Capital asset management teams have been exploring several strategies to mitigate risks associated with Diminishing Manufacturing Sources (DMS) and repeated life extensions of complex systems. Asset management cost and the performance of a system depend heavily on the obsolescence mitigation strategy chosen by the decision maker. We have developed mathematical models that can be used to calculate the impact of various obsolescence mitigation strategies on the Total Cost of Ownership (TCO) of a system. We have used classical multi-arm bandit (MAB) and restless bandit models to identify the best strategy for managing obsolescence in such instances wherein organizations have to deal with continuous technological evolution under uncertainty. The results of dynamic programming and greedy heuristic are compared with Gittins index solution.

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A strategy for managing instrumentation and control (IC) obsolescence and phasing in new technology developed by Exelon Nuclear is discussed. This will balance the need for high reliability against budget constraints of a highly competitive business environment. This strategy meets the needs of the fleet and captures the benefits of applying proven solutions to multiple plants, with reduced incremental costs. It comprises two major segments, the IC systems implementation plan and the component management strategy, and facilitates the identification of those components that have become a major support challenge and also helps prioritize solutions.

Drake, M. (2003). Sharing obsolescence information at Raytheon with the component obsolescence and reuse tool. The International Symposium on Product Quality and Integrity; Transforming Technologies for Reliability and Maintainbility Engineering, Tampa, FL, United states, Institute of Electrical and Electronics Engineers Inc.: 277-279.

Diminishing Manufacturing Sources (DMS) is an industry wide problem that still attains considerable attention [1]. Every company and contract that deals with the manufacturing of electronic equipment has to deal with the problem of component obsolescence, that is using parts that are or soon will be no longer available. This issue has obvious impact on new designs, repairs, and product upgrades. It is especially difficult to plan for obsolescence when so many legacy systems exist as well. It is predicted that 70-80% of the US Military systems will be classified as legacy by the year 2010 [2]. Therefore, the challenge is to try to make an estimated 5 year redesign cycle [3] last considerably longer than 5 years. Though many companies have developed policies and procedures to deal with obsolescence, software tools are needed to accompany processes and to gain maximum return on investment of those processes. The Component Obsolescence and Reuse Tool is a software tool that Raytheon Company has developed to enhance our obsolescence best practice process. Currently the tool contains over 100,000 parts each containing obsolescence colored "life" indicators. So far, the return on investment that the tool is generating is exceeding long term savings estimates. Not only has Raytheon Company Northeast sites been using the tool, but Raytheon sites in Fort Wayne, Indiana; Falls Church, Virginia; Towson, Maryland; and Huntsville, Alabama have completed
obsolescence assessments for their programs. Collaboration continues across other Raytheon sites to share and leverage component obsolescence management information.


Rapid advances in computer and electronics technologies has created the situation in which all aviation platforms need to contend with varying degrees of parts obsolescence. Having just entered an Engineering Manufacturing Development (EMD) phase with production in 2006, the Comanche program recognizes the challenges of parts obsolescence and is considering the introduction of selected emerging technologies to proactively address this issue. The presented approaches focus on solutions that reduce space, weight, cost, and power requirements while minimizing the need to deviate from established platform integration and supportability requirements. By introducing technologies during EMD, the cost impact of parts obsolescence in production can be drastically reduced


The Government Accountability Office (GAO) has repeatedly noted the difficulties encountered by the Department of Defense (DOD) in keeping its acquisition of space systems on schedule and within budget. Among the recommendations provided by GAO, a minimum Technology Readiness Level (TRL) for technologies to be included in the development of a space system is advised. The DOD considers this recommendation impractical arguing that if space systems were designed with only mature technologies (high TRL), they would likely become obsolete on-orbit fairly quickly. The risk of on-orbit obsolescence is a key argument in the DOD's position for dipping into low technology maturity for space acquisition programs, but this policy unfortunately often results in the cost growth and schedule slippage criticized by the GAO. The concept of risk of on-orbit obsolescence has remained qualitative to date. In this paper, we formulate a theory of risk of on-orbit obsolescence by building on the traditional notion of obsolescence and adapting it to the specificities of space systems. We develop a stochastic model for quantifying and analyzing the risk of on-orbit obsolescence, and we assess, in its light, the appropriateness of DOD's rationale for maintaining low TRL technologies in its acquisition of space assets as a strategy for mitigating on-orbit obsolescence. Our model and results contribute one step towards the resolution of the conceptual stalemate on this matter between the DOD and the GAO, and we hope will inspire academics to further investigate the risk of on-orbit obsolescence. 2010 Elsevier Ltd. All rights reserved.


A nonuniform influence (NUI) innovation diffusion model for forecasting first adoptions of a new product is proposed. An extension of the Bass model, the proposed model overcomes three limitations of the existing single-adoption diffusion models. First, the
current models generally assume that the word-of-mouth effect remains constant over the entire diffusion span. However, for most innovations, the word-of-mouth effect is likely to increase, decrease or remain constant over time. Second, the existing models assume that an innovation must attain its maximum penetration rate before capturing a prespecified level of potential market, for example, 50%. That is, they restrict the location of the inflection point for the diffusion curves. Third, the current models assume that the adoption patterns after and before the location of maximum penetration rate are mirror images of each other. That is, the diffusion curve is symmetric. By allowing the word-of-mouth effect to systematically vary over time, the proposed model allows the diffusion curve to be symmetrical as well as nonsymmetrical, with the point of inflection responding to the diffusion process. Data from five consumer durables are analyzed to illustrate the generality of the model. [ABSTRACT FROM AUTHOR]

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For decades, the automatic test community has worked to develop hardware standardization and interface protocols that aid in mitigating the impact of equipment obsolescence on the repair and maintenance mission. The traditional view of Test Program Set (TPS) transportability in this environment has always been one of migrating a legacy TPS to a new hardware architecture design born out of a need to replace aging technology or provide new test capability. The Department of Defense (DoD) has recognized the benefit of standardizing automatic test systems (ATS) through policy guidance whose intent is to drive the services to a common configuration test environment, thereby reducing life cycle sustainment costs for all DoD systems. Today, hardware standardization has advanced to the point that many ATS look and function very similar to one another. However, there are two major hurdles that continuously thwart our efforts to develop a standard core test system, the lack of a standard UUT interface and the lack of an open architecture software design that facilitates operations in any environment and on any test system architecture. Automatic Test Markup Language (ATML) provides promise with regards to the development of standardized test software interfaces. Developing a standard hardware configuration for all test requirements is ultimately achievable with the technology currently available today except for one simple, but hugely significant hurdle, the cost involved in re-hosting the myriad of test program sets currently in existence. Therefore, any significant advance in common interface design has to take into account the need to minimize the impact to existing test program sets. This paper will seek to explore the various technological possibilities for overcoming the barriers to true TPS transportability that exist in today's automatic test community.

We study the influence of production on utilization functions. A concrete example of this is the influence of the growth of literature on the obsolescence (aging) of this literature. Here, synchronous as well as diachronous obsolescence is studied. Assuming an increasing exponential function for production and a decreasing one for aging, we show that, in the synchronous case, the larger the increase in production, the larger the obsolescence. In the diachronous case the opposite relation holds: the larger the increase in production the smaller the obsolescence rate. This has also been shown previously by Egghe, but the present proof is shorter and yields more insight in the derived results. If a decreasing exponential function is used to model production the opposite results are obtained. It is typical for this study that there are two different time periods: the period of production (growth) and — per year appearing in the production period — the period of aging (measured synchronously and diachronously). The interaction of these periods is described via convolutions (discrete as well as continuous).

No abstract available

This paper proposes guidance and an approach for assessing and ensuring that the replacement of electrical and electronic parts used in aircraft electrical systems and equipment is addressed safely from the software perspective in the certification process while minimizing manufacturer and operator costs and schedule impacts. Many electronic components used in already certified aircraft systems and equipment are no longer being manufactured, that is, are obsolete, and this paper proposes an effective and efficient approach for ensuring the software aspects of certification for replacement of these parts in existing airborne systems and equipment.

No abstract available

This CAST paper provides responses to some questions that are frequently asked by industry concerning the application of DO-254/ED-80 for certification projects.

This final policy statement sets up Federal Aviation Administration (FAA) certification policy on applying Advisory Circular (AC) 20-152 to complex airborne electronic
hardware (CEH) installed in part 23 aircraft or in airships. The specific issues addressed concern selecting and applying hardware design assurance levels (HDAL) to CEH.


No abstract available


No abstract available


No abstract available


Technology life cycles affect a product manager's ability to sustain systems through their manufacturing and field lives. The lack of availability of critical parts and technologies poses a challenge not only to the acquisition community, but to customers of products that must be maintained for long periods of time. Technology obsolescence has an especially serious impact on systems that have significant electronics content because electronic parts are quickly obsoleted in favor of newer, higher performance components. In this study, market availability data was analyzed for operational amplifiers, a technology integral to most electronic products, and for flash memory devices. Procurement lifetimes are shown to have shrunk since operational amplifiers emerged on the market. Algorithms for forecasting electronic part obsolescence are proposed and the ramifications of electronic part obsolescence on product design planning are discussed. Copyright 2007 by ASME.


Mismatches between electronic part procurement lifecycles and the lifecycles of the products they are used in causes products with long manufacturing and/or support lives to suffer from significant obsolescence management costs. Lifetime buy is a prevalent mitigation approach employed for electronic part obsolescence management. Making lifetime purchases of parts upon obsolescence involves managing interacting influences and concurrent buys for multiple parts in a sequential manner. This thesis is focused on optimizing lifetime buy quantities by minimizing lifecycle cost. The Life of Type Evaluation (LOTE) tool was created to optimize lifetime buy quantities. LOTE requires component and system data and expected demand information. With the given data, LOTE uses stochastic analysis to determine the lifetime buy quantity per part that minimizes the lifecycle cost for the system. Results from a LOTE analysis of a Motorola communication system indicate that organizations may be systematically overbuying at
lifetime buys giving inventory shortage penalties a greater emphasis than other hidden costs.


Mismatches between electronic part procurement lifecycles and the lifecycles of the products that they are used in cause products with long manufacturing and/or support lives to incur significant obsolescence management costs. Lifetime buy is one of the most prevalent mitigation approaches employed for electronic part obsolescence management. Making lifetime purchases of parts when they go obsolete involves managing many interacting influences and multiple concurrent buys for multiple parts. The focus of this paper is optimizing lifetime buy quantities by minimizing life-cycle cost. There are multiple factors that contribute to the life-cycle cost associated with a lifetime buy: procurement cost, inventory cost, disposal cost, and penalty cost. The Life of Type Evaluation (LOTE) tool was created to optimize lifetime buy quantities and minimize life-cycle cost. LOTE requires component and system data. With the given data, LOTE uses stochastic analysis to determine the lifetime buy quantity per part that minimizes the life-cycle cost for the system. LOTE was used to determine the optimum lifetime buy quantities for a Motorola communications system.


Nuclear utilities are upgrading their existing instrumentation and control (I&C) systems. The upgrades are being driven primarily by the growing problems of obsolescence, difficulty in obtaining parts, and increased maintenance costs of existing systems. There also is great incentive to take advantage of modern digital technologies which offer potential performance and reliability improvements. A guideline to assist utilities in these upgrades has been prepared by a committee of EPRI, NUMARC and industry representatives. The committee worked with NRC to reach a consensus approach for design, implementation, and licensing of digital upgrades, which is the basis for the EPRI guideline. This paper briefly recaps the background for development of the guideline, and it gives a brief overview of the approach and content of the document. An update on the status of its use by the industry and acceptance by the NRC is provided. Finally, some lessons learned from recent upgrades and applications of the EPRI guidance are discussed.


In 1993, the Office of Naval Research (ONR), in conjunction with the Undersecretary of the Navy for Research, Development, and Acquisition, established a program known as Technology for Affordability. That program is executed today in many of the Navy's weapon systems procurements and is specifically resident in two ONR programs: Manufacturing Technology and Small Business Innovation Research (SBIR). The technology discussed in this paper was developed under the auspices of the SBIR program and is known as Rapid Retargeting. It is executed through VisiCom.
Laboratories, Inc., a California-based small business. Rapid Retargeting rehosts existing logic into new hardware technology. This rehosting process begins by extracting the functionality of the target hardware and capturing it in VHSIC Hardware Descriptive Language (VHDL). The resulting software models are simulated and compared with the original hardware for verification. Once verified, the models are ported to a new hardware design. Subsequently, parts obsolescence is no longer an issue: software models can be rehosted whenever new technology becomes available.


A better understanding of the costs associated with contracting component lifetimes is enabling engineers to create more obsolescence-friendly designs.


Obsolescence is becoming much more of an issue as chip making technology speeds up. Devices made on 0.5um and 0.35um are reaching the end of their product lifetimes and going 'end of life', and that raises questions for industrial designers on how to manage that. Having a strategy to tackle the obsolescence of parts in three to five years is vital, and the latest survey from the National Obsolescence Centre gives engineers, for the first time, the metrics they need to argue the cost savings to put such a strategy in place.


The solution of the problems of component obsolescence issues, for military, high-reliability and long-lifetime applications, are discussed. The first necessity is to nip problems in the beginning by preventing obsolescence issues in the first place, this means ensuring that products and systems are specified with back-ups and alternatives for critical components. Many component manufacturers are beginning to offer contractual lifetime support (CLS) plans or non-obsolescence policies to eliminate the problem altogether. It is worth noting that valuable though these can be, they can not be accepted at face value, purchasing and engineering professionals need to work together to ensure that such guarantees are not only correctly framed to protect the customer, but also technically achievable. Another way of securing supply is to use an obsolescence and parts procurement specialist to provide contact logistics support services.


It is difficult to avoid using commercial off-the-shelf hardware in military systems. You need to have plans in place to make sure the components will suit long lifetimes and high-reliability environments. The military and aerospace communities now regard the use of commercial off-the-shelf (COTS) equipment as commonplace. The shift to use ready-made hardware and software encompasses not just individual components, but, sometimes, entire sub-assemblies. The impact of this change is already evident, particularly in terms of obsolescence: projects with development phases that last up to 20 years and in-service lifetimes of 40 years are being built using components with lifecycles that are, in some cases, measured in months. The scale of the problem is illustrated by
recent estimates suggesting that electronic components are now going obsolete at a rate of more than 13,000 per month. The effects in terms of reliability, although important, are less clear, simply because insufficient in-service data currently exists to assess real failure rates and lifetimes. Against this background, military and aerospace engineers need to ensure the reliability safety integrity and lifetime of their designs. In particular, whole-life component management planning is essential to ensure adequate supplies of fit-for-purpose components and subassemblies throughout the lifecycle, from concept, assessment, development, manufacture and in-service life through to disposal.


This paper tells a logistics success story. It describes the successful application of an obsolescence mitigation technique developed by Naval Supply Systems Command (NAVSUP), Rapid Retargeting, to the AN/ALQ-126B by Titan Systems Corporation VisiCom Products Division. Through Rapid Retargeting, Titan created a UniModule that can be used as a form, fit, and functional replacement for any of eight SRAs used in eleven different slots in the ALQ-126B.


The service lives of weapon systems and their electronic subsystems are being extended well beyond the affordable lives of the test equipment used to support them. The increasing commercial item content of these testers is shortening their product life cycles by increasing the frequency of obsolescence issues and the need for configuration changes. In addition, as the Department of Defense searches for ways to reduce the cost of operating and sustaining its aging tester infrastructure, the replacement of peculiar, obsolete testers with common, more efficient and cost-effective testers becomes an effective tactic. These factors all increase the probability that test programs for legacy electronics will need to be rehosted at least once during their service lives. This paper presents a test requirements-based approach to the design and verification of rehosted TPSs as a method to address these challenges. The approach will be to express test requirements, extracted from legacy TPSs and available product data, in a consistent information-based model, the Test Requirements Model (TeRM). This will, in turn, provide the TPS engineer with an objective and consistent basis for validating the rehosted TPS as a natural byproduct of the reengineering process. It will be shown that this approach can address TPS rehost challenges as well as extend to the reengineering of obsolete electronics. The service lives of weapon systems and their electronic subsystems are being extended well beyond the affordable lives of the test equipment used to support them. The increasing commercial item content in these testers is shortening their product life cycles and increasing the frequency of obsolescence issues and configuration changes. In addition, as the Department of Defense searches for ways to reduce the cost of operating and sustaining its aging infrastructure, replacing peculiar, obsolete testers with common, more cost effective and efficient testers becomes an effective tactic.

Software modernization is critical for organizations that need cost-effective solutions to deal with the rapid obsolescence of software and the increasing demand for new functionality. This paper presents the XIRUP modernization methodology, which proposes a highly iterative process, structured into four phases: preliminary evaluation, understanding, building and migration. This modernization process is feature-driven, component-based, focused on the early elicitation of key information, and relies on a model-driven approach with extensive use of experience from the previous projects. XIRUP has been defined in the European IST project MOMOCS, which has also built a suite of support tools. This paper introduces the process using a case study that illustrates its activities, related tools and results. The discussion highlights the specific characteristics of modernization projects and how a customized methodology can take advantage of them.


The increasing discrepancy between the life cycles of professional electronics equipment and the life cycles of the components (which are largely intended for volume markets) means that professional electronics manufacturers must implement methods processes and tools to give their customers long-term availability guarantees for their products despite obsolescence problems in the components. Although this effort must be made at the level of each unit and adapted to the type of product the customers needs and internal organization the existence of common methodological tools and principles can significantly help each unit set up the appropriate procedure for their particular case. This paper gives an overview of the methods and tools set up within the Thomson-CSF group to support the units in this procedure.


Obsolescence makes equipments supporting and maintaining hard and costly. It hurts the equipments reliability seriously. In the past decades, electronic technology has developed very rapidly causing components (and particularly the FPGAs) to have a shortened life span. So the problem of electronic component obsolescence in complex electronic or long life systems such as aircraft submarines and ships is getting more and more severe, therefore has heighten the interest of researchers. This paper analyses the FPGA obsolescence drivers, on based of which it introduces some traditional methods to deal with obsolescence, and proposes a model to predict the obsolescence trend of FPGA. It can be a reference for system designers selecting FPGAs. For the purpose of verifying the model, XC4085 is used to be an example.

Algebraic modelling languages have simplified management of many types of large linear programs, but have not specifically supported stochastic modelling. This paper considers modelling language support for multistage stochastic linear recourse problems with finite distributions. We describe basic language requirements for formulation of finite event trees in algebraic modelling languages and show representative problems in AMPL using three commonly used scenario types.


No abstract available


The paper points to a serious conceptual inconsistency in conventional measures of capital used in most empirical work on economic growth. When appropriate corrections are made, it is found that plausible alternative values for the relative magnitude of obsolescence and physical decay imply very different rates of growth in capital. This, in turn, leads to large differences in the fraction of growth in output attributed to input augmenting technical change as compared with the 'Solow residual'.


The last two decades have witnessed manufacturers of sustainment-dominated long field life electronic systems incorporate Commercial Off the Shelf (COTS) technology products into their systems on a large scale. Many of these products, however, have lifetimes of significantly shorter duration than the systems they are incorporated into and as a result become obsolete long before the system’s intended duration of useful life is over. This problem is especially prevalent in avionics and military systems, where systems may encounter obsolescence problems even before they are fielded and always during their support life. Manufacturing that takes place over long periods of time exacerbates this problem. Many part obsolescence mitigation strategies exist including: lifetime buy, last-time buy, part replacement, aftermarket source, uprating, emulation, re-engineering, salvage, and ultimately redesign of the system. Design refresh (or redesign) has the advantage of treating multiple existing and anticipated obsolescence problems concurrently and additionally allows for functional upgrades. Hitherto, there have been studies concentrated on determining the optimum combination of different obsolescence strategies by using life cycle cost as the deciding criterion. However, these studies take into account only hardware life cycle costs. In many systems, such as avionics systems, software life cycle costs (redesign, rehosting and requalification) have a significant bearing on total life cycle cost. Thus software redesign due to part obsolescence triggered hardware redesign should also be addressed during life cycle management planning. This thesis describes a methodology and it’s implementation for determining the hardware part obsolescence impact on life cycle sustainment costs for system software based on future production projections, maintenance requirements and part obsolescence forecasts. The methodology extends the MOCA (Mitigation of Obsolescence Cost Analysis) methodology/tool that determines the optimum design refresh plan during the field-
support-life of the product in order to minimize life cycle cost. The design refresh plan consists of a set of design refresh activities and their respective calendar dates. The methodology incorporates the use of two software commercial cost analysis models: PRICE S and COCOMO. The methodology developed in this thesis has been validated using a Navy test case (VH-60N Digital Cockpit Upgrade Program). It has also been applied to Honeywell International, Inc.’s AS900 engine controller. The results obtained demonstrate the necessity of taking software redesign analysis into account during life cycle management planning.


This paper describes how to design open computer systems for mission critical applications within the avionics of military aircraft using Commercial Off The Shelf (COTS) computer components. Design aspects of 'Integrated Modula Avionics' (IMA) are incorporated. How these aspects contribute to an effective obsolescence management is also described. The content of this paper is presented within the context of projects currently running at the European Aeronautic Defence and Space (EADS) Deutschland GmbH, Military Aircraft Business Unit (MABU), which are dealing with the subjects COTS and obsolescence.


