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

Ye Yang

Stevens Institute of Technology

SYSTEMS ENGINEERING RESEARCH CENTER

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

Turki Alelyani, Ye Yang, Jon Wade, Dinesh Verma (Stevens Institute of Technology)
Ronald Michel (RDECOM CERDEC)
Martin Törngren (KTH Royal Institute of Technology)

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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

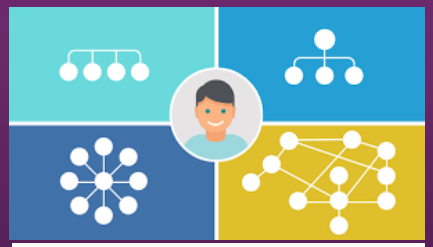
Literature Review

- Understanding trend in COTS related CPS Obsolescence studies

Mapping Framework

- Align existing MPTs
- Identify gap

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



COTS Technical Debt

- Taxonomy
- Meta attributes
- Simple Model

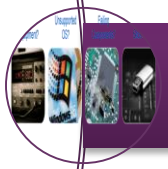
Literature Review Methodology

- Follow Kitchenham's systematic literature review methodology
- Search Protocol
  - Keywords:
    - ("Technical debt" OR "Obsolescence") AND
      ("COTS" OR "NDI" OR "GOTS" OR "Component*") AND
      ("cyber physical system" OR "military systems" OR ("embedded systems")
  - Databases
    - DMSMS; ACM Digital Library, IEEExplore, ScienceDirect, SpringerLink, Scopus, and Web of Science
- Search process
  - Three-round
  - Snowballing
  - Inclusion/Exclusion criteria
    - Only publications that define or discuss COTS and obsolescence issues in a Cyber Physical Systems (CPS) context are included.
    - Only publications written in English are included.
    - Publications where the full text cannot be located are excluded.
    - Publications earlier than 1980 are excluded.
- Results: a collection of 57 literatures included for further analysis

Review Questions

RQ1: Trend in existing MPTs for COTS obsolescence?

RQ2: Types of data used?



RQ3: Sources of COTS obsolescence?

RQ4: Metrics for analyzing COTS obsolescence cost/risk?

RQ5: COTS obsolescence management approaches?

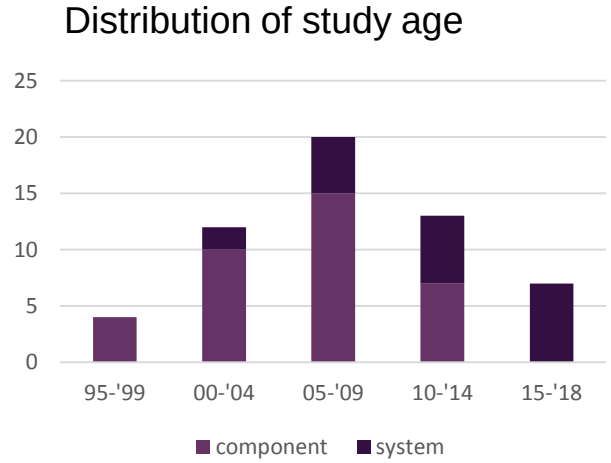
The review process focuses on extracting key information from individual study with regarding to the above review questions.

