A Literature Review on Obsolescence Management in COTS-Centric Cyber Physical Systems

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A Literature Review on Obsolescence Management in COTS-Centric Cyber Physical Systems

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Background and Objectives

• Background
  — Obsolescence is the inevitable reality affecting all systems, especially military systems with long lead times and many COTS components.
  — Prior studied viewed Obsolescence Management as planning how to address the loss of materials, manufacturers, human skill, etc.
  — Largely focused on hardware obsolescence, although in most CPS systems, software costs contribute as much, or more, to the total costs.

• Objectives
  — To provide a comprehensive overview of current obsolescence management studies and practices
  — To explore, synthesize, and compile past efforts in the context of COTS-based systems
  — To identify gap and propose new opportunity to address obsolescence related issues
Research Methodology

- Understanding trend in COTS related CPS Obsolescence studies
- Align existing MPTs
- Identify gap
- Taxonomy
- Meta attributes
- Simple Model

Morning talk: Towards a taxonomy of technical debt for COTS-intensive cyber physical systems
Literature Review Methodology

• Follow Kitchenham’s systematic literature review methodology

• Search Protocol

  — Keywords:
    o (“Technical debt” OR “Obsolescence”) AND
    (“COTS” OR “NDI” OR “GOTS” OR “Component*”) AND
    (“cyber physical system” OR “military systems” OR (“embedded systems”))

  — Databases
    o DMSMS; ACM Digital Library, IEEExplore, ScienceDirect, SpringerLink, Scopus, and Web of Science

• Search process

  — Three-round

  — Snowballing

  — Inclusion/Exclusion criteria
    o Only publications that define or discuss COTS and obsolescence issues in a Cyber Physical Systems (CPS) context are included.
    o Only publications written in English are included.
    o Publications where the full text cannot be located are excluded.
    o Publications earlier than 1980 are excluded.

• Results: a collection of 57 literatures included for further analysis
The review process focuses on extracting key information from individual study with regarding to the above review questions.
Attributes for Study Analysis

- From the 57 articles, different attributes were extracted to guide review data collection.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
</table>
| MPTs       | Four types of contribution of the studies:  
- A method: if the paper introduces a new method  
- A processes: if the paper introduces a new process  
- A tool: if the paper introduces a new tool, or  
- Others: position papers, reviews, case studies, etc. |
| Sector     | Four sectors including:  
- Academia, Government, Industry, and Others |
| LC Phase   | Five phases to map the focus or applicability of the study results:  
- Materiel solution analysis (i.e. Milestone A)  
- Technology maturation and risk reduction (i.e. Milestone B)  
- Technology maturation and risk reduction (i.e. Milestone C)  
- Production and deployment (i.e. Initial Operational Capability, IOC)  
- Operations and support |
| Granularity| Two levels of obsolescence issues:  
- System level, Component |
RQ1: Existing MPTs for COTS obsolescence?

**Methods**
- Design Refresh; Life Time Buy; Last Time Buy; Substitution; Forecasting Model; Design Longevity Agreements, etc.

**Processes**
- Open source software products; Software Application programming Interfaces (API) and wrappers; After-market Supplier; Emulation/Cloning; Software Obsolescence Trigger Map

**Tools**
- COCOTS; MOCA (mitigation of obsolescence cost analysis) tool; Total Obsolescence Management Capability Assessment Tool (TOMCAT); etc.
RQ2: Types of data used?

- **Technology forecasting:** 20
  - E.g. High risk COTS/CCA (Circuit Card Assembly), OEM, BOM, contract incentives

- **Business Trending (Demand forecasting):** 10
  - E.g. regression modelling to forecast business trend based on the obsolescence data and increased functionality of integrated circuits

- **Obsolescence data:** 9
  - E.g. electronic/sw/media component

- **Logistics data:** 17
  - E.g. DMSMS

- **Others:** 19
RQ3: Sources of COTS obsolescence?

- **S/w and media support tooling:** 22
  - E.g. operating system, ERP, database, etc.

- **Electronic components/Mechanical components:** 20
  - E.g. EEE (electrical, electronic, mechanical) components, etc.

- **Test equipment:** 4

- **Documentation:** 2

- **Skills/personnel/training:** 1

- **Others:** 8
RQ4: Metrics for analyzing COTS obsolescence cost/risk?

- Seven categories of COTS metrics used in existing studies:
  - Multiplicity (e.g. #of COTSs, #of components, etc.): 8 studies
  - Complexity (e.g. system complexity, application complexity, Requalification complexity, etc.): 23
  - Interdependency (e.g. Coupling level and package density, etc.): 20
  - Platform diversity: 11
  - PBS (product breakdown structure): 7
  - OM strategy: 17
  - Financial Metrics (e.g. RO, NPV, etc.): 14
RQ5: COTS obsolescence management approaches?