No abstract available


The problem of technological obsolescence in vendor supplied parts in the new product development process has increased in importance in recent years. This is compounded by both the rapid pace of technological advance and increasingly disintegrated supply chains. This issue has become particularly problematic for products with both a high degree of technology and long life cycles. This exploratory study relates empirical obsolescence findings to theoretically predicted models of innovation diffusion for different product-market conditions. Implications are analyzed for supply chain evolution and obsolescence management. 2009 Elsevier Inc. All rights reserved.


British Energy has a fleet of 8 nuclear power stations in the UK. Much of the control and instrumentation (CI) equipment is over 30 years old. British Energy and its predecessors have a long history of effectively managing ageing and obsolescence of CI equipment. There are new internal and external expectations and challenges. These arise from aspirations to extend the life of plant, the need to manage risk and investment, newly
published standards and not least the continuing march of time and its effects on equipment. This presentation will describe the development of British Energy's response to these challenges. The strategy and some implementation details will be presented. While what will be presented will represent work in progress, it has progressed to a point where there are some useful lessons for other organisations involved in similar asset lifetime management programmes. British Energy Generation Ltd.


Today many companies are facing the problem of component obsolescence in embedded systems. The incredibly fast growth-rate of semiconductor companies is reducing dramatically the time components are available on the market. Twenty years ago, components remained on the market for 5 to 10 years, while nowadays they disappear from the market in less than 2 years. Developers of safety- or mission-critical systems are particularly sensitive to the obsolescence problem as their systems are expected to remain operative for very long periods of time (e.g., 30 years or more), and maintaining them fully operative is becoming difficult as the needed components may be no longer available. A possible solution for this problem may be the implementation of the needed components using FPGAs. The purpose of this paper is to provide an overview of the different possibilities designers have to face when developing such dependability-oriented solution. Also a design flow is presented, describing its applicability to the implementation of processor cores, to be employed as replacement of obsolete parts in safety- or mission-critical applications. Results show that there is a strong dependence of the reliability of the design with the specific application. The scrubbing process can also be optimized using the related technique.


A Development Before the Fact system is an intelligent system in that it contains built-in properties to provide itself the best opportunities that are available for its own development. It provides the opportunity to begin its own development tasks as soon as possible and to check as you go throughout its own development process. It is an independent system in that it is not locked into obsolescence. The 001 technology directly addresses the issues of Development Before the Fact systems. With 001, integration happens early with the use of TMaps and FMaps; errors are eliminated early when, for example, the primitive structures are ultimately used to eliminate interface errors. Flexibility and the ability to handle the unpredictable are issues that are dealt with early since system definitions based on the three primitive structures have properties of single-reference and single assignment, ensuring traceability and safe reconfiguration, preparing for distributed environments happens early, with explicit delineation of independencies, dependencies and decision making. Reusability happens early with the use of mechanisms such as defined structures and parameterized types. Automation happens early, since
TMaps, FMaps and their associated instantiations support automated tools with sufficient and necessary information to understand formally both a system and its definition.


The Georgia Tech Research Institute, sponsored by the Warner Robins Air Logistics Center, has developed an approach for efficiently postulating and evaluating methods for extending the life of radars and other avionics systems. The technique identifies specific assemblies for potential replacement and evaluates the system level impact, including performance, reliability and life-cycle cost of each action. The initial impetus for this research was the increasing obsolescence of integrated circuits contained in the AN/APG-63 system. The operational life of military electronics is typically in excess of twenty years, which encompasses several generations of IC technology. GTRI has developed a systems approach to inserting modern technology components into older systems based upon identification of those functions which limit the system's performance or reliability and which are cost drivers. The presentation will discuss the above methodology and a technique for evaluating and ranking the different potential system upgrade options.


No abstract available


Some statistical methods developed recently in the biometrics and econometrics literature show great promise for improving the analysis of duration times in marketing. They incorporate the right censoring that is prevalent in duration times data, and can be used to make a wide variety of useful predictions. Both of these features make these methods preferable to the regression, logit, and discriminant analyses that marketers have typically used in analyzing durations. This paper is intended to fulfill three objectives. First, we demonstrate how decision situations that involve durations differ from other marketing phenomena. Second, we show how standard modeling approaches to handle duration times can break down because of the peculiarities inherent in durations. It has been suggested in recent marketing articles that an alternative to these conventional procedures, i.e., hazard rate models and proportional hazard regression, can more effectively handle duration type data. Third, to investigate whether these proposed benefits are in fact delivered for marketing durations data, we estimate and validate both conventional and hazard rate models for household interpurchase times of saltine crackers. Our findings indicate the superiority of proportional hazard regression methods vis-à-vis common procedures in terms of stability and face validity of the estimates and in predictive accuracy.

The primary objective of our Phase I effort was to explore the feasibility of a Navy-wide DMSMS prediction system and develop improved methods of obsolescence prediction. In pursuit of this goal we investigated the DMSMS process at various Navy sites and identified and evaluated tools or processes currently in use. We decided to focus our efforts on micro circuit obsolescence prediction, because our study revealed that other types of parts are not nearly as significant a DMSMS problem. Furthermore, we concentrated on automating the largely manual obsolescence prediction currently performed by the MOM program. We used the artificial intelligence techniques of knowledge engineering, case-based reasoning, knowledge base development and object oriented programming to devise a solution to the obsolescence prediction problem. We also developed a preliminary design and functional description for a pro active Navy-wide DMSMS intelligent system which will be developed in a Phase II effort. We implemented both these solutions in a prototype improve their feasibility beyond a doubt. There is great potential for use of the Phase II system throughout the Navy, other branches of the military and in the commercial sector.


In military, civil, and commercial systems there exists a need to affordably manage the operational effectiveness of the system of interest through the acquisition and operational stages of its life cycle. Once a system design is baselined and instantiated, then the challenge during development, production, and utilization life cycle stages is to maintain the currency of the physical system baseline to facilitate affordable system support. In essence, the system must adapt to potentially frequent asynchronous obsolescence of its constituent elements, requirements growth (driven by the operational environmental and external constraints such as funding, schedule or risk), and external environment changes. This paper specifically addresses the impact that system element obsolescence has on a system baseline during the various system life cycle phases and provides a framework for affordable system evolution. 2008 Wiley Periodicals, Inc.


The effectiveness of commercial, civil, and military systems must be affordably managed through their life cycles. Once the design baseline of such systems is defined and instantiated, the challenge during the development, production, and utilization life cycle phases is to affordably sustain the physical system baseline. This baseline is continuously evolving in response to external influences such as; frequent and asynchronous obsolescence of system elements, changing requirements (mission, schedule and funding related), and changing policy and regulations (i.e., security, export laws and safety standards).

This research specifically addresses the impact of asynchronous obsolescence of system elements on system effectiveness and cost during its operational and support life cycle phases. An overview of a system obsolescence forecasting model, se-Fly Fisher, is provided. This model uses technology curves of individual system elements (parts) for an understanding
of obsolescence at the lowest level. The model analyzes this system element data and formulates three key strategic system outputs. Output 1 forecasts how often a system baseline should synchronously change to minimize system ownership costs through support (i.e., the change strategy). Output 2 uses the forecast strategy to plan system element changes (i.e., the system change plan). The output strategy and system element plans provide program management and engineering with planning insight for technical change management, resource identification, and assessment of scope impacts of the recommended changes. Output 3 addresses the performance potential that is gained from each proposed system element baseline change. This performance potential becomes part of the systems engineering trade space for potential system operational gains.

The current literature provides a range of obsolescence forecasting approaches for electronic components (i.e., chips, resistors, capacitors), and optimization of change recommendations for the next expected obsolete part. This research model extends existing obsolescence forecasting in three dimensions. Dimension 1 extends the time span from the next-forecasted part obsolescence date to a complete support life cycle timeline perspective. Dimension 2 extends the forecast scope from electronic components to all electronics, electrical, mechanical and software system elements. Dimension 3 extends obsolescence change analysis from a single product-view to a system-view.


The cost of ownership of avionics includes not only the development and acquisition cost, but also the yearly operating and support (O&S) (maintenance) cost of hardware, software, and support equipment. This paper presents the avionics cost of ownership methodology developed for USAF, its data sources, and business metrics computed for USAF decision makers as we move toward operating avionics as a business. The business model is used to determine which existing avionics are candidates for replacement with new technology and to prioritize the replacements. These avionics are often used on multiple aircraft types which necessitates analysis of the causes of the high cost of ownership on each type. Databases are used to document the functions, and constraints of the item being analyzed. These constraints include physical, environmental, electrical, and data interfaces. Databases containing alternatives are evaluated against standard mission scenarios for aircraft utilizing these high cost avionics to determine their impact on performance, O&S costs, and mission effectiveness. The results of the foregoing analyses steps are then used in life cycle cost analyses which consider different retrofit scenarios for each alternative for each aircraft type against the avionics being analyzed for replacement. The alternatives are prioritized based on the foregoing and a risk analysis performed considering technical, schedule, and cost growth risks.


A method of assessing technology obsolescence and the tools to determine the impact of technology obsolescence and new technology on business management are addressed. Many complex systems, particularly major aircraft and military weapon systems, often
have life spans of many of the supporting components. As customers use of technology accelerates, new products are introduced at ever increasing frequencies. Understanding and dealing with these market forces will separate the very successful program managers from those who constantly work only today's problem.


When current domestic Active Matrix Liquid Crystal Display (AMLCD) sources became unavailable, prime contractors for military aircraft faced a severe problem with the sudden obsolescence of these assemblies. AMLCDs had become central to crew station design, but the only qualified North American source had failed. The problem was further complicated as several programs were beginning production, and supplies of existing, useable AMLCDs were rapidly being depleted. Solutions to the availability of AMLCDs had to be found quickly. The F/A-18E/F program faced a unique situation in that three different displays, manufactured by two different suppliers, were affected by the loss of the AMLCD source. Both of the suppliers, for various technical and programmatic reasons, chose different approaches to the crisis. The advantages and disadvantages of each approach are examined in this paper. In addition, Boeing has formed a Displays Process Action Team (DPAT) to examine whether or not it is possible to use common displays across the Company's diverse product lines.


Stochastic demand forecasting methods for service parts of a discontinued product are proposed. The identified four major factors are the number of product sales, the discard rate of the product, the failure rate of the service part, and the replacement probability of the failed part. During a given period, typically a year, the number of failed service parts is estimated using the first three factors, and then the demand for those service parts is obtained with the use of the last factor. A stochastic model is derived to estimate the demand in a certain prediction interval, and the closed-form solutions in the case of a constant failure rate are provided. An approximate model is proposed to render actual computation possible when the part failure time is not distributed exponentially. Numerical data from the automotive industry are used to validate the model.


Fueled by constant and rapid technology changes, component obsolescence has long been a fact of life for users and managers of electronic components. Organizations like the Government Industry Data Exchange Program (GIDEP) and the Defense Microelectronics Activity (DMEA) have developed over the years to help pull together and apply Government and commercial resources to solve obsolescence problems for electronic components. Although obsolescence is not a thing of the past for electronics,
GIDEP, DMEA, and others have made significant strides toward creating viable, cost effective solutions for program managers with electronic obsolescence problems. For nonelectronic components, drastic shifts in technology are not as common. As a result, nonelectronic obsolescence problems have generally been slower to develop. While an electronic component may become obsolete in a matter of a few years or even months, nonelectronic components typically remain supportable for a few decades. Today, however, large and complex aging systems in the military (such as aircraft, ships, and tanks) with tens of thousands of nonelectronic components have been in operational service for over 40 years. Many of these systems are projected to remain in service for another 40 years or more. Given these facts, system operators and managers are beginning to face significant obsolescence problems with nonelectronic components and will continue to face them in the future. This paper describes common signs and symptoms of nonelectronic obsolescence problems in military aviation and proposes an approach based on the author’s experience that integrates both short term and long term solutions. Short term solutions recognize that there are immediate requirements for components that must be met to keep critical resources operational. Long term solutions are focused on eliminating the root cause of the obsolescence problem and solving the obsolescence problem for the life of the system. In addition to describing specific approaches to solving existing obsolescence problems, this paper describes two obsolescence management strategies that could be used by system managers to help predict and respond to obsolescence of nonelectronic components.


This paper presents a model of intentional industrial innovation that features the endogenous obsolescence of existing capital goods as a result of the introduction of new capital goods of higher quality. In contrast to existing models of endogenous obsolescence, the introduction of new capital goods in this model does not immediately result in the displacement of older capital goods. Instead, many old capital goods remain in use, albeit less intensively than the newer machines. In addition, since the rate at which new capital goods become obsolete depends on expectations of the rate at which new higher quality capital goods are expected to be introduced in the future, this creates the possibility of multiple equilibria, one with high growth rates, in which capital goods quickly become obsolete and another with low growth rates, in which capital goods are used for a long time.


This paper presents an approach to forecast the life cycle stage and the years to obsolescence of ASICs. Forecasting is based on curve fitting past sales data of each ASIC type. We then show how attributes such as package style and voltage can modify the forecasts. In addition, the trends in the ASIC industry, by ASIC category, are discussed, and a roadmap is presented.

This paper describes a practical approach for the stock control of slow-moving items subject to obsolescence. A heuristic procedure is developed for determining stocking quantities and inventory retention times. A spreadsheet is presented for implementation of the heuristic, with an example demonstrating its use. The advantage of the proposed approach is its simplicity in comparison with dynamic programming optimization. As illustrated by a set of examples, the proposed approach can provide near-optimal cost performance.


Although component obsolescence has always been a fact of life, it previously occurred so infrequently that it didn’t have to be planned as a specific activity and was probably handled on an ad hoc basis by most equipment suppliers. Unfortunately, the present situation is quite different with many semiconductor components having a life cycle of less than 5 years. This is now causing significant challenges for commercial aircraft equipment which first entered service more than 10 years ago, as many key parts are now being threatened with obsolescence due to a shift in emphasis within the electronics sector towards very high volume, highly integrated low cost components. Equipment currently being procured for use within the aerospace sector must therefore be designed in a manner which minimises the cost and impact of changes due to obsolescence whilst complying with the various international guidance being generated on these issues. Meeting the stringent requirements for a fully documented, supportable, modular design which can be cost effectively manufactured to meet the reliability and performance requirements with commercial components may favour the higher volume avionic equipment suppliers.


No abstract available


This International Standard gives guidance for establishing a framework for obsolescence management and for planning a cost-effective obsolescence management process that is applicable through all phases of the product life cycle, the term ‘product' includes: capital equipment; infrastructure; consumer durables; consumables; software products. Obsolescence management covers the following areas: a) design of new products; b) new technology insertion into existing products; c) support and maintenance of legacy products.


No abstract available

This paper presents an overview of the IHS Life Cycle Content, its relationship with ED and an insight into the factors that are considered for generating Life Cycle Prediction data and the processes.


No abstract available


No abstract available


This paper presents an overview of a risk-informed methodology for electronic parts selection and management, which addresses both application-independent processes (part availability, part cost, part manufacturer quality, distributor quality and part family quality and integrity) and application-specific processes (determination of the local environment, part performance, part reliability, assembly and life cycle obsolescence). Risk management activities, which follow the parts selection activities, are also addressed.


This paper presents a stochastic dynamic programming model for determining the optimal ordering policy for a perishable or potentially obsolete product so as to satisfy known time-varying demand over a specified planning horizon. We have considered random life time perishability where, at the end of each discrete period, the total remaining inventory either becomes worthless or remains usable for at least the next period. Two approximate solution methods are shown. The optimal and heuristic methods are compared on a large set of test problems and their performance as a function of various problem parameters is analyzed.


No abstract available


Distribution of functions in engine control systems is closely related to the control strategy and control platform capabilities based on open and COTS technologies. Particularly in a distributed environment, control system platforms can play the role of key differentiator in terms of system and software architecture development approach, system integration, engine maintenance, obsolescence management, upgradeability,
system reuse and other lifecycle costs. This means that the distributed control platform helps reduce the time to develop, integrate, modify and change a control system and thus engine capabilities. This paper analyzes how time-triggered systems and architectures enable the design of modular and distributed engine controls.


This standard outlines the practices to be used by government contractors and government buying activity regarding component obsolescence issues. Due to the dynamics of the commercial electronic component industry, it is essential that government contractors manage the electronic content of their designs to ensure they maintain the supportability and affordability of these systems. By managing obsolescence issues, an overall decrease in system lifecycle cost should be realized by the contractor and its customers. The purpose of this standard is to provide fundamental guidelines for component selection for managing this issue.

JEDEC (2005). PRODUCT DISCONTINUANCE.

This standard was developed by suppliers and users of electronic components to provide a standard set of requirements for timely customer notification of planned product discontinuance, which will assist customers in managing end-of-life supply, or to transition on-going requirements to substitute products.

JEDEC (2006). GUIDELINES FOR USER NOTIFICATION OF PRODUCT/PROCESS CHANGES BY SEMICONDUCTOR SUPPLIERS.

This standard establishes procedures to notify customers of semiconductor product and process changes. Requirements include: documentation; procedures for classification, notification and customer response; content; and records. Documentation of a suppliers change notification system should set clear and understandable expectations for both the originators of the change and their end customers.


Obsolescence management techniques can be categorized as either production engineering based techniques that attempt to control an existing situation or design based approaches that attempt to minimize the initial problem. This paper addresses system architecture design as an approach to obsolescence management. The work of the ASAAC program in developing open architecture standards designed to exhibit a high level of obsolescence robustness is described. Other issues that relate to the financing and organization of obsolescence management are also discussed.


Tools used in a machining process are vulnerable to frequent wear-outs and failures during their useful life. Maintenance is thus considered essential under such conditions.
Additionally, it is widely recognized that the maintenance of manufacturing equipments and the quality of manufactured product are highly interrelated. However, few detailed study has been found in the literature dealing with the effects of maintenance policies on the operational performance of such a system, especially the long-term average cost. The need for a method to determine the optimal tool maintenance policy has become increasingly important. Since the multiple tools in a multi-station machining system generally have significant interactive impacts on the product quality loss, the optimal multi-component maintenance models for several policies are investigated to address the interdependence among these tools. Three distinctive multi-component maintenance policies, i.e., age replacement, block replacement, and block replacement with minimal repair, are identified and analyzed. The proposed approach focuses on these maintenance policies with consideration of both component catastrophic failures, and the interdependence of component degradations on the product quality loss as well as the obsolescence cost. The effects of various maintenance policies on the system performance are simulated, and they are used to determine the best policy for a given system. An illustrative example is used to demonstrate effectiveness and applicability of the proposed approach. The results presented a comparative analysis of specified maintenance policies with respect to the total maintenance cost with consideration of the product quality loss and the obsolescence cost. 2009 Elsevier Ltd. All rights reserved.


Recently, approximate formulas for determining the relevant total costs and the optimal lot size in face of sudden obsolescence were proposed. In this paper, we provide an exact formulation of the relevant costs which, when minimized, give the true optimal lot size. The estimation errors of the approximate model are significant in some situations, and the use of our exact model is recommended.


Commercial standards adopted from the volume driven electronics markets provide improved processing capacities over those widely used military standards and at reduced cost. Desired future capabilities and advanced functions, such as RPA, require the throughput, bandwidth, and memory provided by commercial processors and data buses. The primary issues needing resolution prior to implementation are related to operations in military rotorcraft environment, reliability, redundancy management, and fault and battle damage tolerance. In addition, some required network components presently do not exist in the preferred form factors. The ROSA project is providing effective laboratory demonstrations of COTS products and open systems specifications and standards to rotorcraft avionics. Preliminary cost estimates forecast large potential savings and create a compelling business case for follow on research and transition to production systems. In addition, the project is developing a rotorcraft technical architecture with the participation of many industry partners and will promote the resulting documentation as background materials for the JTA-A
Custom low volume products and systems, such as those utilized by military and avionics applications; often make use of commercial high-tech components. In the past decade, technology has advanced very rapidly causing such components to have a shortened life span. Newer and better technologies are being introduced frequently, rendering components obsolete. Yet, custom low volume products and systems such as ships, submarines and aircraft can be in use for decades. Being proactive about obsolescence is critical to maintaining fully capable products and systems and satisfied customers. This paper presents an obsolescence risk measurement tool that is being developed to better predict and manage component obsolescence. Critical variables in this assessment that are precursors to a component becoming obsolete are described. A multiple regression model developed for forecasting obsolescence is presented. An industrial case study with Kollmorgen, an international manufacturer of motion control systems, is also presented.


A number of optimal maintenance policies have been proposed and studied based on several types of warranty policies. As the criteria for optimality, the expected cost rate per unit time during the life cycle of the system is quite often used by many authors. However, the expected cost rate may depend on the length of life cycle and so the definition of life cycle plays a significant role in optimizing the maintenance policy. This paper considers a system maintenance policy during the post-warranty period under the renewing warranty policy and the life cycle is defined from the user's perspective. The life cycle starts with the installment of a new system and ends when the system is replaced by a new one at the expense of the user. In many renewing warranty models, the life cycle is defined as the lifelength of the new system installed initially, which is quite different from our definition. The expected cost rate per unit time is evaluated based on the life cycle newly defined and is compared with the existing results.


The NS16000 microprocessor family, presented by National Semiconductor Co. (Santa Clara, CA), is a totally new generation of devices, using the advanced XMOS technology. It consists of a selection of CPU chips and a set of peripherals and slave processors. The NS16000 architectural features allow easy future growth path, so that the introduction of next generation processors will not make present-day designs obsolete.