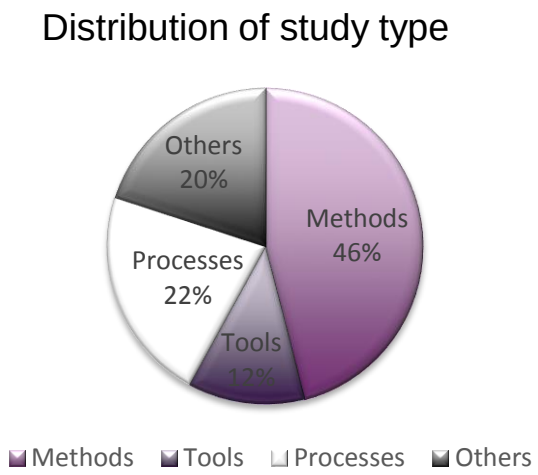
Attributes for Study Analysis

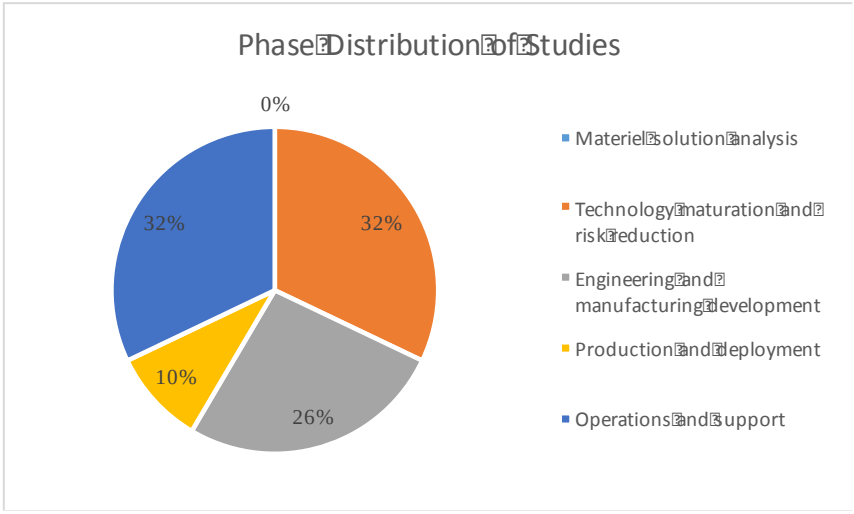
- From the 57 articles, different attributes were extracted to guide review data collection

Attribute	Description
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?



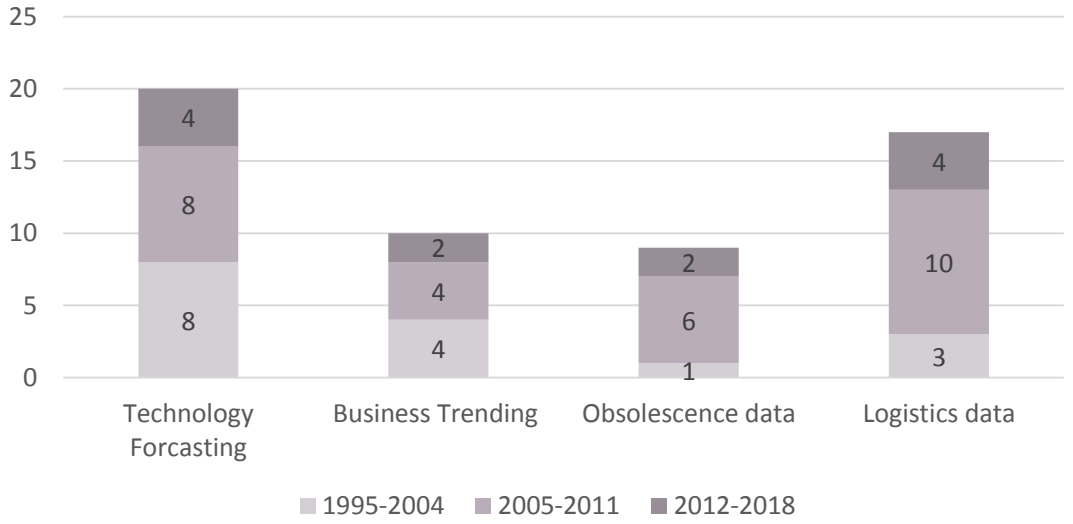




- Methods
  - Design Refresh; Life Time Buy; Last Time Buy; Substitution; Forecasting Model; Design Longevity Agreements, etc.
- Processes
  - Open source software products; Software Application programming Interfaces (API) and wrappers; After-market Supplier; Emulation/Cloning; Software Obsolescence Trigger Map
- Tools
  - COCOTS; MOCA (mitigation of obsolescence cost analysis) tool; Total Obsolescence Management Capability Assessment Tool (TOMCAT); etc.

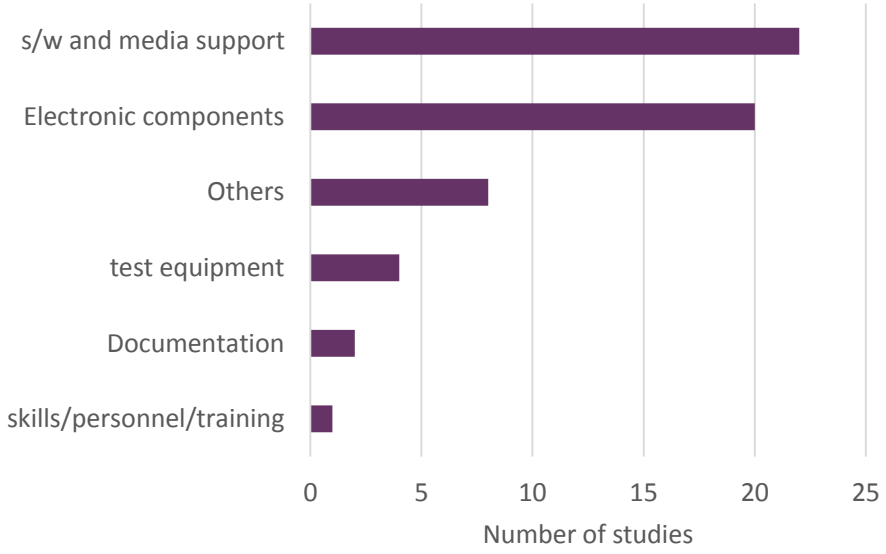
RQ2: Types of data used?