- Three categories:
  - Strategic
    - Supply-chain: risk mitigation buy (RMB) and partnering agreement
  - Proactive
    - Design: open system architecture, modularity, use of multi-sourced components
    - Planning: obsolescence mgmt. plan, technology roadmap, monitoring tools
  - Reactive
    - Emulation or redesign (e.g. use of state-of-art technology to replicate or redesign the component)
    - Others: last-time buy, Form, fit & function(FFF) replacement (e.g. equivalent-component)
Mapping Framework

Hybrid Flow of Obsolescence Risk and COTS Technical Debt Management
## COTS TD Taxonomy in CPS Context

<table>
<thead>
<tr>
<th>TD Category</th>
<th>Description</th>
<th>Analogy to existing work</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Function</strong></td>
<td>The degree of functionality mismatch between COTS capabilities and system needs.</td>
<td>Local TD; Data TD</td>
</tr>
<tr>
<td><strong>Performance</strong></td>
<td>The degree of mismatches between COTS capabilities and system needs, w.r.t. performance properties.</td>
<td>MacGyver TD; Data TD</td>
</tr>
<tr>
<td><strong>Interoperability</strong></td>
<td>The degree of interface/ assumption mismatches among various interdependent COTS components, as well as among COTS and system custom components.</td>
<td>MacGyver TD; Data TD</td>
</tr>
<tr>
<td><strong>Configuration</strong></td>
<td>CPS configuration version planning needs to address solution availability plan. Greater tendency of COTS version upgrade/refresh may lead to more obsolete COTS.</td>
<td>Unavoidable TD; Local TD; MacGyver TD; Foundational TD; Data TD</td>
</tr>
<tr>
<td><strong>Version</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Documentation</strong></td>
<td>Lack of documentation and vendor support will seriously impact on issue resolution related to obsolete COTS.</td>
<td>Unavoidable; Data TD</td>
</tr>
<tr>
<td>&amp; Support</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>System Evolution</strong></td>
<td>Requirements imposed by COTS may place great limitation on system evolution.</td>
<td>Unavoidable TD; Foundational TD; Data TD</td>
</tr>
<tr>
<td><strong>Limitations</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Organic</strong></td>
<td>People-centric perspective of TD focusing on organizational decision-making, behaviours, and practices associated with those personnel responsible for introductions of new technologies &amp; systems and/or the sustainment of existing systems</td>
<td>Local TD; Naïve TD; Strategic TD</td>
</tr>
</tbody>
</table>
COTS TD Management Activities

- TD identification
- TD representation
- TD communication
- TD measurement
- TD prioritization
- TD Monitoring
- TD repayment
- TD prevention
Take-Aways

- This study provided a review of the current state of obsolescence-centric research and related practices

- COTS-based CPSs need to embrace greater use of proactive monitoring and planning to assure affordability and system readiness, from the early stage of systems design

- The mapping framework allows for the project management and design teams to work in tandem towards addressing obsolescence risk and technical debt

- More industrial studies are needed to deal with COTS technical debt in CPS context, e.g.:
  - Capture interdependencies of COTS components in CPS systems;
  - Identify “technical debt” items associated with COTS decisions;
  - Predict the effects of COTS technical debt items on the system across its system life cycle;
  - Make informed technical decisions associated with COTS usage.
Thank You!

&

Questions?
Example 1 - Cost metrics for requalification of air/safety critical components [Romero Rojo et al. 2012]

- The cost metrics represent the non-recurring costs of resolving an obsolescence issue using each of the resolution approaches.
  - during the contracted period within the in-service phase.

<table>
<thead>
<tr>
<th>Obsolescence management approach</th>
<th>Integration level</th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
<th>Very large</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing stock</td>
<td></td>
<td>£300</td>
<td>£300</td>
<td>£300</td>
<td>£300</td>
</tr>
<tr>
<td>Life time buy</td>
<td></td>
<td>£2,000</td>
<td>£2,000</td>
<td>£2,000</td>
<td>£2,000</td>
</tr>
<tr>
<td>Cannibalisation</td>
<td></td>
<td>£1,700</td>
<td>£2,500</td>
<td>£3,400</td>
<td>£4,500</td>
</tr>
<tr>
<td>Equivalent</td>
<td></td>
<td>£3,500</td>
<td>£3,500</td>
<td>£3,500</td>
<td>£3,500</td>
</tr>
<tr>
<td>Alternative</td>
<td></td>
<td>£10,100</td>
<td>£10,100</td>
<td>£15,200</td>
<td>£21,500</td>
</tr>
<tr>
<td>Authorised aftermarket</td>
<td></td>
<td>£13,000</td>
<td>£13,000</td>
<td>£19,800</td>
<td>£25,800</td>
</tr>
<tr>
<td>Emulation</td>
<td></td>
<td>£52,100</td>
<td>£193,000</td>
<td>£489,000</td>
<td>£2,690,000</td>
</tr>
<tr>
<td>Minor redesign</td>
<td></td>
<td>£50,100</td>
<td>£167,000</td>
<td>£244,000</td>
<td>£549,000</td>
</tr>
<tr>
<td>Major redesign</td>
<td></td>
<td>£250,000</td>
<td>£2,000,000</td>
<td>£3,400,000</td>
<td>£13,700,000</td>
</tr>
</tbody>
</table>

Volatility effects just cancel increased integration experience

Volatility effects dominate increased integration experience

Increased integration experience dominates volatility effects

*Fn (synchronization, complexity of system, no. planned upgrades, etc.)