Embedded systems pose special challenges to system evolution: they're embedded in a changing environment, often interacting with evolving processes of human organizations, and thus must be verified because of their critical nature. Complicating the situation, the analyses and testing regimens used to verify them must evolve as well. Both software
engineering research and industrial practice need to improve to address these problems. While admittedly underemphasized in software engineering education, system evolution is crucial, and the challenges discussed here will be addressed by improving on the initial results presented.


This article presents a life cycle cost (LCC) model of a repairable system. The model is based on a marked point process and allows for non-constant failure intensity as well as stochastic nature of costs associated with system's failures. The model is applied to failure data from computer numerically controlled (CNC) machines.


Depot-level automatic test equipment has been used over the years by various facets of both the government and commercial industry. Over time, the instrumentation used in the depot will need to be repaired or replaced and, oftentimes, the older instruments are no longer serviceable or manufactured. This paper discusses how to replace the obsolete instrument and its associated hardware. Test module adapter with a software module and driver that allows compatibility between the original test executive and the modern instrument without re-hosting existing test program sets. Systems & Electronics, Inc. has implemented this procedure for a digitizer and precision DC power supply on a depot that utilizes the IEEE-488 general purpose interface bus (GPIB) for communication between the control computer and instrumentation.


No abstract available


The automotive industry is now facing many problems and challenges that put many restrictions on car design, towards the minimization of the car cost. Most of the problems arise from the continuously increasing need to provide more advanced features in the modern cars. This lead to a dramatically increase in the percentage electronics inside the car, which lead to increasing the number of Electronic Control Unit in the Cars. This will lead to power consumption problems, wiring problems, code complexity problems, and the most important, the obsolescence problems. In this paper, we will use the runtime partial reconfiguration feature of the FPGA to minimize the costs associated with migration and porting of the software due to microcontroller obsolescence.

Current programmatic metrics for obsolescence reporting do not provide actionable information to logistics, engineering, or program managers. At best, they provide feedback on the volume of cases being worked, and provide a rough order of magnitude on cost avoidance, but with no indication of the criticality of cases, or the time frame in which avoidances will be realized. This paper introduces the Reactive Obsolescence Health Indicator, a new way to analyze reactive programs, ensuring that resources are being spent wisely. 2010, American Society of Naval Engineers.


No abstract available


Long-term relationships between original equipment manufacturers (OEMs) and stakeholders in their supply chain and end-of-life process can be designed, while considering uncertainty in future environmental legislation changes. This study proposes a method to analyze the capability of OEMs to reconfigure their supply chain and end-of-life operations to achieve performance targets, which are defined in terms of environmental impacts and life-cycle costs. Using life-cycle simulation (LCS), the physical deterioration and the functional obsolescence of individual products are considered as stochastic elements in the analysis. The analyzed reconfiguration capability provides the OEM with robustness against uncertainty from a life-cycle perspective.


The military, in conjunction with their contractors, are facing a major problem: their hardware life cycle is increasing while component life cycle is decreasing. In the face of declining budgets, the military must maintain their hardware for up to 30 years. This is becoming increasingly difficult to accomplish when the average component life cycle has gone from over 20 years to less than five. In the past, the military electronics market used to drive semiconductor device development. Now the military accounts for only 1% of the entire semiconductor market and has very little influence in product direction, pricing and life cycle. The military and industry have come up with tools to counteract this diminishing resources problem. Most available tools in industry and military for combating obsolescence deal with individually packaged chips. MCM manufacturers face the same problems as circuit card manufacturers plus additional ones of die size and pad locations. This paper addresses strategies for dealing with obsolete chip components in military applications. The MCM manufacturer can be proactive or reactive in fighting chip obsolescence. The proactive techniques start with the initial electrical and physical design of the MCM and continue until the system is removed from service. The reactive techniques come into play when the MCM manufacturer is notified that chips are becoming, or have become, unavailable. Some of the reactive techniques include lifetime
buys, part substitution, physical redesign, use of interposers with alternate parts, electrical redesign and emulation


Minimizing the effects of obsolescence in MCMs requires the MCM manufacturer develop a strategy starting in the design stage to maximize the life cycle of each of the components while controlling costs. This strategy includes selecting components in their early stages of life, identifying alternate sources and providing flexibility in the substrate layout. While in production, the MCM manufacturer needs to stay abreast of the semiconductor market to learn of possible obsolescence while viable, low risk options are available.


In this paper, we provide an integrated framework for forecasting and inventory management of short life-cycle products. The literature on forecasting and inventory management does not adequately address issues relating to short life-cycle products. We first propose a growth model that can be used to obtain accurate monthly forecasts for the entire life-cycle of the product. The model avoids limiting data requirements of traditional methods. Instead, it extracts relevant information from past product histories and utilizes the information on total life-cycle sales and the peak sales timing. Using disguised demand data from a personal computer (PC) manufacturer, we validate the model. Next, we model the inventory management problem for the short life-cycle environment. The uncertainty in demand is modeled through the uncertainty in the realized values of the parameters of the forecasting model. The high cost of terminal inventory, shortages, and rapidly changing procurement costs are all included in the model. Extensions to the basic model are also developed. Using optimal control theory, we derive a solution that provides valuable information on procurement cutoff time and terminal service levels. A detailed example explains the characteristics of the policy and its relevance in decision making. Many of the issues covered in the models were brought to our attention while implementing a forecasting model at a PC manufacturer. The benchmark monthly forecasts and the associated inventory levels provide information that can be very helpful in planning and controlling marketing, sales, and production.


Short product life cycles are becoming increasingly common in many industries. Traditional approaches to medium-term forecasting are not designed for the type of information available (or the lack thereof) in the short life-cycle environment. A typical demand curve for these products consists of rapid growth, maturity, and decline phases coupled with seasonal variation. With reference to product demand curves of a personal computer (PC) manufacturer, we suggest the use of information on total life-cycle sales and the peak sales timing to obtain initial monthly forecast in the absence of a sales
history. Three growth models are presented in which such information can be utilized to estimate the parameters. We also outline procedures that use demand history of prior products to estimate the seasonal variation in demand. Using data on PC products, we empirically validate the models and compare their fit and forecast performance with ARIMA models. We show that the accuracy of the forecast made multiple periods ahead using two of the three models investigated is comparable to that made one period ahead using ARIMA models. Empirical observations and issues relating to the implementation of the models at a PC manufacturer are also discussed.


Problems are discussed that arise when equipment/systems reach the upper end of and even beyond their intended useful lifetime and replacement parts are no longer available. Rapid advances in the state-of-the-art (SOTA), as well as economic considerations, result in parts obsolescence. Various approaches to the problems are presented and some solutions are suggested for the military equipment parts.


This paper presents a comprehensive model of how military and commercial operators achieve benefits in Health and Usage Monitoring Systems (HUMS) equipped helicopters. The model uncovers the substantial set of the potential benefits and presents a framework that each operator can use as a tool to analyze particular benefits that are tuned to the operating environment for which HUMS is being used or being considered. The model presents real-life cases to show the benefits that can be achieved from operational HUMS systems and actual operational data and analysis. The paper examines HUMS as it affects potential roles and missions of helicopters, including commercial and military. Consideration is given to such issues as fleet readiness, management of spares assets, cost of M&O staff, and effects of aircraft downtime. The model includes all sources of costs for the HUMS, including the costs of equipment, installation costs, downtimes for installation, cost of support of the HUMS, etc. The model also looks into the perceived future operational environment, where the operator and the aircraft manufacturer are integrated into a real-time team to get the best performance from the deployed fleet. A major emphasis of the paper is the use of practical, real-life experience as a feedback into the HUMS system. The system includes equipment, operating procedures and personnel, integrated into a cohesive force.


Even in times of increased defense spending, defense systems have been required to operate beyond their originally estimated lifetimes. Periodic technology insertion helps to remedy parts and performance obsolescence by keeping a fielded system more in tune with commercial designs. The benefits of keeping a design close to the commercial marketplace are many, but the primary results are reduced parts costs and reduced design
labor costs. Unfortunately, a recurring problem with technology insertion efforts is that the government does not own the data rights to the original design, which makes form, fit, and functional compatibility requirements difficult to fulfill by any, but the original supplier of the system. If government ownership is maintained by using an independent design agent, lower costs are possible, since the resultant system is not tied to a single manufacturing source. With governmental ownership of the design, the government can shop for low cost production. A downside to governmental ownership of the design exists if selecting a production source and first-article qualification lengthens the procurement cycle. These delays build obsolescence into the system. This problem can be eliminated by selecting a preferred manufacturing source early in the technology insertion design phase. Having the preferred source manufacture the first articles allows the reprocurement data package, the design, and the production line to be qualified simultaneously. This paper details the use of technology insertion, government ownership of independent design agent produced designs, and preferred manufacturing sources as the basis for a cohesive business plan to economically reduce parts and performance obsolescence problems in aging military systems. Actual results for the use of this plan in several recent technology insertion projects are discussed.


A new generation of durable goods makes an old generation economically, even if not physically, obsolete. Economic obsolescence due to technological innovation requires the durable goods monopolist to implement price discrimination in two dimensions, both between consumers with different valuations and between consumers with different purchase histories. Equilibrium in the game between the durable goods monopolist and consumers depends on the extent of economic obsolescence and the relative sizes of the consumer groups. Underinvestment in innovation may take place. This contrasts with the standard literature on planned obsolescence where the durable goods monopolist overinvests in durability reducing technology.


Electronic microcircuit technology has evolved so rapidly that parts designed may become obsolete when production starts or during the production cycle. The authors explore methods to combat the parts obsolescence problem. They argue that the earlier in a program that obsolescence is treated, the greater the possibility that obsolescence will not become a problem.


Cost estimation for space science missions is critically important in budgeting for successful missions. The process requires consideration of a number of parameters, where many of the values are only known to a limited accuracy. The results of cost estimation are not perfect, but must be calculated and compared with the estimates that the
government uses for budgeting purposes. Uncertainties in the input parameters result from evolving requirements for missions that are typically the "first of a kind" with "state-of-the-art" instruments and new spacecraft and payload technologies that make it difficult to base estimates on the cost histories of previous missions. Even the cost of heritage avionics is uncertain due to parts obsolescence and the resulting redesign work. Through experience and use of industry best practices developed in participation with the Aerospace Industries Association (AIA), Northrop Grumman has developed a parametric modeling approach that can provide a reasonably accurate cost range and most probable cost for future space missions. During the initial mission phases, the approach uses mass- and power-based cost estimating relationships (CER)'s developed with historical data from previous missions. In later mission phases, when the mission requirements are better defined, these estimates are updated with vendor's bids and "bottoms-up", "grass-roots" material and labor cost estimates based on detailed schedules and assigned tasks. In this paper we describe how we develop our CER's for parametric cost estimation and how they can be applied to estimate the costs for future space science missions like those presented to the Astronomy Astrophysics Decadal Survey Study Committees.


No abstract available


Consignment stock (CS) is a special case of vendor managed inventory (VMI). The present literature on CS model has focused on the one-vendor, one-buyer system with or without the presence of product obsolescence. This paper extends the present works from two aspects. One is to change the system to one-vendor and two-buyer. The overlapped effects of the CS mechanism and different transportation policies are analyzed. Results demonstrate that system costs with different transportation policies depend on the demand, cost parameters and production policies. A numerical method to compare system costs is given. Another is to change the product lifetime from determinate to indeterminate. The several production and transportation policies under this setting are analyzed. Results show that high production flexibility and keeping outdated products in the vendor's site could lead to lower system costs.


Current and future military avionic systems require real-time embedded software based on the latest technological advances in software tools, capabilities, and languages. However, the development time and lifecycle of avionic systems is so long, that the tools, processes, methodologies, and languages used by the system developers are often obsolete by the time the systems need significant upgrades or replacement. Hence, software obsolescence is a major issue faced by many avionic systems. Previously, avionics programs have tackled software obsolescence using different approaches. These
approaches have included code conversions by hand, which are costly and time consuming, scripting tools/languages which have scalability problems, emulators which involve re-engineering of the peripheral code base and retention of the obsolete code engineering environment, and software wrappers which are not costly, but hinder future modifications to the legacy software that is accessed by the software wrappers. Each of these approaches has its own liabilities. For our research and development effort we chose to upgrade our legacy code base with a specially developed code refactoring transformer, the Boeing migration tool (BMT). Specially developed code transformers based on new technologies and more powerful computers are scalable, capable of converting almost the entire code base, allow for future development on the updated code base with the latest tools, processes, methodologies, and languages, and are less costly than updating code by hand. This paper details the inputs, the code transformer itself, the outputs, and how well the code transformer performed its task for updating a software code base. This work was performed for the Defense Advanced Research Projects Agency (DARPA) program composition for embedded systems (PCES) program. The resulting code base generated by the code transformer could be updated with the most recent tools, processes, and languages. DARPA's objective was to find faster and easier software code base conversion processes that lead to new software code bases that were closer to the final product than previous mechanizations.


With decreasing defense dollars available to purchase new military aircraft, the inventory of existing aircraft will have to last many more years than originally anticipated. As the avionics computers on these aging aircraft get older, they become more expensive to maintain due to parts obsolescence. In addition, expanding missions and changing requirements lead to growth in the embedded software which, in turn, requires additional processing and memory capacity. Both factors, parts obsolescence and new processing capacity, result in the need to replace the old computer hardware with newer, more capable microprocessor technology. New microprocessors, however, are not compatible with the older computer instruction set architectures. This generally requires the embedded software in these computers to be rewritten. A significant savings-estimated in the billions of dollars-could be achieved in these upgrades if the new computers could execute the old embedded code along with any new code to be added. This paper describes a commercial-off-the-shelf (COTS) based form, fit, function, and interface (F³I) replacement strategy for legacy avionics computers that can reuse existing avionics code as is while providing a flexible framework for incremental upgrades and managed change. It is based on a real-time embedded software technology that executes legacy binary code on the latest generation COTS microprocessors. This technology, developed by TRW and being applied under the sponsorship of the Air Force Research Lab (AFRL), promises performance improvements of 5-10 times that of the legacy avionics computer that it replaces. It also promises a 4X decrease in cost and schedule over rewriting the code and provides a known good starting point for incremental upgrades of the embedded
flight software. Code revalidation cost and risk are minimized since the structure of the embedded code is not changed, allowing the replacement computer to be retested at the blackbox level using existing qualification tests.


With decreasing defense dollars available to purchase new military aircraft, the inventory of existing aircraft will have to last many more years than originally anticipated. As the avionics computers on these aging aircraft get older, they become more expensive to maintain due to parts obsolescence. In addition, expanding missions and changing requirements lead to growth in the embedded software which, in turn, requires additional processing and memory capacity. Both factors, parts obsolescence and new processing capacity, result in the need to replace the old computer hardware with newer, more capable microprocessor technology. New microprocessors, however, are not compatible with the older computer instruction set architectures. This generally requires the embedded software in these computers to be rewritten. A significant savings—estimated in the billions of dollars—could be achieved in these upgrades if the new computers could execute the old embedded code along with any new code to be added. This paper describes a commercial-off-the-shelf (COTS)-based form, fit, function, and interface (F3I) replacement strategy for legacy avionics computers that can reuse existing avionics code "as is" while providing a flexible framework for incremental upgrades and managed change. It is based on a real-time embedded software technology that executes legacy binary code on the latest generation COTS microprocessors. This technology promises performance improvements of 5-10 times that of the legacy avionics computer that it replaces. It also promises a 4x decrease in cost and schedule over rewriting the code and provides a "known good" starting point for incremental upgrades of the embedded flight software. Code revalidation cost and risk are minimized since the structure of the embedded code is not changed, allowing the replacement computer to be retested at the "blackbox" level using existing qualification tests.


Obsolescence is a critical factor that need to be addressed by all businesses and manufacturers. Two strategies can be implemented to tackle this problem. One is to be reactive, that is, solving the problem when it arises and implies that no specific provision has been made for obsolescence. Another approach is to become proactive, meaning, identify critical components and stringently monitor their inclusion in equipment for any event of obsolescence.


Defense and commercial electronics systems need upgrading for a number of reasons; obsolete parts, diminishing manufacturing sources (DMS), availability of newer technologies that are superior to older ones, requirements for newer functionality and form-fit-function replacements, in addition to the drive towards using commercial-off-
the-shelf (COTS) technology. We propose a comprehensive methodology and a set of enabling technologies that facilitate the efficient recovery of legacy component and system functionality, tradeoff-based redesign and functional replacement, followed by synthesis and test of the upgraded system (consisting of hardware and software). Our VHDL-based methodology is currently being evaluated on several avionics programs under the auspices of the Air Force Electronics Parts Obsolescence Initiative (EPOI), and some recent results are presented


This paper assesses the state-of-the-ad of the diffusion models of new product acceptance. A number of issues related to the further development and validation of these models are discussed


Since the publication of the Bass model in 1969, research on the modeling of the diffusion of innovations has resulted in a body of literature consisting of several dozen articles, books, and assorted other publications. Attempts have been made to reexamine the structural and conceptual assumptions and estimation issues underlying the diffusion models of new product acceptance. The authors evaluate these developments for the past two decades. They conclude with a research agenda to make diffusion models theoretically more sound and practically more effective and realistic. [ABSTRACT FROM PUBLISHER]

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This article discusses the empirical generalizations that stem from the diffusion model and it also discusses some of the managerial applications of the model. The model was developed by F.M. Bass, which represents a pattern or regularity that has been shown to repeat over many new products and services in many countries and over a variety circumstances. As a theory of communications, diffusion theory's main focus is on communications channels, which are the means by which information about an innovation is transmitted to or within the social system. These means consist of both the mass media and interpersonal communications. Members of a social system have different propensities for relying on mass media or interpersonal channels when seeking information about an innovation. Interpersonal communications, including nonverbal observations, are important influences in determining the speed and shape of the S-shaped pattern of the diffusion process in a social system. The model is designed to apply
to initial purchase of the product and not to apply to replacement demand. Over time the replacement component of total demand will increase relative to the initial purchase component and if sales data, as opposed to adoption data, are used in fitting the model, care must be taken to restrict time periods to those in which the replacement demand is negligible.


Using the analytical logic underlying the classical adopter categorization approach proposed by Rogers, the authors suggest that adopter categories for a product innovation can also be developed by using other well-established diffusion models such as the Bass model. With data on 11 consumer durable products, they compare adopter categories generated by the classical approach and the Bass diffusion model, respectively. An application examining the diffusion of personal computers is documented to illustrate the usefulness of the adopter categorization based on the Bass diffusion model in studying differences among adopter categories. [ABSTRACT FROM AUTHOR]

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A simple algebraic estimation procedure is developed to estimate the parameters of diffusion models of new product acceptance. The procedure required knowledge of the occurrence of the point of inflection (based on actual data, analogous products, or management judgments). It is conceptually easy to use and can be implemented by using a hand calculator. Since the procedure does not employ period-by-period time-series diffusion data, it is not expected to provide the best fit to the data as compared to the maximum likelihood and nonlinear least squares estimation procedures. However, the procedure can provide very reasonable estimates about the relative magnitudes of the parameter estimates. In that respect, the procedure can be used to generate good starting values for the maximum likelihood and nonlinear least squares estimation procedures. In the absence of data, using management judgments about the point of inflection, the procedure can be implemented in a decision-support system to develop conditional diffusion curves for a new product. Data from four diverse innovations are used to illustrate the procedure.

Customer lifetime value (LTV)—which is a measure of the profit generating potential, or value, of a customer—is increasingly being considered a touchstone for customer relationship management. The central challenge in predicting LTV is the production of estimated customer tenures with a given service supplier, based on information contained in company databases. Classical survival analysis techniques like proportional hazards regression focus on covariate effects frequently presumed to be linear, and examination of age-wise effects can be difficult. Further, segments of customers, whose lifetimes and covariate effects can vary widely, are not necessarily easy to detect. A new neural network model for hazard prediction is used to free proportional hazards-like models from their linearity and proportionality constraints, and clustering tools are applied to identify segments of customer hazard patterns. Using the proportional hazards and neural network models in tandem, we demonstrate how data mining tools can be apt complements of the classical statistical models, and show that their combined usage overcomes many of the shortcomings of each separate tool set resulting in a LTV tenure prediction model that is both accurate and understandable.


The paper deals with development of platform based, embedded, hard real-time systems for traction and power engineering applications. Such systems are intended to have lifecycle of more than 20 years. Several cases of successful projects based on two typical platform architectures are presented. Both hardware and software platforms and components are described along with some topics that can help to identify advantages and disadvantages of such an attitude. Particular attention is given to the problem usually not taken into account, component obsolescence.


Maintaining and supporting complex systems within a developing world context has many challenges including dealing with systems that are being operated beyond their designed life or where obsolescence is a major concern. Current methodologies to develop an integrated logistics support system (ILSS) are based on assumptions that are not valid in all cases, and a more robust framework with grounded design rules is required. The approach followed in developing the grounded technological rules was by deconstructing the available ILSS and related literature six case studies into the a framework. After analysis of this qualitative work, a third phase was added on where a questionnaire was used to explore the key areas of concern. Some of the insights regarding obsolete and beyond life complex systems were found to be: the effect of obsolescence is significantly wider than the obsolescence and retirement element of the existing frameworks; obsolescence planning must be done on reliability data for the specific operating environment, it is essential to understand technological changes and scan continuously for the impact on system or component obsolescence and that a risk based approach is essential to develop a obsolescence plan as part of the ILSS.

In this paper we develop a parameter estimation procedure for a stochastic process when that process is non-stationary. Although the estimation procedure itself is very general, we derive the model for the particular case of a Poisson process with parameter \( t \) subject to exponential decay. We then illustrate the application of this particular model to a fundamental problem in the management of inventories subject to obsolescence, i.e., how to identify excess inventories in sufficient time to ensure that stocks are cleared before the end of the season.


No abstract available


No abstract available


This paper describes our experience using dependency analysis and visualization as a tool to identify intervention points for migrating applications to environments where they can live out their natural lives, less dependent of the vagaries of platform obsolescence. The first part of the paper describes our methodology and deliverables. The second part presents case studies on applying this approach to commercially installed applications.


No abstract available


The paper identifies 29 models that the literature suggests are appropriate for technological forecasting. These models are divided into three classes according to the timing of the point of inflexion in the innovation or substitution process. Faced with a given data set and such a choice, the issue of model selection needs to be addressed. Evidence used to aid model selection is drawn from measures of model fit and model stability. An analysis of the forecasting performance of these models using simulated data sets shows that it is easier to identify a class of possible models rather than the 'best' model. This leads to the combining of model forecasts. The performance of the combined forecasts appears promising with a tendency to outperform the individual component models.

This paper proposes an approach to analyzing demand scenarios in technology-driven markets where product demands are volatile, but follow a few identifiable lifecycle patterns. After examining a large amount of semiconductor data, we found that not only can products be clustered by lifecycle patterns, but in each cluster there exists a leading indicator product that provides advanced indication of changes in demand trends. Motivated by this finding, we propose a scenario analysis structure in the context of stochastic programming. Specifically, the demand model that results from this approach provides a mechanism for building a scenario tree for semiconductor demand. Using the Bass growth model and a Bayesian update structure, the approach streamlines scenario analysis by focusing on parametric changes of the demand growth model over time. The Bayesian structure allows expert judgment to be incorporated into scenario generation while the Bass growth model allows an efficient representation of time varying demands. Further, by adjusting a likelihood threshold, the method generates scenario trees of different sizes and accuracy. This structure provides a practical scenario analysis method for manufacturing demand in a technology market. We demonstrate the applicability of this method using real semiconductor data.


Identical components are considered, which become obsolete once new-type ones are available, more reliable and less energy consuming. We envision different possible replacement strategies for the old-type components by the new-type ones: either purely preventive, where all old-type components are replaced as soon as the new-type ones are available; either purely corrective, where the old-type ones are replaced by new-type ones only at failure; or a mixture of both strategies, where the old-type ones are first replaced at failure by new-type ones and next simultaneously preventively replaced after a fixed number of failed old-type components. To evaluate the respective value of each possible strategy, a cost function is considered, which represents the mean total cost on some finite time interval [0, t]. This function takes into account replacement costs, with economical dependence between simultaneous replacements, and also some energy consumption (and/or production) cost, with a constant rate per unit time. A full analytical expression is provided for the cost function induced by each possible replacement strategy. The optimal strategy is derived in long-time run. Numerical experiments conclude the paper. Copyright 2008 John Wiley Sons, Ltd.


Identical components are considered, which become obsolete once new-type ones are available, more reliable and less energy consuming. We envision different possible replacement strategies for the old-type components by the new-type ones: purely preventive, purely corrective and different mixtures of both types of strategies. To
evaluate the respective value of each possible strategy, a cost function is considered, which takes into account replacement costs, with economical dependence between simultaneous replacements, and energy consumption (and/or production) cost, with a constant rate per unit time. A full analytical expression is provided for the cost function induced by each possible replacement strategy. The optimal strategy is derived in long-time run. Numerical experiments close the paper. Taylor Francis Group, London. 2009 Taylor Francis Group.


Most maintenance policies assume that failed or used components are replaced with identical units. Actually, such a hypothesis neglects the possible obsolescence of the components. When a new, more reliable and less consuming technology becomes available, a decision has to be made as for the replacement strategy to be used: old-type components can all be immediately replaced, or new-type units can be introduced progressively, each time a corrective action is undertaken. Partly corrective, partly preventive policies can also be envisioned. This work tackles this issue in the case of a series system made of \( n \) identical and independent components with a constant failure rate. It provides, under given modelling assumptions, the fully analytical expression of the mean total cost induced by each possible strategy, as well as the optimal replacement policy, as a function of the problem parameters. This is performed by accounting for different costs for preventive or corrective replacements, with some economical dependence between replacements, different energy consumption rates for old-type and new-type components as well as a discount rate. Copyright 2004 John Wiley Sons, Ltd.


Software is the primary focus of integration efforts for development of Open Architected, scalable, adaptable solutions in today's Defense Systems of Systems. Unfortunately, successful software vendors obsolete their own product versions to maintain the pace with the market, without regard for the military need for continued support or expandability. Recognized by many professionals as being of equal gravity as the hardware obsolescence issue, software obsolescence has to-date not enjoyed the same level of visibility. This paper reveals the obsolescence problem in development, integration, test, production, and program management environments; a different perspective compared to the typical focus on obsolescence risk management and mitigation in the end-user, operational environment. Despite the portfolio of methods implemented for the effective management of COTS hardware obsolescence on a growing number of military programs, the software obsolescence problem is not being managed or mitigated. Could software obsolescence become more overwhelming than the hardware obsolescence dilemma? 2006 IEEE.


This paper provides an overview on the problem of component obsolescence. It discusses typical influences and drivers of obsolescence during the through life support of complex electronic or long life systems. Obsolescence management planning requirements in support of the identified influences and drivers is presented. Simplified life cycle costing models are presented together with proposed supply and design related mitigation options. 2004 IEEE.


This paper provides an overview on the problem of component obsolescence. It proposes a model to develop an obsolescence mitigation timeline for the through life support of complex electronic or long life systems. Obsolescence mitigation actions are presented as a function of mitigation options during the life cycle until end of life. 2004 IEEE.


This paper examines the welfare implications of planned obsolescence in situations where the traditional monopoly undersupply exists. We find that the monopolist's introduction of incompatibility between successive generations of products alleviates the monopoly undersupply problem and may therefore generate higher social welfare than compatibility. Paradoxically, the stronger the network effects, the more likely welfare will increase as a result of incompatibility. Our result also extends to two-sided markets characterized by indirect network effects. 2010 Elsevier B.V.


COTS (commercial off the shelf) component products undergo a technology refresh and renewal cycle. New versions or releases of COTS component products are brought to the market frequently. And rapid evolution of the COTS component product means the obsolescence of the COTS-based systems, especially during COTS-based systems' maintenance (in a long run). This is the fundamental problem to application developer. So the evaluation of the system's COTS component part is primary issue. This paper provides an open evaluation model to complete the task. The model bases on AHP and WSM, considering of COTS components lifecycle


No abstract available

The authors describe the goals and objectives of integrated modular avionics (IMA) and present one candidate architecture for IMA as applied to the Boeing 777 airplane. It is pointed out that the integration concepts being developed for the 777 Boeing represent an important first step in real world application of the IMA technologies being developed in the ARINC subcommittees. It is concluded that it is the realization of these concepts that will allow the necessary step improvement in system quality, reliability, safety, and maintainability demanded for all next-generation avionic equipment.


Over the last decade the United States Government has significantly increased its use of commercial-off-the-shelf (COTS) software as stand-alone solutions and as components in safety-critical systems. This increased use stems from the realization that pre-existing software products can be a means of lowering development costs, shortening development time, and keeping pace with the changing software market. The Federal government, particularly with regards to safety-critical systems, has found that COTS software is currently not plug-and-play, has significant tradeoffs, and usually contains a 'cradle-to-grave' dependence on the software manufacturer. Unfortunately, there is currently no standard 'best commercial practice' with regard to the acceptance of COTS software. Ad hoc attempts to apply standards for commercial software acceptance have been based upon subjective criteria and have proven to be imprecise and prone to error. Moreover, acceptability in safety-critical systems generally demands analysis of source code. Many software vendors, however, have chosen to keep all such source code proprietary due to liability and intellectual property concerns. When the source code is not available, there is very little that can be done to ensure the safety, reliability, and integrity of the software. This paper discusses the COTS Score, an approach that aids in determining the acceptability of COTS software. The process involves the application of predictive techniques used for financial credit scoring to the COTS domain. The methodology addresses the issue of acceptability by incorporating both functional and environmental software measures related to reliability, compatibility, certifiability, obsolescence, and life cycle including trade-off analyses. This approach satisfies NASA and ISO 9001 requirements to define an acceptance procedure for COTS software.


Markovian model is presented of class of items with use-rate that is randomly distributed and with mean use or popularity that diminishes exponentially with time; tables are given of functions involved; as example, it is shown that yearly circulation of books in library corresponds to model, thus enabling circulation characteristics of various book classes to be predicted probabilistically. (15708)

The role of warranty has become increasingly important, both as a promotional (particularly where competing products are nearly indistinguishable) and as a protectional device (for complex and expensive products where customers need some assurance). Offering warranty implies additional cost to the manufacturer over the period from product launch to obsolescence. This cost is influenced by technical decisions made prior to the launch. This paper develops a strategic approach to warranty management where warranty-related decisions are made in a framework encompassing the product life cycle and from a business perspective which links technical and commercial issues.


We consider the problem of deciding whether to keep a piece of equipment or to replace it with a more advanced technology. This decision must take into account both the nature of the available replacement technology and the possibility of future technological advances. Existing models are restrictive in the way they model the appearance of future technologies and the costs and revenues associated with those technologies. In an earlier paper we allowed the probability of appearance of new technologies to be non-stationary in time, but required the costs and technologies to be different, but constant over time. In this paper, we allow the technology forecasts and revenue functions associated with technologies to be non-stationary in time and consider salvage values for technologies. We develop a simple and efficient algorithm for finding the optimal decision using a forecast horizon approach. This approach finds the optimal decision in any period with minimal reliance on forecast data.


The meeting proceedings from this symposium on Strategies to Mitigate Obsolescence in Defense Systems Using Commercial Components was organized and sponsored by the Systems Concepts and Integration (SCI) Panel of the Research and Technology Organization of NATO in Budapest, Hungary from 23 to 25 October 2000. The symposium's goal was to propose new strategies for obsolescence management including open architecture, functional partitioning and technology insertion that have to be addressed during system engineering, detailed design, production and product support. The symposium outlined actual problems and solutions to the issue of obsolescence by the entire defense system community. It also addressed burning questions related to the problem of parts obsolescence and diminishing manufacturing sources and material shortages. Management tools and methodologies to cope with the risk of obsolescence were discussed. This included new design concepts and system architectures to allow advanced technology insertion during the system life cycle. Session topics were organized under the four topics of: status and experience with COTS technology in defense electronic systems, obsolescence management tools, new design concepts and architectures to combat obsolescence, strategies and initiatives for life cycle management.
NATO (2010). Obsolescence Management, NATO.

No abstract available


When an original equipment manufacturer no longer supplies and/or supports a product then the product is considered to be obsolete. Obsolescence is a significant problem for systems whose operational and support life is much longer than the procurement lifetimes of their constituent components. Unlike high-volume, commercial products, which are quickly evolved, long field life, low-volume systems, such as aircraft may require updates of their components and technology called design refreshes to simply remain manufacturable and supportable. However these systems can’t perform design refreshes all the time due to the high nonrecurring and re-qualification costs. One approach to optimally managing this problem is to use DRP (Design Refresh Planning), which is a strategic method for scheduling design refreshes such that the life cycle cost impact of obsolescence is minimized. The planning of these design refreshes is restricted by various constraints, which need to be implemented into the DRP process. These constraints can reflect technology roadmap requirements, obsolescence management realities, logistical restrictions, budget ceilings and management policy. In this paper, constraints imposed on the DRP process are explored, classified within a taxonomy, and implemented in the planning process. A communications system design example is included


The service life of military assets significantly exceeds design life of commercial electronic systems used within them. Electronic obsolescence is increasingly associated with physical characteristics that reduce component and system reliability, both in usage and storage, with few design margins outside commercial warranty periods. Software content, however, remains a dominant limiting factor for reliability of electronic systems, and emerging commercial trends compound this. Traditional approaches to manage and sustain electronic systems are therefore increasingly ineffective and costly. This report surveys the interrelated concerns of obsolescence and reliability of electronic systems, and describes emerging responses to these concerns


The original system instrumentation in many nuclear power plants is aging, and as a result, system reliability is decreasing while maintenance and testing costs are increasing. Replacement components and spare parts are difficult, if not impossible, to obtain, therefore decreasing the feasibility repairing these devices. In addition, compared to today's technology, system operation functions are limited by the original analog technology. In response to this situation, GE Nuclear Energy (GE-NE) has developed
replacements for both safety and non-safety BWR instrumentation and control systems which resolve the equipment obsolescence problem while improving reliability and reducing maintenance costs. Digital technology offers BWR owners the opportunity to install a high degree of intelligence, various levels of redundancy, and elaborate operator displays into instrumentation and control systems. The use of digital technology also allows for easy implementation of strategies not previously considered practical in older analog equipment systems. This paper discusses the strategies for instrumentation and control upgrades to replace existing analog systems in operating Boiling Water Reactors (BWR) together with the use of productivity tools developed by Black & Veatch to improve design efficiency, increase design quality, minimize the total implementation cost, and enhance configuration management of the design basis.


Many military aircraft have on-board computers that generate moving map video for display in the cockpit. Many of these same aircraft have computers that record aircraft data in flight. The F/A-18 Hornet and the AV-8B Harrier, manufactured by Boeing (formerly McDonnell Douglas Aerospace (MDA)), have both computers. However, the computers that perform these tasks on the Hornet and Harrier have become obsolete. They were designed in the late 1970's, built in the early 1980's, and contain several electronic components within them that can no longer be procured. In 1995, MDA teamed with the Naval Air System Command's Air Combat Electronics or ACE group, to design and develop the TAMMAC system to replace these computers on the F/A-18 and AV-8B as well as be the common digital map/data recording system for all Navy aircraft. This paper describes the system engineering process used to develop the TAMMAC system and how this process helped maximize the application of COTS technology within TAMMAC while maintaining performance in military aircraft environmental conditions.


Modern high-tech products experience rapid obsolescence. Capacity investments must be recouped during the brief product life-cycle, during which prices fall continuously. We employ a multiplicative demand model that incorporates price declines due to both market heterogeneity and product obsolescence, and study a monopolistic firm's capacity decision. We investigate profit concavity, and characterize the structure of the optimal capacity solution. Moreover, for products with negligible variable costs, we identify two distinct strategies for capacity choice demarcated by an obsolescence rate threshold that relates both to market factors and capacity costs. Finally, we empirically test the demand model by analyzing shipping and pricing data from the PC microprocessor market. 2008 Elsevier B.V. All rights reserved.

A report on the obsolescence which is a major concern of automotive telematics equipment engineers is presented. The legacy software is preserved and the process is relatively cheap and fast. The creation of unusual processor configurations which can be changed at any time to suit changes in the specifications is reduced to a simple task. It was shown that emulation requires about twenty clock cycles of the latest processor for every legacy instruction it executes.

No abstract available


This article describes a method, which helps to cope with aging and obsolescence of long running computerized systems Instrumentation and Control systems (I&C). In this method, a model of the observed system is created. The model is based on the Fault Tree method. The Fault Tree is extended to work with lifetimes of the system components. The aim of the model is to recommend which part of the system should be considered for modernization or replacement.

No abstract available


Purpose: The paper presents an alternative solution to address part obsolescence. This paper discusses approaches to solve part obsolescence including an uprating approach. This paper also describes the methods to uprate parts, and demonstrates the practical application of the uprating approach in the form of a case study.

Design/methodology/approach: This paper has been written to provide an understanding of the uprating approach to mitigate the problems caused by part obsolescence. The paper discusses the challenge faced due to part obsolescence, the temperature ratings for electronic parts, the uprating methods and finally explains the use of uprating to mitigate part obsolescence in the form of a case study. The part being uprated is a microcontroller unit used in many avionics applications. The case study describes a particular use of uprating and the return on investment. Findings: Based on the uprating approach, it was discovered that for the particular application, the commercially available plastic quad flat pack microcontroller could be used as a substitute for the "military" ceramic BGA version, which was discontinued by the manufacturer. It was discovered that there would be no problem with the commercial part's quality or reliability for the particular application. Parametric tests showed no evidence of instability of electrical characteristics over the uprated temperature range. There was substantial return on investment due to the use of uprated parts. Practical implications: This paper can help electronics manufacturers deal with part obsolescence. This paper demonstrates the practicality of uprating parts. Uprating can save companies money by reducing the need for life-time buys, substitution
of parts and even redesign. Originality/value: The paper provides an alternative approach to address the problem of part obsolescence. This paper shows that proper uprating leads to cost saving while continuing to provide reliable service. Emerald Group Publishing Limited.


No abstract available


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No abstract available


Uprating is a process that assesses the capability of a part to meet the functional and performance requirements for an application in which the part is used outside the specified temperature range provided in the manufacturer's datasheet. This article discusses the use of uprating as a means to address obsolescence. The article begins by explaining the rationale and opportunities for using parts outside the specification range. The technical issues for using uprating to address obsolescence [obsolescence is known in the military community as diminishing manufacturing sources and material shortages (DMSMS)] are then presented. Finally, a case study is presented.


No abstract available


The Consignment Stock (CS) inventory policy is becoming an important strategy that companies adopt to face new manufacturing and supply chain management challenges. A CS policy implies great collaboration between the buyer and supplier, pushing them towards a complete exchange of information and a consistent sharing of management risks. In such a context, the effects of the obsolescence of products have to be carefully evaluated since they fall onto both actors, causing an increase in total supply chain costs. This paper proposes an analytical model able to take into account the effects of obsolescence in a supply chain managed with a CS policy. The deterministic single-vendor, single-buyer CS model is used as a base to develop the proposed model. A comparison with a non-obsolescence optimal solution available in the literature is presented. Moreover, the stochastic behaviour of the product lifetime estimation is also taken into consideration. Results demonstrate that the effects of obsolescence can consistently influence the global optimum condition.

The shortage of sources for qualified electronic devices used in defense systems has continued to grow at an accelerating pace and creates a serious dilemma for contractors and military centers producing and supporting DoD systems. Major suppliers of MIL devices have chosen to discontinue the manufacture of these devices and suggest they be replaced by similar commercial devices manufactured by their commercial facilities. Having studied this situation and related problems with the quality and availability of good component information, the Electronic Industries Alliance (EIA) recognized the need to establish a data warehouse. This warehouse, entitled the Component Information Management System; (CIMS), promises to alleviate the dilemma of diminishing manufacturing sources. With the CIMS data warehouse, access to accurate component and supplier information for both commercial and military applications will be readily available for a variety of individuals as well as small, medium, or large sized firms. Smaller organizations can access the data directly through the Internet Home page, while larger firms may choose to access the data through value added data product suppliers using various bulk data access methods.


Generalized Emulation of Microcircuits (GEM) technology is currently being validated by producing emulated microcircuits for logistics support of military systems. The perspective provided by the GEM development is the basis of a strategy that can break the microcircuit obsolescence cycle. With the 1992 National Military Strategy directing Service Life Extension for major DoD weapon systems, emulation is increasingly recognized as an important technology. The constrained defense budget further increases the importance of logistics (supportability, reliability, and maintainability) during the design, upgrade, or redesign phases of weapon systems. The lack of long-term supply for microcircuit components places a major supportability burden on military organizations. The absence of microcircuits for logistics support places undue pressure on program managers to authorize costly upgrades or redesigns to compensate for nonavailable replacement microcircuit components. GEM was developed to address this problem by providing a source for needed, but nonavailable integrated circuits (ICs). Emulation was identified as an approach that has significant promise to provide a cost-effective and reliable source for needed ICs. The GEM system provides a generic approach to emulation and is producing FFF microcircuits of military quality at minimum cost, when needed, and in the quantities required for logistics support.


The paper identifies and discusses the presently unresolved contradictions between the requirements of the national customers (MODs or Purchasing Agencies) and the viable
options the industry can offer to mitigate the adverse effects of obsolescence for defense material with emphasis on the extended use of COTS.


The ever-increasing complexity of electronic systems makes it imperative to develop effective systems level design automation languages, methodologies, and tools. Commercial systems face increasing complexity and performance requirements, while achieving decreasing times to market and maximizing profits despite shrinking product life-cycles. Defense systems face similar issues, but must also support life cycles which span years or decades, thus requiring redesign, support or prevention of parts obsolescence challenges. For cost-effective development of systems in this context, design teams need to exploit the best commercial and defense design practices and adapt them as needed to also support concurrent engineering considerations. This paper explores requirements for the emerging system level design language and the methodological needs for it to support multi-disciplinary design, including hardware software co-design, mechanical and packaging support, concurrent engineering, test, and related issues.


The ever-increasing complexity of electronic systems and interdependency of hardware and software throughout the system life cycle makes it imperative to develop effective electronic design automation languages, methodologies, and tools. Commercial systems face increasing complexity and performance requirements, while achieving decreasing times to market and maximizing profits despite shrinking product life-cycles. Defense systems face similar issues, but must also support life cycles spanning years or decades, thus requiring redesign support or prevention of parts obsolescence challenges. For cost-effective development of systems in this context, design teams need to exploit the best commercial and defense design practices and adapt them as needed to also support concurrent engineering considerations. This paper explores requirements for the emerging system level design language and the methodological needs for it to support multi-disciplinary design, including hardware software co-design, mechanical and packaging support, concurrent engineering, test, and related issues. By employing these techniques and representations, weapons systems acquisition programs will reduce technical, cost, and schedule risk to help ensure mission success.


The progress in the digital signal processing (DSP) applications in specific integrated circuits (ASIC) technology was analyzed. While progressing towards modern and smaller geometries, the ASIC suppliers must consider maintaining the older fabrication processes. In a design flow, an application goes through an up-front design and simulation to ensure the operation and performance of the ASIC. In order to reduce the effects of truncation errors within the design, an ASIC can be over-designed to guarantee a level performance.
in all the operation modes. Programmable logic allows for improvements and enhancements to the design of a product after shipment to the customer.


A stochastic single product convex cost inventory problem is considered in which there is a probability, $p_{ij}$, that the product will become obsolete in the future period $j$. In an interesting paper, Barankin and Denny essentially formulate the model, but do not describe some of its interesting and relevant ramifications. The present paper is written not only to bring out some of these ramifications, but also to describe some computational results using this model. The computational results show that if obsolescence is a distinct possibility in the near future, it is quite important that the probabilities of obsolescence be incorporated into the model before computing the optimal policies. (Author)


In this paper, we consider a continuous review inventory system of a slow moving item for which the demand rate drops to a lower level at a known future time instance. The inventory system is controlled according to a one-for-one replenishment policy with a fixed lead time. Adapting to lower demand is achieved by changing the control policy in advance and letting the demand take away the excess stocks. We show that the timing of the control policy change primarily determines the tradeoff between backordering penalties and obsolescence costs. We propose an approximate solution for the optimal time to shift to the new control policy minimizing the expected total cost during the transient period. We find that the advance policy change results in significant cost savings and the approximation yields near optimal expected total costs. 2011 Elsevier B.V. All rights reserved.


The consortium of Professional Employer Organization (PEO), Crane Division of Naval Surface Warfare Center (NSWC), and Naval Undersea Warfare Center (NUWC) Division has been working closely with Knudsen Engineering to develop the Commercial off-the-shelf (COTS) depth sounder solution. The solution will replace the AN/UQN-4,4A sonar sounding set and harnesses the power of technology for the warfighter. Knudsen has developed 320N navigation echo-sounder to better serve the Navy's needs for navigational depth sounding. The echo-sounder is configured with a touch screen for setup, operation, and echogram display, and a hard drive that records and stores depth data and supports all AN/UQN-4,4A unique interfaces essential in replacing the AN/UQN-4,4A. The 320N design incorporates state-of-the-art digital signal processing technology and operates with the legacy system's standard 12-kilohertz transducer. Installation of the 320N on Navy ships can be accomplished utilizing simple adapter brackets mounted to the existing AN/UQN-4,4A foundation.

Product displacement has been occurring for many years and will continue to challenge the market as technological advances result in product obsolescence. While opportunities do exist to incorporate environmentally conscious design and engineering criteria into the product development process, much of the ultimate environmental success is dependent upon closing the product life cycle, through reuse (upgrade and/or repair), re-manufacture and recycling. This paper reports on the analysis and evaluation of three successional audio video home electronic products: the VHS Video Cassette Recorder (VCR), the Laser Disc Player (LD) and the Digital Video/Versatile Disc Player (DVD). The newly released DVD player has rendered the LD player obsolete and will soon render the VCR obsolete. This paper investigates potential environmental improvements to the DVD player through design strategies for upgrading a successional product and for reducing its end-of-life impact.


No abstract available


We consider a consumer electronics (CE) manufacturer’s problem of controlling the inventory of spare parts in the final phase of the service life cycle. The final phase starts when the part production is terminated and continues until the last service contract or warranty period expires. Placing final orders for service parts is considered to be a popular tactic to satisfy demand during this period and to mitigate the effect of part obsolescence at the end of the service life cycle. To satisfy demand for service in the final phase, previous research focuses on repairing defective products by replacing the defective parts with properly functioning spare ones.

However, for consumer electronic products there is a remarkable price erosion while repair costs may stay steady over time. As a consequence, this introduces the idea that there might be a point in time at which the unit price of the product is lower than repair associated costs. Therefore, it would be more cost effective to adopt an alternative policy to meet demands for service such as offering customers a replacement of the defective product with a new one or giving a discount on the next generation of the product. This paper examines the cost trade-offs of implementing alternative policies for the repair policy and develops an exact formulation for the expected total cost function. Based on this developed cost function we propose policies to simultaneously find the optimal final order quantity and the time to switch from the repair to an alternative replacement policy. Numerical analysis of a real world case study sheds light over the effectiveness and advantage of these policies in terms of cost reduction and also yields insights into the quantitative importance of the various cost parameters.

The development and validation of fault-tolerant computers for critical real-time applications are currently both costly and time consuming. Often, the underlying technology is out-of-date by the time the computers are ready for deployment. Obsolescence can become a chronic problem when the systems in which they are embedded have lifetimes of several decades. This paper gives an overview of the work carried out in a project that is tackling the issues of cost and rapid obsolescence by defining a generic fault-tolerant computer architecture based essentially on commercial off-the-shelf (COTS) components (both processor hardware boards and real-time operating systems). The architecture uses a limited number of specific, but generic, hardware and software components to implement an architecture that can be configured along three dimensions: redundant channels, redundant lanes, and integrity levels. The two dimensions of physical redundancy allow the definition of a wide variety of instances with different fault tolerance strategies. The integrity level dimension allows application components of different levels of criticality to coexist in the same instance. The paper describes the main concepts of the architecture, the supporting environments for development and validation, and the prototypes currently being implemented.


Sustainment engineers, responsible for insuring that military avionics systems are supportable, are facing increasing challenges to assure that the systems for which they are accountable are mission ready. Deciding what sustainment actions are necessary and when they need to be performed is the key to the "just-in-time" sustainment concept being pursued by the F-15 Hardware Avionics Section at the Warner Robins Air Logistics Center (WR-ALC/LFEFA). This concept requires that the sustainer have visibility into all aspects of a system. The sustainer must consider system configurations, indentured parts lists and their interchangeability, component obsolescence, assembly repair information, repair history down to the component level, spares at all assembly levels, Defense Logistics Agency (DLA) and depot component inventory and usage rates, and anticipated force structure. The sustainer needs an analysis tool to correlate all these data to determine what needs to be done and when it needs to be accomplished before mission readiness is impacted. The SUSTAIN™ (sustainment strategy for avionics information needs) tool, developed by the Georgia Tech Research Institute (GTRI), allows implementation of a true just-in-time sustainment approach by consolidating all the required information into a single automated tool that displays data in a concise and informative manner. This paper describes SUSTAIN™, its data sources, and analysis capabilities.

Long life-cycle products, commonly found in aviation, medical and critical infrastructure applications, are often fielded and supported for long periods of time (20 years or more). The manufacture and support of long life-cycle products rely on the availability of suitable parts, which over long periods of time, leaves the parts susceptible to a number of possible supply chain disruptions such as suppliers exiting the market, counterfeit part risks, and part obsolescence. One solution to mitigating the supply chain risk is the strategic formulation of suitable part sourcing strategies (optimally selecting one or more suppliers from which to purchase parts over the life of the part's use within a product or within an organization). Strategic sourcing offers one way of avoiding the risk of part unavailability (and its associated penalties), but at the possible expense of qualification and support costs for multiple suppliers. Existing methods used to study part sourcing decisions are procurement-centric where cost tradeoffs focus on part pricing, negotiation practices and purchase volumes. These studies are commonplace in strategic parts management for short life-cycle products; however, conventional procurement-centric approaches offer only a limited view when assessing parts used in long life-cycle products. Procurement-driven decision-making provides little to no insight into the accumulation of life-cycle cost (attributed to the adoption and use of the part), which can be significantly larger than procurement costs in long life-cycle products. This paper presents a new life-cycle modeling approach to quantify risk that enables cost effective part sourcing strategies. The method quantifies obsolescence risk as "annual expected total cost of ownership (TCO) per part site" modeled by estimating the likelihood of obsolescence and using that likelihood to determine the TCO allowing sourcing strategies to be compared on a life-cycle cost basis. The method is demonstrated for electronic parts in an example case study of linear regulators and shows that when procurement and inventory costs are small contributions to the part's TCO, the cost of qualifying and supporting a second source outweighs the benefits of extending the part's effective procurement life.


Dedicated part selection and management groups within large original equipment manufacturers are responsible for various tasks involved with managing parts or components used in electronic systems. The tasks range from part adoption to obsolescence management and include numerous assembly and support activities that are performed on a regular basis. Long life-cycle electronic systems typically utilise commercial 'off-the-shelf' parts, which subject them to the same supply chain constraints imposed by a market that is oriented towards short-term, high-volume products. Relevant issues involve a high frequency of part procurement obsolescence, reliability concerns, and the risk of long-term supply-chain disruptions. Unfortunately, initial part selection decisions are often driven by procurement management processes with little or no insight into the total cost of ownership (TCO) of the part's adoption and use within the organisation. The part TCO model proposed in this article enables better informed part selection and management decisions. The article discusses and demonstrates the model's use in Lifetime Buy and Design Reuse case studies for an example surface-mount
electronic part. Additionally, the model proposed in this article is well suited for addressing the impacts of part number reduction, retirement of parts from databases, organisational adoption of new parts, sourcing strategies and part-specific long-term supply chain disruptions by influencing initial component selection and providing guidance on what actions taken at the component management level provide the maximum payback (or maximum future cost avoidance).


The problem of component obsolescence has been around for as long as the industry, but it has become a more serious concern in the last decade. In a technology sector in which rapid progress is the norm, new generations of components succeed the previous ones in only months, and manufacturers cannot keep every variant of every generation in production indefinitely. As the demand for each variant drops below economic viability the component disappears from production in a more or less orderly fashion. The electronics industry's problem has always been that it designs products whose life cycles regularly far exceed the life spans of the components inside them. Also military/high-reliability systems that evolved to handle component obsolescence are now coming under strain as the influence of COTS purchasing grows. However, the long-established procedures for establishing reserves of deleted semiconductors still work well and software tools are in development to help optimize life cycles with programmed design revisions and redesigns.

QinetiQ (2003). QinetiQ new web-base cuts obsolescence cost. III-Vs Review. 16: 12.

No abstract available


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Operating plants have a large investment in their existing instrumentation and control systems. Engineers are trained on and have implemented monitoring programs for the existing hardware; maintenance technicians have been trained and have years of experience with the existing systems; operations personnel have had extensive training in how the existing systems operate, as well as hands-on experience with the human-machine interface and the response of the systems. The training department typically has lesson plans for both engineering, maintenance, and operations on the various systems. And finally, the other NSSS plants that use common equipment have contributed a wealth of operating experience, improving overall reliability and reducing down time. So an operating plant is reluctant to replace any instrumentation and control system. However, the systems are or are becoming obsolete. Parts and repairs and service are getting harder and harder to find, and in general operating plants want to focus on power generation, not equipment maintenance. This paper will discuss the four main options available for
operating plants: buy a new one, repair it, buy a replacement, or replace it. 'Repair' includes (1) only replacing the failed components, and (2) replacing all aging capacitors, worn switches and adjustments, and generally resetting the qualified life of the module. Buy a replacement includes (1) duplicate the existing design, and (2) redesign a form/fit/function replacement for the module with new parts and current technology. Finally, 'replace' means removing the old equipment - usually at the system level - and replacing it with a new digital system. The advantages and disadvantages of each will be presented, with input from the recent EPRI/NRC meeting on digital upgrade licensing. A balanced view will be presented, resulting in some guidance to plants on which option to chose.


The GPS Receiver R-2332J/AR (RCVR3A) is a five-channel airborne Precise Positioning Service (PPS) GPS Receiver that currently supports the navigation and timing requirements of nearly 70 military platforms. This 25-year old technology receiver is at a life-cycle phase in which its supportability is severely impacted by parts obsolescence. The Avionics Component Obsolescence Management (AVCOM), reports that currently 18% of the integrated circuits, hybrids, discretes and radio frequency devices are obsolete. Additionally, AVCOM projects that by the year 2015 obsolescence issues will be over 50%. Rockwell Collins, Cedar Rapids was tasked by Warner Robins Air Logistics Command (WRALC) to develop a design that mitigates the obsolescence issues of the RCVR3A while maintaining backward compatibility to Host Vehicles (HV) with respect to form, fit, and function. In order to keep this new receiver functionally viable for the next decade, the receiver is to incorporate current Selective Availability Anti Spoofing Module (SAASM) technologies and provide a platform to expand to future capabilities such as the Joint Precision Approach and Landing System (JPALS) and Global Air Traffic Management (GATM). Additionally, a clear roadmap to M-Code technology is required. A key issue in developing this new receiver is to maintain full backwards compatibility with the RCVR3A with respect to its interfaces of the HV. This interface compatibility will enable existing RCVR3A platforms to an upgraded R-2332M/AR (RCVR3A-S) replacement with minimal integration effort. This paper describes the key activities for Phase 1 of a three phase effort, which paid significant dividends for the engineering team's efforts. A description of how Rockwell Collins has achieved the goal of maintaining backward compatibility to the RCVR3A while integrating Rockwell Collins' GPS Embedded Module with All-In-View SAASM functionality is provided. The future phases of the modernized RCVR3A development will also be addressed. Finally, we address the RCVR3A relative to the future phases of the initial development and describe the plans going forward to develop the full suite of HV interfaces and the challenges that we will encounter going forward into the platform integration phase of the 3A Upgrade program.

Products evolve to accommodate competitive market pressures, rapid rates of technology change, and constant improvements in performance and functionality. While adding functionality and value, the fast moving technologies also make products obsolete quickly. One of the primary reasons for product obsolescence is technological obsolescence which results when consumers are attracted to functions in newer models of products that are more technologically advanced. One way to deal with problem is piggybacking a strategy that enables renewed functionality of a technologically obsolete product through the integration or add-on of a secondary device or component. Not to be confused with upgrading strategies, piggybacking requires a device that fits adjacent to, upon, or within the existing product architecture. Piggybacking is an attractive strategy for consumer electronic products that are particularly prone to technological obsolescence as it offers a means to accommodate fast and slower changing technologies within a single product. Currently, piggyback products are realized with ad-hoc methods that rely on the experience and intuition of the designer, often applied inconsistently and not well known by less experienced designers. In this paper, a set of formal principles is presented for guiding the design of piggyback products. These principles are derived from the results of an empirical study of 72 different products. As part of the study, various products are analyzed with a dissection tool with representative principles derived from the data. The utility of these principles is demonstrated via the conceptual design of a novel piggyback products.


Due to ever tightening budgets in the defense arena, the armed services are making conscious efforts to extend the service life of existing aircraft beyond what was intended at the time of their original design. These aircraft types include extremely old airframes such as B-52H and variants of the C-130, which continues to play a part in 21st century military actions. Relatively new weapons systems are also included, such as the F-117A and B-2A, which are already beginning to experience component obsolescence problems. A major aspect of these upgrade programs involves replacing existing aging avionics with modern digital systems that are more reliable and more capable. In many cases, however, these retrofits are not simply "plug-and-play". Careful analysis is required to ensure that no existing capabilities are lost and that the new system can function properly in the legacy aircraft. These considerations can vary depending upon aircraft type and mission. Factors are to consider include interoperability with legacy systems, aircraft mass properties, A-kit wiring, human factors, training, and growth capability for future upgrades. The paper provides guidance on the evaluation of a potential retrofit, thus assisting the readers in developing their own decision support system.


The main focus of the Parts Obsolescence Management Tools (POMT) program was the definition of a reengineering methodology that supports both the initial design and the reengineering of modern products. This methodology begins with the product specification using the concept of the simulatable specification as defined by the
Continuous Electronic Enhancements using Simulatable Specifications (CEENSS) program and continues with the reengineering process whereby an implementation is developed and culminates with the interface to the manufacturing process. This effort also focused on the development of two key computer-aided design (CAD) tools needed to support the application of this methodology in real-world product challenges. These tools include a behavioral product reengineering (BRP) tool and design verification test generator (DVTG) tool.


Northrop Grumman Electronic Systems (Baltimore, Maryland) in cooperation with the AFRL Material and Manufacturing Directorate (WPAFB, Ohio) developed a 58-month ManTech obsolescence program to pursue a diverse group of tasks in various areas of parts obsolescence. The objective of the program was to reliably use COTS parts in military systems, implement ManTech funded tools and processes, integrate tools and processes in the Northrop Grumman design environment, and document the resulting cost avoidance. The program has completed its work with notable success. This succinct report highlights the results and benefits.


Some applicants, developers, and commercial-off-the-shelf (COTS) software vendors have proposed reverse engineering as an approach for satisfying RTCS/DO-178B objectives for airborne software. RTCA/DO-178B, Software Considerations in Airborne Systems and Equipment Certification, serves as the means of compliance for most airborne software in civil aircraft. DO-178B defines reverse engineering as "the method of extracting software design information from the source code" and provides guidance particular to reverse engineering, when it is used to upgrade a development baseline. For purposes of this paper, reverse engineering is an approach for creating software life cycle data that did not originally exist, cannot be found, is not adequate, or is not available to a developer in order to meet applicable DO-178B objectives. Reverse engineering is not just the generation of data - rather it is a process to assure that the data is correct, the software functionality is understood and well documented and the software functions as intended and required by the system. Reverse engineering is not, as some software developers propose, just an effort to generate the software life cycle data without intent to build in quality and the resulting design assurance. This paper explores reverse engineering in airborne software projects, by explaining a definition for the certification domain, describing the motivation for its use, and documenting the certification concerns. Two actual cases of reverse engineering are also described to illustrate the certification concerns in real projects.

Replacing computing equipment before it is obsolete is a daunting challenge. Hardware vendors offer the latest technology at a rapid pace and new versions of software quickly take advantage of the new hardware. The variables involved in technology replacement with constrained resources are discussed, along with the planned technology replacement on faculty desktops. As an example, the Desktop Computing Replacement Plan of Bucknell University is described.


No abstract available


Summary form only given. Management of tester technology has been a real challenge with Motorola's diverse product portfolio. Global support for multiple tester hardware architectures and operating systems is very expensive, difficult, and time consuming. Migration to new proprietary tester platforms requires massive efforts from design, test engineering, production, maintenance, and other areas. The semiconductor industry is ready for a common OA (open architecture) tester. The OA tester will provide many benefits to semiconductor manufacturers such as: lower costs, faster access to new technology, wider supplier base, and protection from obsolescence. Also, the OA tester will provide benefits to the ATE suppliers such as: substantially reduced support costs, reduced training, and larger market potential. Development and acceptance of the OA tester concept will not be easy, but should be achievable.


Currently, manufacturing organisations worldwide are shifting their business models towards Product-Service Systems (PSS), which implies the development of new support agreements such as availability-based contracts. This transition is shifting the responsibilities for managing and resolving obsolescence issues from the customer to the prime contractor and industry work share partners. This new scenario has triggered a new need to estimate the Non-Recurring Engineering (NRE) cost of resolving obsolescence issues at the bidding stage, so it can be included in the support contract. Hence, the aim of this research is to develop an understanding about all types of obsolescence and develop methodologies for the estimation of NRE costs of hardware (electronic, electrical and electromechanical (EEE) components and materials) obsolescence that can be used at the bidding stage for support contracts in the defence and aerospace sectors. For the accomplishment of this aim, an extensive literature review of the related themes to the research area was carried out. It was found that there is a lack of methodologies for the cost estimation of obsolescence, and also a lack of understanding on the different types of obsolescence such as materials and software obsolescence. A systematic industrial investigation corroborated these findings and revealed the current practice in the UK defence sector for cost estimation at the bidding stage, obsolescence management and obsolescence cost estimation. It facilitated the development of an understanding about obsolescence in hardware and software. Further collaboration with experts from more
than 14 organisations enabled the iterative development of the EEEFORCE and M-FORCE frameworks, which can be used at the bidding stage of support contracts to estimate the NRE costs incurred during the contracted period in resolving obsolescence issues in EEE components and materials, respectively. These frameworks were implemented within a prototype software platform that was applied to 13 case studies for expert validation.


As the UK Ministry of Defence (MoD) moves away from the traditional support contracts to contracting for availability/capability, it is essential that the MoD has confidence in Industry's capability to manage the risk of obsolescence. For this purpose, it was necessary to develop a set of metrics to demonstrate it. The eight key elements identified are as follows: obsolescence management governance; supplier; design for obsolescence; risk assessment; obsolescence monitoring; communication; and obsolescence resolution process. Each one was assessed, ranked, and was further broken down into major constituents. They formed the basis of the final 25 metrics, which were then ranked and weighted accordingly. These metrics are embedded into the Total Obsolescence Management Capability Assessment Tool (TOMCAT), which provides a mean for contractors to perform self-assessment and for the MoD to set obsolescence management capability improvement targets. This tool was subjected to rigorous industry scrutiny through different means, including workshops and piloting sessions, which led to refining the TOMCAT tool and the way in which the metrics are formulated. This tool has been developed as a web based application. The MoD is planning to standardise its usage by incorporating it to the obsolescence management policy for defence contracting.


A component becomes obsolete when it is no longer available from the original manufacturer to the original specification. In long-lifecycle projects, obsolescence has become a major problem as it prevents the maintenance of the system. This is the reason why obsolescence management is now an essential part of the product support activities in sectors such as defence, aerospace, nuclear and railway; where systems need to be supported for several decades. The obsolescence risk assessment for the bill of materials (BoM) is a paramount activity in order to manage obsolescence proactively and cost-effectively. This is the reason why it was necessary to undertake a benchmarking study to develop best practice in this process. A total of 22 obsolescence experts from 13 different organisations/projects from across UK and USA have participated in this study. Their current processes and experience have been taken into account in the development of the best practice process for obsolescence risk assessment. The key factors that have to be analysed in the risk assessment process for each component in the BoM are: number of manufacturers, years to end of life, stock available, consumption rate and operational
impact criticality. For the very high risk components, a more detailed analysis is required to inform the decisions regarding the most suitable mitigation strategies. On the contrary, for the low risk components, a fully proactive approach is neither appropriate nor cost effective. Therefore, it is advised for these components that obsolescence issues are dealt with reactively. This process has been validated using case studies with several experts from industry and is currently being implemented by the UK Ministry of Defence as technical guidance within the JSP 886 Volume 7 Part 8.13 standards.


This paper provides a comprehensive literature review on the problem of obsolescence in "sustainment-dominated systems" that require support for many decades. Research on this topic continues to grow as a result of the high impact of obsolescence on the in-service phase of long-term projects. Research on obsolescence also seeks to understand how it can be managed, mitigated and resolved. The paper aims to clarify and classify the different activities that may be included in an obsolescence management planning, taking into account not only electronic components, but also other aspects of the system such as mechanical components, software, materials, skills and tooling. The literature review shows that although there are many commercial tools available that support the obsolescence management during the in-service phase of the life cycle of a system, little research has been done to forecast the costs incurred. 2009 Springer-Verlag London Limited.

Romero Rojo, F. J., R. Roy, et al. (2012). A study on obsolescence resolution profiles, 55 City Road, London, EC1Y 1SP, United Kingdom, SAGE Publications Ltd.

This paper presents a study assessing the probability of selecting a resolution approach to tackle an obsolescence issue. First, the Delphi method was applied across an industry expert panel to derive a set of 15 obsolescence resolution profiles (ORPs). The ORPs represent the probability of using each obsolescence resolution approach to tackle an obsolescence issue. Each ORP is characterized by the complexity level of the obsolete component and the level of proactiveness for obsolescence management, which have been identified as the two major factors that influence the probability of using each resolution approach. Second, the results were enhanced by means of a definitions refinement workshop. Finally, the ORPs were refined and validated by means of a workshop with experts based on the theoretical trends expected for each resolution probability. More than 40 experts in obsolescence from across the UK from the defence, aerospace, railway and nuclear sectors have participated in the study. 2011 Authors.


This paper provides a cost estimating framework for electrical, electronic and electromechanical (EEE) components obsolescence, which represents the main source of obsolescence issues, owing to the increasingly short life cycle of these types of
component. The framework comprises several areas: component complexity levels, obsolescence management levels, obsolescence resolution profiles and obsolescence cost metrics. Several studies, based on the literature and on interaction with numerous obsolescence management experts from industry, have been employed in this research, following a systematic approach. The framework is able to estimate the non-recurring cost of obsolescence during the contracted period within the inservice phase. This is based on the information available at the bidding stage concerning the product breakdown structure (PBS) and the obsolescence management strategy deployed. This framework has been validated at four different UK organizations in the defence and aerospace sectors using seven case studies, one of which is presented in this paper in detail. 2011 Authors.


The aerospace and defence industries are moving towards new types of agreement such as availability contracts based on Product-Service System (PSS) business models. Obsolescence has become one of the main problems that will impact on many areas of the system during its life cycle. This paper presents the major challenges to managing obsolescence for availability contracts, identified by means of a comprehensive literature review and several interviews and forums with experts in obsolescence management. It is observed that there is a lack of understanding of the impact of obsolescence on whole life cost. Experts agree that the development of a framework to support estimation, management, and mitigation of these costs is desirable, but the difficulty in forecasting future obsolescence issues constrains industry to a reactive approach rather than proactive.


After providing an introduction to the obsolescence problem, this paper explains how the topic is handled to dated using an airborne radar system development as an example. In this the supplier primarily reacts on obsolete components with post design measures. In contrast to this a pro-active approach is suggested that starts with defining an architecture that eases the substitution of obsolete components and allows upgrades without involving major redesigns. This includes the need to safeguard the effort spend for developing and qualifying application software. The article presents a modular structured signal processing architecture that employs COTS modules and standards. It discusses the ability of such an architecture to cope with the obsolescence problem by separating interfaces from processing units and applying COTS interface standards. Means of the designer are examined that allow to proactively design a processor that is likely to survive hardware and software component changes at minimum cost. Forming standard building blocks that encapsulate processing functions is presented as an approach that will considerably reduce the involved risk.

Escalating time-to-market and cost pressures are no longer limited to new board designs. They play an equally important role in the replacement of obsolete parts and the constant renewal of established designs. Fortunately, the new comprehensive development environments with integrated obsolescence management capabilities can help designers cope with this ongoing problem. By focusing on team collaboration, and ensuring timely and accurate communication across the entire enterprise, board designers can minimize the impact of parts obsolescence and ensure that their boards are updated quickly and in the most cost-effective manner possible.


Lifetime buys are a common practice in the electronics and telecommunication industries. Under this practice, manufacturers procure their repair parts inventory in one order to support the spare part needs of a product for the duration of its warranty repair period. In this paper, we consider a repair operation in which defective items under warranty are returned to a manufacturer who either repairs these items using its spare parts inventory or replaces each defective unit with a new product. We show how fixed repair capability costs, variable repair costs, inventory holding costs, and replacement costs affect a firm's optimal repair and replacement decisions. The model is used to gain insights for products from a major mobile device manufacturer in the United States. 2010 Operational Research Society Ltd. All rights reserved.


In engineering design, metrics play a critical role in guiding design choices. It is therefore of prime importance that the metrics used to guide decision-making be the "right" metrics. This paper makes the case that two metrics used to guide communications satellites design, namely cost per operational day, and cost per transponder, are flawed under certain conditions in the sense that they result in design choices-increasingly longer lived satellites and larger payloads-that do not necessarily maximize the system's value. This paper advocates a value-centric mindset in system design, and proposes shifting the emphasis from cost to value analyses to guide design choices that maximize a system's value. Counter-examples are provided that challenge the traditional wisdom that longer lived or bigger satellites, being more cost effective on a per-day or per-transponder basis, are also more profitable or valuable. It is shown that while these metrics are useful guides for design choices in a supply-constrained market (in which a cost-centric mindset can prevail), they are flawed metrics on which to base decisions if the market is competitive, and in which the revenues from the system are not guaranteed to remain stable over time, through the impact of technology obsolescence, or overcapacity resulting in downward pressure on transponder lease prices. Finally, the case is made that the current market conditions require a value-centric mindset (as opposed to a cost-centric mindset) that views a spacecraft as a value-delivery artifact, and integrates considerations about the system's cost, its technical environment, and the market it is serving.

No abstract available


Many types of products that have to be manufactured and supported for long periods of time lack control over critical parts of their supply chain, e.g., avionics, telecom infrastructure, and industrial controls. As a result, the components and technologies that these products depend on become obsolete long before the product's field life (and sometimes even manufacturing life) ends. Obsolescence management, which is an inevitability for these products, should be considered during product design and when planning for life cycle sustainment. This paper addresses forecasting obsolescence and other strategic planning methods to minimize future obsolescence impact.


No abstract available


No abstract available


Sustainability means keeping an existing system operational and maintaining the ability to manufacture and field versions of the system that satisfy the original requirements. Sustainability also includes manufacturing and fielding revised versions of the system that satisfy evolving requirements, which often requires the replacement of technologies used in the original system with newer technologies. Technology sustainment analysis encompasses the ramifications of reliability on system management and costs via sparing, availability and warranty. Sustainability also requires the management of technology obsolescence (forecasting, mitigation and strategic planning) and addresses roadmapping, surveillance, and value metrics associated with technology insertion planning.


Many technologies have life cycles that are shorter than the life cycle of the product or system they are in. Life cycle mismatches caused by the obsolescence of technology can result in large life cycle costs for long field life systems, such as aircraft, ships, communications infrastructure, power plant and grid management, and military systems. This paper addresses DMSMS (Diminishing Manufacturing Sources and Materials Shortages) obsolescence, which is defined as the loss of the ability to procure a technology or part from its original manufacturer. Forecasting when technologies and specific parts will become unavailable (non-procurable) is a key enabler for pro-active DMSMS management and strategic life cycle planning for long field life systems. This
paper presents a methodology for generating algorithms that can be used to predict the obsolescence dates for electronic parts that do not have clear evolutionary parametric drivers. The method is based on the calculation of procurement lifetime using databases of previous obsolescence events and introduced parts that have not gone obsolete. The methodology has been demonstrated on a range of different electronic parts and for the trending of specific part attributes.


Component reuse in multiple products has become a popular way to take advantage of the economies of scale across a family of products. Amongst electronic system developers there is a desire to use common electronic parts (chips, passive components, and other parts) in multiple products for all the economy of scale reasons generally attributed to platform design. However, the parts in electronic systems (especially those manufactured and supported over significant periods of time), are subject to an array of long-term life-cycle supply chain disruptions that can offset savings due to part commonality depending on the availability of finite resources to resolve problems on multiple products concurrently. In this paper we address the application of product platform design concepts to determine the best reuse of electronic components in products that are subject to long-term supply chain disruptions such as reliability and obsolescence issues. A detailed total cost of ownership model for electronic parts is coupled with a finite resource model to demonstrate that, from a life-cycle cost viewpoint, there is an optimum quantity of products that can use the same part beyond which costs increase. The analysis indicates that the optimum part usage is not volume dependent, but is dependent on the timing of the supply chain disruptions. This work indicates that the risk and timing of supply chain disruptions should be considered in product platform design. Copyright 2008 by ASME.


No abstract available


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.

No abstract available


Product sustainment means keeping an existing system operational and maintaining the ability to continue to manufacture and field versions of the system that satisfy the original requirements. Sustainment also includes manufacturing and fielding revised versions of the system that satisfy evolving requirements, which often requires the replacement of technologies used to construct the original system with newer technologies. Technology insertion involves determining which technologies to replace during a design refresh, i.e., deciding the design refresh content, and deciding when that design refresh should take place. Technology replacement decisions are driven by a broad range of issues including performance, reliability, environmental impact, cost, and logistics, and when, or if other design refreshes will take place. Traditional "value" metrics go part of the way toward providing a coupled view of performance, reliability and cost, but are generally ignorant of how product sustainment may be impacted. A metric that measures both the value of the technology refreshment and insertion, and its ability to support both the system's current and future affordability and capability needs including hardware, software, information and intellectual property is required. This paper discusses a concept called viability. Viability is a measure of the producibility, supportability, and evolvability of a system and can serve as a metric for assessing technology insertion opportunities.


Many technologies have life cycles that are shorter than the life cycle of the product they are in. Life cycle mismatches caused by the obsolescence of technology (and particularly the obsolescence of electronic parts) results in high sustainment costs for long field life systems, e.g., avionics and military systems. This paper demonstrates the use of data mining based algorithms to augment commercial obsolescence risk databases thus improving their predictive capabilities. The method is a combination of life cycle curve forecasting and the determination of electronic part vendor-specific windows of obsolescence using data mining of historical last-order or last-ship dates. The extended methodology not only enables more accurate obsolescence forecasts, but can also generate forecasts for user-specified confidence levels. The methodology has been demonstrated on both individual parts and modules.

This paper presents a model that enables the optimal interpretation of prognostics and health management (PHM) results for electronic systems. In this context, optimal interpretation of PHM results means translating PHM information into maintenance policies and decisions that minimize life-cycle costs, or maximize availability or some other utility function. The electronics PHM problem is characterized by imperfect and partial monitoring, and a random/overstress failure component must be considered in the decision process. Given that the forecasting ability of PHM is subject to uncertainties in the sensor data collected, the failure and damage accumulation models applied, the material dimensions and properties used in the models, the decision model in this paper addresses how PHM results can best be interpreted to provide value to the system maintainer. The result of this model is a methodology for determining an optimal safety margin and prognostic distance for various PHM approaches in single and multiple socket systems where the LRU's in the various sockets that make up a system can incorporate different PHM approaches (or have no PHM structures at all). The discrete event simulation model described in this paper provides the information needed to construct a business case showing the application-specific usefulness for various PHM approaches including health monitoring (HM) and life consumption monitoring (LCM) for electronic systems. An example business case analysis for a single socket system is provided. 2007 Elsevier Ltd. All rights reserved.


French tax structure with respect to write-off for scientific research and development, patent assignment and licensing, accelerated depreciation of equipment is described, with quotations from tax laws and sample questionnaires to be completed for exemption. Present and future impact of technical progress on national economy and world development is discussed and projected. Controversial opinions on allocation and tangible results of Government-sponsored and private R & D, between US and European economists are debated.


Technological improvements in today's electronic systems continuously occur. For example, each and every year, computer platforms change significantly in functionality, reliability, and interface needs. In contrast, the Instrumentation and Controls (I&C) used in nuclear plant systems are generally very customized and demand a frozen design with long-term supplier participation in I&C support strategies. And for 20+ year-old plants, eventually such custom systems become more costly to maintain and out-of-sync with today's technology. As a result, today's nuclear I&C maintenance departments are faced with outdated electronics, increased failure rates, and tight plant operating budgets - it becomes a constant dilemma to identify solutions and strategies for sustained plant operation. This paper offers some strategies, techniques, and guidelines for obsolescence-proofing through I&C inventory service contracts, spare parts, repairs, and upgrades/mods. In addition, a Control Room Initiative program is discussed to create a
framework for electronics life extension thereby improving the reliability, functionality, and human factors of the overall plant.


RASSP will dramatically reduce the obsolescence of new electronic systems at their introduction and will maintain their technological currency over an extended life cycle. The four-year program will evolve and continually improve a design environment capable of yielding four times reduction in digital electronics design cycle time along with a similar improvement in quality. Success is demonstrated with the rapid development and easy model-year upgrade of an image signal processor for an infra-red search and track (IRST) application. Additional RASSP design environment (RDE) feedback and proof are obtained through a series of beta site evaluations and benchmarks assessments.


This dissertation is an historical and evaluative study of the Semiconductor Industry Association's (SIA) Technology Roadmap, now referred to as the *International Technology Roadmap for Semiconductors (ITRS)* or simply, the "Roadmap." Technology roadmaps and roadmapping practices comprise new and emerging tools in technology strategy, planning and management that have gained increasing attention by researchers. This study addresses how technology roadmaps affect technological innovation, corporate strategies, and public policies in the semiconductor industry.

This inquiry is accomplished through an examination of the technology roadmap 'landscape' more generally and a case-based analysis of the ITRS in particular. Several hypotheses were formulated to help seek greater and deeper understanding of not just the Roadmap, but the surrounding context within which it emerged and has since evolved. This unique approach will demonstrate the overall thesis that the Roadmap is part of a continuing tradition wedded to the goal of sustaining historical industrial productivity—also referred to as "Moore's Law."

In support of this, an important contribution of the study is substantial historical research of key developments within the semiconductor industry. The findings depart from more widely accepted interpretations of technological innovation advanced by much previous research. Specifically, this research is concerned with the industry's heritage of incremental or evolutionary technological change following a normal innovation pattern, particularly involving manufacturing process innovations in semiconductors.

The findings also suggest that the Roadmap continues the decades-long heritage of normal innovation, now conducted at an international level and reaching across a wide and complex supply chain network. Finally, the analysis supports a new structural approach to technological innovation, one that is more coordinated with the help of a global industry roadmap. Thus a theory of organized innovation is advanced that helps explain how the increasingly fragmented semiconductor innovation community is able to
continue working in cadence to address the daunting technical and economic challenges facing the industry 'down the road'.


The whole vacuum control system of the electron storage ring (SR) of the ESRF is in operation since more than ten years now. Apart from difficulties to have appropriate support for the old system, we start facing problems of aging and obsolescence. We have been reviewing our philosophy of data acquisition and remote control in order to upgrade our systems with state of the art technology, taking into account our operational experience. We have started installing shielded "intelligent" devices inside the SR and taking advantage of the latest developments linked to new technologies, such as OPC Server (Openness, Productivity, Connectivity), Webpage instrument control and more. This paper outlines our actual work dedicated for Programmable Logical Controller (PLC) applications.


A maximum likelihood approach is proposed for estimating an innovation diffusion model of new product acceptance originally considered by Bass (1969). The suggested approach allows: (1) computation of approximate standard errors for the diffusion model parameters, and (2) determination of the required sample size for forecasting the adoption level to any desired degree of accuracy. Using histograms from eight different product renovations, the maximum likelihood estimates are shown to outperform estimates from a model calibrated using ordinary least squares, in terms of both goodness of fit measures and one-step ahead forecasts. However, these advantages are not obtained without cost. The coefficients of innovation and imitation are easily interpreted in terms of the expected adoption pattern, but individual adoption times must be assumed to represent independent draws from this distribution. In addition, instead of using standard linear regression, another (simple) program must be employed to estimate the model. Thus, tradeoffs between the maximum likelihood and least squares approaches are also discussed.


Various ways of product obsolescence management of chip manufacturers are discussed. Semiconductor manufacturers are trying to meet the requirements of Europe's Restrictions on Hazardous Substances (RoHS) to switch over to lead-free products. International lead-free mandates must contend with changing out virtually entire product inventories, assigning part numbers to the new devices and communicating all of these changes in real time to their distributors, OEMs and contract manufacturers. The British government is partially finding the National Obsolescence Center to support those companies suffering from the commercial consequences of component obsolescence.

Scientific Research Corporation designed a Smart Multi-Function Color Display with Positive Pilot Feedback under the funding of an U. S. Navy Small Business Innovative Research program. The Smart Multi-Function Color Display can replace the obsolete monochrome Cathode Ray Tube display currently on the T-45C aircraft built by Boeing. The design utilizes a flat panel color Active Matrix Liquid Crystal Display and TexZec's patented Touch Thru Metal bezel technology providing both visual and biomechanical feedback to the pilot in a form, fit, and function replacement to the current T-45C display. Use of an existing color AMLCD, requires the least adaptation to fill the requirements of this application, thereby minimizing risk associated with developing a new display technology and maximizing the investment in improved user interface technology. The improved user interface uses TexZec's Touch Thru Metal technology to eliminate all of the moving parts that traditionally have limited Mean-Time-Between-Failure. The touch detection circuit consists of Commercial-Off-The-Shelf components, creating touch detection circuitry, which is simple and durable. This technology provides robust switch activation and a high level of environmental immunity, both mechanical and electrical. Replacement of all the T-45C multi-function displays with this design will improve the Mean-Time-Between-Failure and drastically reduce display life cycle costs. The design methodology described in this paper can be adapted to any new or replacement display.


Planned obsolescence involves a design plan that is intended to hasten existing products to become undesirable (not necessarily below that of competitive offerings) either functionally or psychologically and consequently to be replaced by new products. Many manufacturing companies since the last decade have adopted the policy of planned obsolescence in their products. Their main objective is to cut costs, increase profits and secure continuous consumption and production. When this policy is abused, however, so that customers are not getting products which can perform adequately and safely for a reasonable amount of time, the end result may prove to be more detrimental than beneficial, not only to producers and consumers, but to the nation as a whole. In this age of scarce resources, energy shortages and new challenges, this paper re-examines planned obsolescence and searches for quality in todays products.


CBTC is now the technology chosen by many Transit operators worldwide. As operators target efficient train operations, they also take the opportunity of the change to CBTC technology to ask for improved performances and for the integration of more constraints. This paper presents these enhanced requirements and constraints and the ways in which advanced engineering solutions help to deal with these as well the varied operating conditions now found in urban environments. The advanced solution from Alstom is the URBALIS networked CBTC. The previous non-CBTC Train Control systems from Alstom have delivered design headways of 90 seconds for operations at around 105 seconds. Examples of such operations include lines in Sao Paulo and Santiago giving real
peak throughput of 40,000 to 70,000 pphpd (passengers per hour per direction). Now the
target, for example on a project such as Milan Metro Line 1, is to achieve a 15% improvement to allow operation at 90 seconds on a heavy metro rail line. A first CBTC innovation was the implementation in 2003 of a Radio-based CBTC for the 20 km Singapore North-East line. This allowed driverless operation of a heavy metro rail line with a capacity of 42,000 pphpd. Now, the 36 km Shanghai Line 10 project, to be delivered in 2010, will be the world's second heavy metro rail driverless line. This line, as well as the 110 kph driverless Beijing Airport Express link, are being implemented with URBALIS as an advanced and affordable solution for driverless metros. For CBTC systems, the many trackside and train-borne interfaces are of paramount importance to the safety and performance of the system. The URBALIS networked CBTC has a communication system based on three integrated networks: a trackside network, a train network and a radio network. Standard radios are used, but with a choice of propagation medium: Free Propagation, Leaky Feeder or Wave Guide. This choice of medium allows an optimum match to the radio environmental constraints found in Transit applications. Advanced technologies also facilitate rapid migration to CBTC in difficult Transit projects where there is little time to do the work. Facilitating equipment fitment to existing trains is another key issue. Interoperation can be a key issue and covers many facets. An example is given of a major suburban Metro line that has to allow interoperation of CBTC equipped Metro trains with ETCS equipped Mainline trains. Finally, to meet the needs of such a wide range of performance and operating constraints, the System Engineering approach is now integrated with a product line engineering approach. This also helps to deal with other key customer needs such as achieving on-time delivery and obsolescence management.


Several tips for ICs to protect the systems from obsolescence are discussed. Component engineering in the design phase should be included and the problem components and cost drivers should be identified. The probability of an early discontinuation notice should be minimized by choosing the right part for the socket. The parts should be chosen that specifically target the market and application, and a vendor should be selected that has a reputation for supplying devices for the length of time which is required. One should be bewareed of compatibility in picking a processor and calculate the entire life-cycle costs of non-recurring costs and logistics costs. Reviewing one's plans and problem parts will also provide great help. A strategy should be developed to predict and respond before the part goes end of life (EOL). Prediction tools can become a part of the system if the suppliers are contacted frequently.


Obsolescence management, an ever-increasing topic in the Department of Defense, is not new. Since the service life of military systems is much longer than commercial systems, maintaining military systems when parts and components go out of production remains a sustainment challenge. Typically, resolving obsolete parts problems are incorrectly identified as reliability and maintainability issues that provide no improved capability or
reduced cost; the primary benefit is continued sustainability of the existing system. Since loss of a capability is not an option, maintaining the capability without a part redesign does require increased cost for the commercial market to support a military-unique application. In addition, constrained defense funding will necessitate prudent use of limited funding to balance current systems maintenance and new systems acquisition. The specific objective of this project is to show the need for automated cost-benefit analysis tools to assist program/item managers in identifying the cost savings associated with resolving obsolete parts problems. The project provides an analysis of the cost-benefit relationship of the resolution options available to the program/item manager. Additionally, the project identifies and analyzes cost-benefit analysis tools for making decisions associated with sustaining the obsolete item versus acquiring a supportable replacement.


Obsolescence management, an ever-increasing topic in the Department of Defense, is not new. Since the service life of military systems is much longer than commercial systems, maintaining military systems when parts and components go out of production remains a sustainment challenge. Typically, resolving obsolete parts problems are incorrectly identified as reliability and maintainability issues that provide no improved capability or reduced cost; the primary benefit is continued sustainability of the existing system. Since loss of a capability is not an option, maintaining the capability without a part redesign does require increased cost for the commercial market to support a military-unique application. In addition, constrained defense funding will necessitate prudent use of limited funding to balance current systems maintenance and new systems acquisition. The specific objective of this project is to show the need for automated cost-benefit analysis tools to assist program/item managers in identifying the cost savings associated with resolving obsolete parts problems. The project provides an analysis of the cost-benefit relationship of the resolution options available to the program/item manager. Additionally, the project identifies and analyzes cost-benefit analysis tools for making decisions associated with sustaining the obsolete item versus acquiring a supportable replacement.


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.

Many technologies have life cycles that are shorter than the life-cycle of the product they are in. Life-cycle mismatches caused by the obsolescence of technology (and particularly the obsolescence of electronic parts) results in high sustainment costs for long field life systems, e.g., avionics and military systems. This article presents a methodology for performing optimum design refresh planning for sustainment-dominated electronic systems based on forecasted technology obsolescence and a mix of obsolescence mitigation approaches ranging from lifetime buys to part substitution. The methodology minimizes the life-cycle cost by determining the optimum combination of design refresh schedule for the system (i.e., when to design refresh) and the design refresh content for each of the scheduled design refreshes. The analysis methodology can be used to generate application-specific economic justifications for design refresh approaches to obsolescence management.


The Georgia Tech Research Institute (GTRI) has developed an approach for efficiently postulating and evaluating methods for addressing IC obsolescence and thereby extending the life of radars and other avionics systems. The GTRI approach identifies specific assemblies for potential replacement and evaluates the system level impact. The initial impetus for this research was the increasing obsolescence of the ICs contained in the AN/APG-63 system. Just recently, the approach has been applied to the AN/ALQ-135 Internal Countermeasures Set of the F-15 aircraft.


The determination of when a process control computer system is obsolete and requires replacement is a problem that must be approached in a logical and objective manner. An approach has been developed which uses specific trigger points to determine when a detailed investigation of obsolescence is needed and which defines specific criteria against which the performance and continued suitability of the system can be judged. The methodology described can be applied to any type of process control computer system to give a systematic approach to determining and justifying the need to replace an existing system.


The accelerating pace of technology change requires new approaches to the design manufacture and through life support of military and long life cycle commercial platforms to minimize the effects of short-term technology obsolescence. The purpose of this paper is to describe medium and long-term strategies for the mitigation of obsolescence.
currently being considered in the UK. All complex military equipment are at risk from the effects of unmanaged technology obsolescence before and after they enter service. A systems sentineling approach is described for the evolution of strategies that would involve co-operation between users and manufacturers to produce affordable through life solutions.


Recent announcements by major Integrated Circuit (IC) manufacturers to discontinue various Transistor Transistor Logic (TTL) devices has resulted in a very serious problem for the military community. The number of military systems utilizing these devices as well as the different types and number of devices involved is staggering. Redesign is an alternative, but in most cases, should be the last option exercised due to the costs, time, and other considerations involved. An overview of some alternatives is given that are available to minimize the impact of IC obsolescence, and what is being done to lessen the impact of this problem.


No abstract available


Electronic component obsolescence occurs when parts are no longer available to support the manufacture and/or repair of equipment still in service. Future instrumentation containing complex components WILL face obsolescence issues as technology advances. This paper describes hardware and software obsolescence as well as factors to consider when designing new instrumentation.


Obsolescence of electronic parts is a major contributor to the life-cycle cost of long-field life systems such as avionics. A methodology to forecast life cycles of electronic parts is presented, in which both years to obsolescence and life-cycle stages are predicted. The methodology embeds both market and technology factors based on the dynamic assessment of sales data. The predictions enabled from the models developed in this paper allow engineers to effectively manage the introduction and on-going use of long field-life products based on the projected life-cycle of the parts incorporated into the products. Application of the methodology to integrated circuits is discussed and obsolescence predictions for dynamic random access memories (DRAMs) are demonstrated. The goal is to significantly reduce design iterations, inventory expenses, sustainment costs, and overall life-cycle product costs.

How should inventory management respond when there is a possibility of imminent obsolescence (or, more generally, deteriorating demand)? We use an inventory-control model to address this question. The model incorporates a Markovian submodel to describe the uncertain events leading to obsolescence. These events and their uncertainties come in a variety of patterns. We devote considerable attention to specifying the submodel, and we compare a few alternatives numerically. Also, we compare optimal policies to simpler alternatives, and we investigate the response of the model to parameter changes. Generally, we find that obsolescence does (or should) have a substantial impact in the way inventories are managed. The nature of these effects, moreover, is fairly intricate. It appears that obsolescence cannot be captured in a simpler model through parameter adjustments. These conclusions presume that we cannot dispose of excess stock, either directly or through price promotions; we show also that the disposal option can make the problems of obsolescence more manageable.


In this paper we consider a stochastic-demand periodic-review inventory model with sudden obsolescence. We characterize the structure of the optimal policy and propose a dynamic programming algorithm for computing its parameters. We then utilize this algorithm to approximate the solution to the continuous-review sudden obsolescence problem with general obsolescence distribution. We prove convergence of our approximation scheme, and demonstrate it numerically against known closed-form solutions of special cases. 2003 Elsevier B.V. All rights reserved.


No abstract available


The US Air Force has launched an initiative to develop an affordable, systematic approach to dealing with obsolete electronic parts. In addition to management and reengineering tools, the initiative is developing reliability models for commercially manufactured electronics used in defense systems Abstract Numbers: B1999-07-0140-00101


The authors discuss how engineers can avoid the problem of obsolescence of their designs. Two types of solutions are examined. Those that deal with the problem after it occurs include discussion with the vendor, which may provide a solution not previously known to the designer, and life-of-type buys, i.e., buying a large quantity of the component that will carry the product through its expected life. Alternatively, the design can anticipate the parts obsolescence problem and make it a major design criterion. The authors discuss this solution.

No abstract available


This paper describes a joint EPRI/Utility/Supplier project for evaluating the Reactor Protection Systems and Plant Protection Systems at Combustion Engineering (C-E) operating plants. The goal of the project is the development of long term maintenance plans that will solve obsolescence problems and extend the systems' useful life. Solutions developed under this project could be applied generically to other plant systems. The paper will describe each of the five phases of the project including: data collection and analysis, development of obsolescence evaluations and solutions, development of maintenance support evaluations and plans, development of long term plans for participating plants, development of a generic methodology for IC obsolescence and maintainability evaluations.


Automatic test engineers are faced with replacing obsolete software and hardware in systems that remain in operation longer than individual components are supported. Replacing obsolete hardware can be especially challenging because of the need to modify test software in order to support new instrumentation. Changes to test software to support new instrumentation might affect multiple areas of the application and require time-consuming development or costly revalidation. This explains how you can mitigate hardware obsolescence with the use of well-designed hardware abstraction layers.


The purpose of this document is to define the requirements for developing a Diminishing Manufacturing Sources and Materials Shortages (DMSMS) Management Plan. It is intended for use by system integrators, original equipment manufacturers (OEM), and logistic support providers of aerospace, defense and high reliability equipment to help develop their own DMSMS Management Plan, hereinafter also called the Plan, to document the processes used to meet the Technical Requirements detailed in clause 5 which will minimize the impact that obsolete parts and materials have on equipment life cycle costs. It is not intended for use by suppliers of parts or materials. This document states objectives to be accomplished; it does not specify how tasks are to be performed, specific data to be collected or reports to be issued. Those who prepare Plans in compliance with this document are encouraged to document processes that are the most effective and efficient for them in accomplishing the requirements stated in this
document. In order to allow flexibility in implementing and updating the documented processes, Plan authors are encouraged to refer to their own internal process documents instead of including detailed process documentation within their Plans. Organizations that prepare such Plans may prepare a single Plan, and use it for all relevant products supplied by the organization, or may prepare a separate Plan for each relevant product or customer.


National Oceanic and Atmospheric Administration's (NOAA) Tropical Atmosphere Ocean (TAO) buoy array has a long history of providing valuable climate data to both the climate and forecast communities. A major concern for a sustained and long-term TAO operation is the impending obsolescence of the technology used in the current version of the TAO array. An increasing number of components are being discontinued or are no longer supported by the manufacturers due to the technology presently used being more than 10 years old. During the transition of the TAO array from NOAA's Pacific Marine Environmental Laboratory (PMEL) to NOAA's National Data Buoy Center (NDBC), it was decided to take this opportunity to "refresh" the TAO buoy system by replacing the obsolescent components in the current TAO system to ensure continuity of the TAO array. This paper first discusses the obsolescent components in the existing TAO array system. Then, the refreshed components of the refreshed TAO buoy system are discussed, including a newly-designed data logger, modified battery system, commercial off-the-shelf underwater sensors, a new compass, Iridium communication, modified and enhanced shore-side data system, and other minor design modifications. The field testing of the TAO refreshed buoys is also presented.


Philips is a company that produces electronic equipment like kitchen appliances, television sets, videorecorders, medical equipment, and so on. This equipment is sold world-wide. The central service organization of Philips, situated in Eindhoven (The Netherlands), is responsible for providing spare parts for these products during the entire service period. The length of this service period depends on the type of product. Television sets, for instance, have a service period of eight years. Since the service period is typically much longer than the production period, the service department places a large 'final order' for spare parts at the moment the product is taken out of production. This final order is expected to suffice, with a sufficiently large probability, until all service obligations have ended. In this paper we seek close to optimal final order quantities. Actually, this paper is a follow-up on a more theoretical paper, in which a close to optimal final order quantity, given by an explicit formula was derived. This paper presents the results of trying to apply that formula in practice.


Producers of complex machines offer lasting service contracts to their customers. To be able to provide service, spare parts are held in stock. Since the service period is typically much larger than the production period, the service department places a large 'final order'
for spare parts at the moment the machine is taken out of production. This final order is expected to last until all service contracts have ended. In this paper we deal with finding (close to) optimal final order quantities. The main result is the derivation of a close to optimal final order quantity, given by an explicit formula. Furthermore, we also determine 'remove-down-to' levels for spare parts. These levels are used to reduce cost by removing stock before all service contracts have expired. The effects of introducing remove-down-to levels on the expected cost and the optimal final order quantity are shown


When the service department of a company selling machines stops producing and supplying spare parts for certain machines, customers are offered an opportunity to place a so-called final order for these spare parts. We focus on one customer with one machine. The customer plans to use this machine up to a fixed horizon. Based on this horizon, and on the failure rates of the components, the prices of spare components and the consequences of the machine failing before the critical lifetime is reached, the size of the final order is determined


We consider an appliance manufacturer's problem of controlling the inventory of a service part in its final phase. That phase begins when the production of the appliance containing that part is discontinued (time 0), and ends when the last service contract on that appliance expires. Thus, the planning horizon is deterministic and known. There is no setup cost for ordering. However, if a part is not ordered at time 0, its price will be higher. The objective is to minimize the total expected undiscounted costs of replenishment, inventory holding, backorder, and disposal (of unused parts at the end of the planning horizon). We propose an ordering policy consisting of an initial order-up-to level at time 0, and a subsequent series of decreasing order-up-to levels for various intervals of the planning horizon. We present a method of calculating the optimal policy, along with a numerical example and sensitivity analysis


The standard method to forecast intermittent demand is that by Croston. This method is available in ERP-type solutions such as SAP and specialised forecasting software packages (e.g., Forecast Pro), and often applied in practice. It uses exponential smoothing to separately update the estimated demand size and demand interval whenever a positive demand occurs, and their ratio provides the forecast of demand per period. The Croston method has two important disadvantages. First and foremost, not updating after (many) periods with zero demand renders the method unsuitable for dealing with obsolescence issues. Second, the method is positively biased and this is true for all points in time (i.e., considering the forecasts made at an arbitrary time period) and issue points only (i.e., considering the forecasts following a positive demand occurrence only). The second issue has been addressed in the literature by the proposal of an estimator (Syntetos-Boylan
Approximation, SBA) that is approximately unbiased. In this paper, we propose a new method that overcomes both these shortcomings while not adding complexity. Different from the Croston method, the new method is unbiased (for all points in time) and it updates the demand probability instead of the demand interval, doing so in every period. The comparative merits of the new estimator are assessed by means of an extensive simulation experiment. The results indicate its superior performance and enable insights to be gained into the linkage between demand forecasting and obsolescence. 2011 Elsevier B.V. All rights reserved.


Currently, there is a plethora of low-cost commercial off-the-shelf (COTS) hardware available for implementing control systems. These range from devices with fairly low intelligence, e.g., smart sensors and actuators, to dedicated controllers such as PowerPC, programmable logic controllers (PLCs) and PC-based boards to dedicated systems-on-a-chip (SoC) ASICS and FPGAs. When considering the construction of complex distributed systems, e.g., for a ship, aircraft, car, train, process plant, the ability to rapidly integrate a variety of devices from different manufacturers is essential. A problem, however, is that manufacturers prefer to supply proprietary tools for programming their products. As a consequence of this lack of "openness", rapid prototyping and development of distributed systems is extremely difficult and costly for a systems integrator. Great opportunities thus exist to produce high-performance, dependable distributed systems. However, the key element that is missing is software tool support for systems integration. The objective of the Flexible Control Systems Development and Integration Environment for Control Systems (FLEXICON) project IST-2001-37269 is to solve these problems for industry and reduce development and implementation costs for distributed control systems by providing an integrated suite of tools to support all the development life-cycle of the system. Work within the Rolls-Royce supported University Technology Centre (UTC) is investigating rapid prototyping of controllers for aero-engines, unmanned aerial vehicles and ships. This paper describes the use of the developed co-simulation environment for a high-speed merchant vessel propulsion system application. 2006 Elsevier Ltd. All rights reserved.


The ever increasing use of digital technologies and products to meet the control, automation and monitoring needs of the nuclear power plant- even though justified by the benefits it provides - comes with an increased risk of technological obsolescence happening through the course of the plant life. Some well considered strategies are being employed in the ACR design process to minimise this risk and alleviate the consequence if it happens. These include application of a modular overall architecture, adoption of
international widely accepted standards to harmonise equipment qualification and software practices, production of control functional specifications that are not influenced by target platform, and careful selection of technologies and products.


These Diminishing Manufacturing Sources and Material Shortages (DMSMS) acquisition guidelines compile the ideas and comments expressed by experienced program managers over the past few years at a variety of forums, meetings, and conferences. This Acquisition Guidelines document for DMSMS provides the program manager and the integrated product team (IPT) with suggested contractual language that could be used to prepare a request for proposal (RFP) or to modify an existing contract to include cost effective DMSMS practices. This document is an adjunct to and its use is complementary with the Resolution Cost Metrics for DMSMS, Program Managers Handbook-Common Practices to Mitigate the Risk of Obsolescence-and the resolution guides referenced therein.


The Program Managers Handbook—Common Practices to Mitigate the Risk of Obsolescence—provides practices and a list of resources that other program managers have used to minimize the impacts and cost of obsolescence. The primary audience for this handbook is a program manager who has been recently introduced to DMSMS. This handbook provides the program manager a shopping list of common practices and resources. The handbook complements the commonly used resolution guides—the Naval Sea Systems Command Case Resolution Procedures Guide, the Air Force Materiel Command DMSMS Program Case Resolution Guide, and the Army Materiel Command DMSMS Case Resolution Guide. Common practices in this handbook can be implemented to minimize the impact of DMSMS.


This paper discusses the insights obtained from managing obsolescence mitigation strategies within the Department of Defense (DoD) during the last two decades. The numerous solutions investigated, from alternative or substitute components to complete system redesign can affect reliability and maintainability (R&M) as well as cost. However, with careful implementation of design practices many of the effects can be mitigated. In addition to presenting the common practices that mitigate the effect and risk of DMSMS, this paper also addresses the nonrecurring engineering (NRE) costs impacts associated with ensuring that solutions meet the original product's system performance and R&M requirements.

Parts obsolescence has initiated an investigation by the Harpoon Program into a new modulator design for the output RF oscillator electron tube (Magnetron). The new modulator design would require full program development including reliability and environmental screening and life cycle determination. Proto-typing and production schedule are factors which would also contribute to a lengthy and costly development program. Following the current trend to out-source the new modulator results in the loss of jobs, reduces company revenue, and eliminates the opportunity for RTIS to make a value added contribution. This paper outlines the proposal to keep the current modulator which has proven to be right for the application, and introduces only minor design changes to overcome the problem of parts obsolescence. During the time interval since this paper was written, a hardware version has been constructed to produce empirical data which initiated the idea to present this paper at the conference to assist in resolving any problems related to incorporation of the proposed concepts.


Utility design engineers, strategic planners, and executives need a comprehensive approach for managing the obsolescence of aging instrumentation and control (IC) as nuclear plants look forward to license extension and decades of future operation. Digital technology has almost entirely displaced the analog technology on which the IC designs were based, but cost-effective modernization strategies that maximize benefits of implementing new technology have proven elusive. A well considered strategy for IC modernization can introduce capabilities that both increase benefits and reduce implementation costs. Automation of error-prone tasks and improved data collection/processing to enable condition-based maintenance are examples. These improvements can potentially result in staff reductions, even while increasing equipment reliability. However, these benefits are largely being left on the table under the prevalent practice of system-level tactical upgrades, because they cannot be realized simply by inserting islands of newer technology into an existing environment. A plant-wide or fleet-wide integrated approach can help utilities to realize these benefits. This paper discusses the risks, benefits and issues associated with IC modernization, and describes an approach for developing a plant-specific obsolescence management strategy. Specific issues considered include: key decisions and who should make them; plant-wide or company-wide issues, such as existing organization and culture; changes in planning or execution that can achieve better and cheaper results; techniques for understanding costs, benefits and risks so that project prioritization and phasing can be done in a more effective manner; and the importance of developing an end-point vision to guide the modernization strategy.


The lifetime of electronic parts has decreased over the years. The result is that companies designing embedded systems with long life-time would have problems. Thus, there are
problems with manufacturing the products for as many years as they would like to as well as being able to provide spare parts for customers. To be able to analyze the extent of the problem as well as learning about how the industry copes with the problem, we have conducted a survey among the foremost Norwegian original equipment manufacturer (OEM) companies and contract manufacturers. This paper presents the main observations from this survey. The main conclusion from the survey is that obsolescence is a problem, but the extent of it depends on how much proactive focus a company has. The companies taking precautions would benefit from that by extending the time span before they have to redesign their systems. 2007 IEEE.


Obsolescence is an increasing problem facing every weapon system in the Department of Defense. Cutbacks in defense spending have resulted in the need to keep currently fielded systems operational for longer periods of time than originally planned. Obsolescence of the components used to maintain these aging systems is resulting in reduced mission readiness. This research project explores where and how obsolescence is effecting weapons systems, what factors drive obsolescence, and how those factors can be used to predict obsolescence problems so that preemptive measures can be taken. An evaluation of currently available automated tools is included as well as a preliminary design of a computer-aided obsolescence prediction system.


The article discusses the nature and risks of obsolescence in UK's electronics-oriented industries. Despite the fact that software, mechanical and other areas are also now under threat, there is still reluctance in some areas to tackle the problem in a truly effective way. It reported that until it is realized that prevention is usually far cheaper than a cure, problems will continue to be resolved in an inefficient and uneconomic way.

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The cost of resolving Diminishing Manufacturing Sources and Material Shortages (DMSMS) problems is of primary concern to Department of Defense (DoD) program managers. The DoD Executive Agent for microelectronics DMSMS, the Defense Microelectronics Activity (DMEA), is developing cost factors for various DMSMS resolutions so that DoD programs can uniformly report cost avoidance and determine the cost impact of implementing a DMSMS program. Under Contract GS-35F-4825G, task order DMEA90-98-F-0018, ARINC identified the resolutions most commonly used by DoD and developed nonrecurring engineering cost factors for each. This final report describes the approach used and presents the identified cost factors.


This guidebook on Diminishing Manufacturing Sources and Material Shortages (DMSMS) is a compilation of the best practices from across the Department of Defense for managing the risk of obsolescence for electronic, electrical, and mechanical parts. In addition, it identifies various tools that may be useful for analyzing and tracking the effectiveness of DMSMS programs. We recommend that the program manager use this guidebook as a desktop reference to quickly pinpoint key actions required to manage DMSMS issues and address concerns.


U.S. Naval Sea Systems Command (1999). Case Resolution Procedures Guide. This Diminishing Manufacturing Sources and Material Shortages (DMSMS) Case Resolution Procedures Guide is intended to provide assistance in both reactive and proactive DMSMS problem identification, analysis, and resolution. It will provide a uniform and systematic approach to assist Naval Sea Systems Command (NAVSEA) activities in analyzing and resolving DMSMS situations throughout weapon system acquisition and life cycle support. It will also provide a baseline for performance of proactive cost-benefit analyses to address emergent DMSMS situations.

The Air Force faces increasingly difficult challenges to maintain and sustain its highly technical weapon systems, struggling against rapid technology advancement and diminishing lifecycle for electronic systems. The reduced lifecycle times have not only complicated sustainment, the lifecycles have diminished to the point that new military aircraft designs face challenges of obsolescence within the manufacturing cycle, and in some cases before manufacturing even begins. This research project explores Diminishing Manufacturing Sources and Material Shortages (DMSMS) and obsolescence cost associated with electronic avionic components. The overall research question asks how obsolescence management can be improved in the Air Force.

This project utilizes two integrated models, the first, to determine electronic avionics demand requirements for a fleet of 96 aircraft over a 30-year period, and the second to evaluate sustainment cost over time for a) re-engineering strategy, b) lifetime buy strategy, and c) programmed redesign strategy. Statistical analysis and long-term cost comparison of these three strategies will provide a framework to evaluate specific weapon systems for future studies and to develop an attainable low-cost sustainment strategy.


Variability in the inflow of end-of-life (EOL) products and fluctuating inventory levels often make the processing of EOL products an economically risky operation for product recovery facilities (PRFs). Choosing an appropriate pricing policy can enhance the performance of PRFs by methodically clearing their inventory and increasing profits. This work presents two pricing models to counter the prospect of product obsolescence that can happen either gradually or suddenly. Product obsolescence can cause demand drop and inventory pile up, both of which could dent the revenues of PRFs. In the first model, gradual obsolescence and environmental regulations that limit the disposal quantity in landfills are considered. In the second model, the case of sudden obsolescence is addressed. Examples are presented to illustrate the pricing strategies for each model.


In this paper, we propose a simple economic order quantity for a class of inventory management problems concerning items with a short and stochastic lifetime. The analysis is relevant to the management of items in industries subject to fast technological progress, where the obsolescence rate is large. The approach is performed in the framework of the total discounted cost criterion. A new economic order quantity is computed; it may turn out to be significantly smaller than the one given by Wilson formula. Finally, we show that a policy maker who faces the risk of obsolescence, can plan stockouts if sufficiently many customers accept late delivery.

In this paper obsolescence of service parts is analyzed in a practical environment. Based on the analysis, we propose a method that can be used to estimate the risk of obsolescence of service parts, which is subsequently used to enhance inventory control for those parts. The method distinguishes groups of service parts. For these groups, the risk of obsolescence is estimated using the behavior of similar groups of service parts in the past. The method uses demand data as main information source, and can therefore be applied without the use of an expert's opinion. We will give numerical values for the risk of obsolescence obtained with the method, and the effects of these values on inventory control will be examined.


We consider a manufacturer of complex machines that offers service contracts to her customers, committing herself to repair failed spare parts throughout a fixed service period. The suppliers of spare parts often discontinue the production of some parts as technology advances and ask the manufacturer to place a final order. We address the problem of determining final orders for such spare parts. The parts that we consider are repairable, but they are subject to the risk of condemnation. We build a transient Markovian model to represent the problem for a repairable spare part with a certain repair probability and repair lead time and we present some approximations that allow for further real-life characteristics to be included. Furthermore, an approximate model that can be computed more efficiently is presented, and the sensitivity of the results obtained with respect to the problem parameters is discussed, helping us develop several managerial insights.


Obsolescence of electronic components is a big concern affecting most electronic equipments involved in safety critical applications (automotive, avionics, airframe, nuclear plants, military applications...). Indeed, such applications are active years longer than was originally anticipated. This paper addresses a methodology to validate emulated replacement solutions and propose solutions to be experienced on a Motorola 6800 processor to illustrate the proposed approach.
Open system architectures based on commercial off-the-shelf (COTS) building block components offer the ability to leverage the latest technology into fielded products while minimizing the impact to the operational flight software, typically the most costly component of an avionics development or upgrade. Our team has developed a layered hardware and software approach based on industry standard hardware and software interfaces to abstract the application (operational) software developers from the underlying technology rolls to the hardware and operating system software that naturally occur as part of the commercial marketplace. A technology roll is defined as the replacement of a current product with a subsequent generation of a product from the same product family. In this article, we describe the components and the layered architecture of our open system architecture approach. We discuss specific system, hardware, and software technology insertions that incorporate the latest available technology and how these changes have been abstracted from the application software. The article concludes by discussing lessons Learned from the use of these common components and corresponding technology rolls across various platforms (3 refs.)


By investing in R&D, a durable-goods monopolist can improve the quality of what it will sell in the future, and in this way reduce the future value of current and past units of output. This article shows that if the firm sells its output, then it faces a time inconsistency problem; i.e., the R&D choice that maximizes current profitability does not maximize overall profitability. The result is that if output is sold rather than rented, then in its R&D decision the monopolist has an incentive to practice a type of planned obsolescence that lowers its own profitability.


Planning for the maintenance and sustainability of legacy systems often involves attempting to time the obsolescence of a component or a system of components. Serious questions arise, such as: When will critical parts no longer be available? Will the next-generation technology replacing the current technology have a serious impact on system maintenance, repair, operation, or performance? When will software systems no longer be supported? These questions, if not outright overlooked, are often answered using qualitative information, such as expert opinions, market forecasts, or supplier assurances. However, reliable quantitative methods have been developed that project the growth and diffusion of technology in time, including projecting technology substitutions, saturation levels, and performance improvements. These quantitative technology forecasts can be applied at the early, mid-life, and even end-life stages of Navy technology platforms to better plan legacy system maintenance and sustainability strategies. In practice, a quantitative technology forecast is completed to ascertain the time in the future when a technology trajectory would have a significant impact on the sustainability of a legacy technology, system, or platform. Such future projections provide reliable time-referenced
information when considering cost and resource requirement trade-off strategies to maintain or replace a component or system. This paper introduces various quantitative technology forecasting techniques and illustrates their practical applications toward considering legacy system support strategies. 2011, American Society of Naval Engineers.


Due to the rapid advance of technology, manufacturers marketing models and quickly changing consumer tastes, products such as apparel, clothing accessories and consumer electronics are likely to face the problem of short product life cycles. This study deals with the problem of determining order quantity and multi-discount selling prices for these types of gradually obsolescent products, in which two novel proposals are presented as follows: (1) without considering any exogenous factors that could affect demand, we develop a time-dependent demand model that appropriately portrays an integrated demand behavior associated with the characteristic of obsolescence; (2) we then treat the selling price as an exogenous factor influencing demand and, referring to the linear demand \( D = -p \), the effect that "the increase of demand due to price change is linearly correlated with the difference between two consecutive selling prices" is incorporated, so as to make the demand model be a function of both time and selling price. Afterwards, optimization models are hereby formulated to predetermine pricing strategy with a limited number of price changes by maximizing retailers profit. As a result, numerical examples illustrate that the multi-discount model indeed provides higher total profit than a single discount one. This is presented along with the result analysis conducted to gain some managerial insights. 2011 Elsevier Inc. All rights reserved.


To reduce the risk of cost and schedule overruns during system development, an integrated hardware and software reuse environment is proposed in which the system development process is integrated with a hardware and software reuse methodology. A reuse technology is proposed that defines system artifacts in terms of domain model artifacts, organizes system artifacts according to their requirements and, the system development life cycle stage in which they were developed, and supports a user role-driven reuse catalog. The corresponding reuse environment requirements are analyzed, and an engineering information system is proposed as the underlying engineering environment to support the tight integration of this reuse methodology and the system development process.


One factor inhibiting adoption of new air traffic management systems is the inability to provide sufficient assurance for the safety-critical software components. This paper
describes an approach to specifying and validating safety-critical systems called SpecTRM (specification tools and requirements methodology). An experimental demonstration of SpecTRM applied to the conflict alert/mode-C intruder (CA/MCI) function of the standard terminal automation replacement systems (STARS) is used as an example. Using SpecTRM to build a model of blackbox software functionality, such as CA/MCI, helps in validating system design early in the development process and in building safety into the design from the beginning. The use of SpecTRM informal and formal specifications/models to specify the system and software functions assists in eliminating inconsistencies and discrepancies common in plain-English documents. In addition, the specifications and models are executable and analyzable. Finally, the resulting specification provides documentation for reference during the maintenance phase of the software life cycle, including the design rationale and the design features related to safety.


In automatic test applications ranging from U.S. Department of Defense (DoD) projects to semiconductor manufacturing, automated test equipment (ATE) and test program sets (TPS) represent a significant investment. While much of the investment in test takes the form of capital expenditures, another significant portion that cannot be ignored is the time spent integrating, validating, and upgrading software and developing driver support to accommodate new ATE hardware. Without ongoing hardware upgrades and associated software maintenance, ATE systems can quickly face obsolescence - resulting in large replacement costs.


The Advanced Test Reactor (ATR) at the Idaho National Laboratory (INL) has provided the capability for irradiation testing of nuclear fuels and materials since 1967, and is expected to operate for several more years. Within the scope of extending the life of a nuclear plant is dealing with aging and obsolescence issues. A component can be considered obsolete if the manufacturer no longer supports the component, or if the manufacturer does not even exist anymore. Though these components can be considered obsolete, the cost of obsolescence may or may not be significant; it may be more cost-effective to leave and/or repair the component rather than to replace it. The project at hand is to develop a tool that will not only identify these components, series of components, or entire systems that are obsolete, but to quantify the cost of obsolescence. This engineering tool will be based on empirical formulas created from data collected from factors that deal with obsolescence. These factors are primarily, the cost of item replacement, current cost of maintenance, cost of maintenance of the replacement, cost of failure, risk of failure, safety, increase in performance/efficiency, length of manufacturer's support, and so forth. The objective is to be able to look at the outcome of this engineering tool and clearly see what needs to be replaced, be it a component, series of components, or an entire system. If there are several such replacements needed, which one(s) have the greatest priority for replacement. Therefore the engineering tool will
identify, quantify, and prioritize the cost of obsolescence in the plant. An engineering tool of this type should find application in a number of nuclear and non-nuclear facilities. While the engineering tool is being developed, the first stage of development will be on system components. Once the foundation is set it will be used to evaluate other systems and eventually expand and develop the engineering tool for the entire plant.


The electronic components obsolescence problem, also called diminished manufacturing sources, components unavailability, or parts obsolescence, is approaching crisis proportions for low volume complex electronics systems manufacturers, which include the military, aerospace and medical industries. Today’s electronic component manufacturers are concentrating on volume-driven electronic products, such as computer, consumer, and telecommunications products, which are primarily designed for office and other benign applications, which generally have shorter design, production, and service lifetimes. The impacts of this phenomenon on the military electronics industry, and the civil aerospace industry as well, are particularly profound and require an immediate and vigorous response. This paper will define the various facets of the problem and will provide some recommended solutions on how to deal with component obsolescence problems in military electronics equipment.


The electronic components obsolescence problem, also called diminished manufacturing sources, components unavailability, or parts obsolescence, is approaching crisis proportions for low volume complex electronics systems manufacturers, which include the military, aerospace and medical industries. Today’s electronic component manufacturers are concentrating on volume-driven electronic products, such as computer, consumer, and telecommunications products, which are primarily designed for office and other benign applications, which generally have shorter design, production, and service lifetimes. The impacts of this phenomenon on the civil and military aerospace industry are particularly profound, and require an immediate and vigorous response.


Especially in the last two decades of an increasingly-competitive business environment, dwindling resources and an ever-increasing need to obtain value for money in all areas of corporate activity, it has become essential that all available resources be used optimally. Physical assets form the basic infrastructure of all businesses and their effective management is essential to overall success. It has thus become essential to plan and monitor assets throughout their entire life-cycle, from the development/procurement stage through to eventual disposal. Life-cycle costing is concerned with optimizing value for money in the ownership of physical assets by taking into consideration all the cost factors
relating to the asset during its operational life. Optimizing the trade-off between those
cost factors will give the minimum life-cycle cost of the asset. This process involves
estimation of costs on a whole life basis before making a choice to purchase an asset from
the various alternatives available. Life-cycle cost of an asset can, very often, be many
times the initial purchase or investment cost. It is important that management should
realize the source and magnitude of lifetime costs so that effective action can
subsequently be taken to control them. This approach to decision making encourages a
long-term outlook to the investment decision-making process rather than attempting to
save money in the short term by buying assets simply with lower initial acquisition cost.
It is suggested project managers should familiarize themselves with what the approach
involves, to better appreciate how they might then contribute to the enhanced quality
decision making which it makes possible.

The pre-injector of the Taiwan Light Source (TLS) is consists of a 140 kV thermionic gun
and a 50 MeV travelling wave type linear accelerator (linac) system. A linac control
system has been renewed to avoid obsolescence. It is also utilized to improve
performance, decouple the vacuum interlock logic from the linac control system, and
provide a better control functionality for top-up operation. One VME crate system is
dedicated for the linac control, the new hardware equipped with high resolution of
analogue interface to provide better control. Vacuum interlock logic will be done via a
dedicated programmable logic controller (PLC). The remained linac devices, which are
necessary for sequential control such as door access interlock, klystron warm up, gun
warm up, trigger interlock, gun high voltage interlock, klystron modulator high voltage
interlock, water flow interlock, will be done by another PLC. Both interlock and
sequential control of PLC will be controlled by the VME crate. All of the other functions
without interlock or sequence requirement will be controlled by the VME crate directly as
well. New control system is expected to provide better control functionality, better
performance, easy for maintenance, and useful easy to add new hardware equipments.

Xiaozhou, M., B. Thornberg, et al. (2011). Embedded system design with maintenance
This paper deals with the problems of maintaining a long lifetime embedded system,
including obsolescence, function change requirement or technology migration etc. The
aim of the presented work is to analyze the maintainability of long lifetime embedded
systems for different design technologies. FPGA platform solutions are proposed in order
to ease the system maintenance. Different platform cases are evaluated by analyzing the
essence of each case and the consequences of different risk scenarios during system
maintenance. Finally, the conclusion is drawn that the FPGA platform with vendor and
device independent soft IP is the best choice.

OpenCores. 6th IEEE International Symposium on Industrial Embedded Systems (SIES):
79-82.
The reuse of predefined Intellectual Property (IP) can shorten development times and help the designer to meet time-to-market requirements for embedded systems. Using FPGA IP in a proper way can also mitigate the component obsolescence problem. System migration between devices is unavoidable, especially for long lifetime embedded systems, so IP portability becomes an important issue for system maintenance. This paper presents a case study analyzing the portability of an FPGA-based M-JPEG decoder IP. The lack of any clear separation between computation and communication is shown to limit the decoder's portability with respect to different communication interfaces. Technology and tool dependent firmware IP components are often supplied by FPGA vendors. It is possible for these firm IP components to reduce development time. However, the use of these technology and tool dependent firmware specifications within the M-JPEG decoder is shown to limit the decoder's portability with respect to development tools and FPGA vendors.


With the advancement of science and technology and the fast change of buyer requirements, the short-life products have been shortened at large, some formerly long-life products gradually turn to value deterioration products. The ratio of value deterioration products to modern products is getting higher and higher. This paper develops a deterministic economic order quantity EOQ inventory model, where the demand rate depends on the on-hand inventory when inventory level exceeds certain quantity, otherwise the demand rate is constant. The effects of obsolescence are taken into account, for it is related to the demand rate. The results are discussed through two numerical examples. A sensitivity analysis of the optimal solution with respect to parameters of the system is carried out. (2011) Trans Tech Publications.


This paper addresses the problem of resource portfolio planning of firms in high-tech, capital-intensive manufacturing industries. In light of the strategic importance of resource portfolio planning in these industries, we offer an alternative approach to modelling capacity planning and allocation problems that improves the deficiencies of prior models in dealing with three salient features of these industries, i.e., fast technological obsolescence, volatile market demand, and high capital expenditure. This paper first discusses the characteristics of resource portfolio planning problems including capacity adjustment and allocation. Next, we propose a new mathematical programming formulation that simultaneously optimises capacity planning and task assignment. For solution efficiency, a constraint-satisfied genetic algorithm (CSGA) is developed to solve the proposed mathematical programming problem on a real-time basis. The proposed modelling scheme is employed in the context of a semiconductor testing facility. Experimental results show that our approach can solve the resource portfolio planning problem more efficiently than a conventional optimisation solver. The overall contribution is an analytical tool that can be employed by decision makers responding to
the dynamic technological progress and new product introduction at the strategic resource planning level.


Sustaining weapons system hardware and software represents a significant and ever-increasing portion of total system cost. Hardware components are becoming obsolete much sooner while weapons system lifetimes are increasing. We must identify more cost-effective solutions to engineering and reengineering these subsystems. Verifying and validating weapons systems are two of the most costly parts of either engineering process. Traditionally, hardware validation and verification is done by simulation and testing. In the past few years, math- and logic-based formal methods tools have begun to scale up to and be applied successfully to real-world problems. Incorporating formal verification methods into engineering and reengineering processes will cost-effectively and significantly improve the level of trust and the quality of our weapons systems. Formal methods are especially well suited for redesigning current weapon systems which have become unsupportable due to component obsolescence because they help minimize the astronomical costs of rigorously reverifying the reengineered components. We believe that formal methods are an important tool for effective engineering of future weapon systems


Multistage investments are common in area-wide developments of privatized telecommunication networks and other complex infrastructure systems. They represent an incremental strategy that maintains flexibility in managing market risks, funding needs, and resource constraints in geographical expansions. Though compound options can be used to valuate multistage investments, their valuation is complex when the project in question requires upfront and interim investments in dedicated assets for future expansions. The problem becomes more complex when infrastructure markets are competitive and the investment in question is prone to rapid technological progress, which quickly makes the currently best in-use technology obsolete. This paper develops a European sequential compound call option pricing model to valuate multistage investments and analyze how competition, dedicated assets, and technological obsolescence influence the value of flexibility in this incremental strategy.


Three primary aspects of this research are investigated. First, ontologies for obsolescence knowledge representation are developed in a systematic way with the use of UML diagrams. The generality of the developed ontology is demonstrated with distinct examples. Diminishing Manufacturing Sources and Material Shortages (DMSMS) obsolescence provides the basis for this study. Second, an ontology-based hybrid approach for integrating heterogeneous data resources in existing obsolescence management tools is proposed. Third, decision support models are developed and
formalized, and include the obsolescence forecasting method for proactively managing obsolescence, and the mathematical models to determine the optimal design refresh plan to minimize the product life cycle cost for strategic obsolescence management. Finally, the design of the obsolescence management information system is provided along with a system evaluation methodology.


Fast moving technologies have caused high-tech components to have shortened life cycles, rendering them obsolete quickly. Obsolescence is a significant problem for systems with operational and support life that are much longer than the procurement lifetimes of their constituent components. Design refresh planning is a strategic way of managing obsolescence. Mathematical models are presented herein to determine the design refresh plan that minimizes total cost. The plan includes guidance on when to execute design refreshes (dates) and what obsolete/non-obsolete system components should be replaced at a specific design refresh. When data uncertainty is considered and obsolescence dates of the components are assumed to follow specific probability distributions, different solutions for executing design refreshes and the probabilities of adopting these solutions can be obtained. The final optimal cost becomes an expected value. An example of an electronic engine control unit (ECU) is included for demonstration of the developed models.