- 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



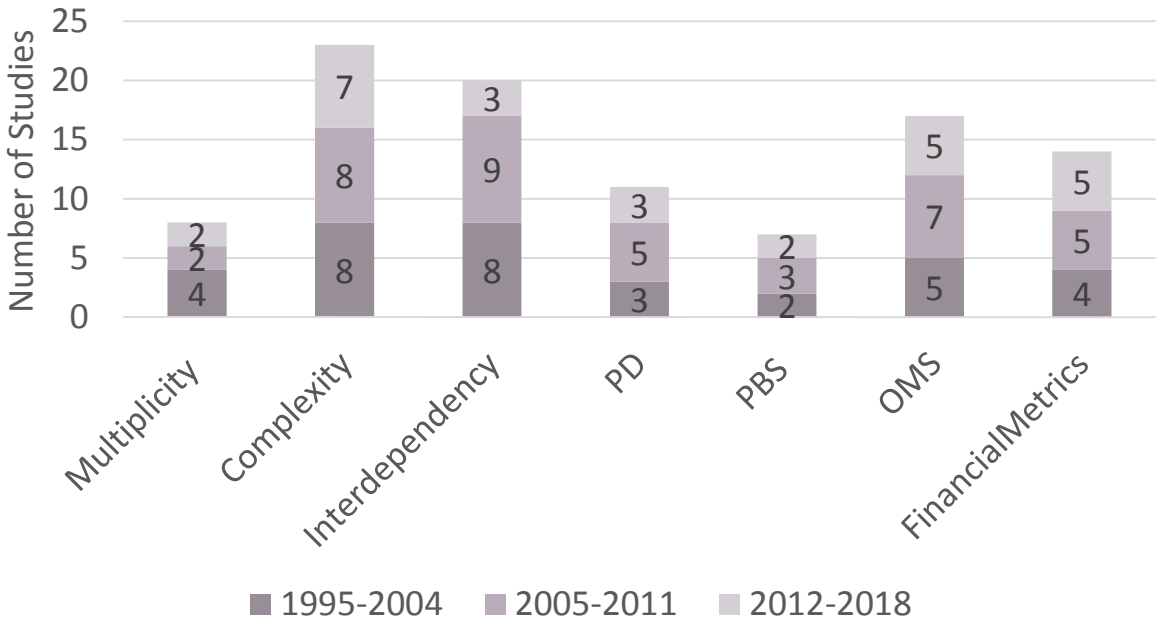
RQ3: Sources of COTS obsolescence?

- 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



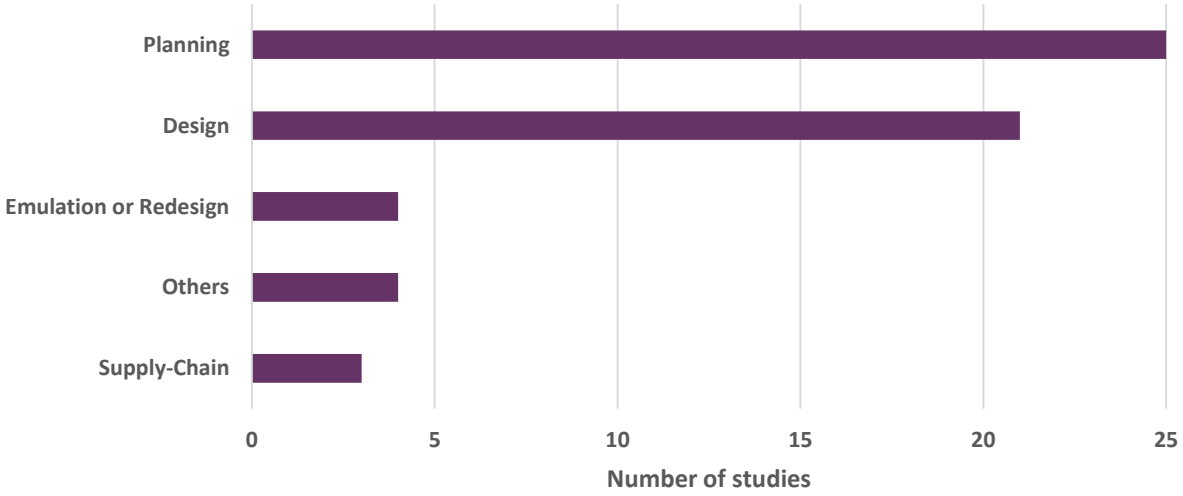
RQ4: Metrics for analyzing COTS obsolescence cost/risk?

- 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

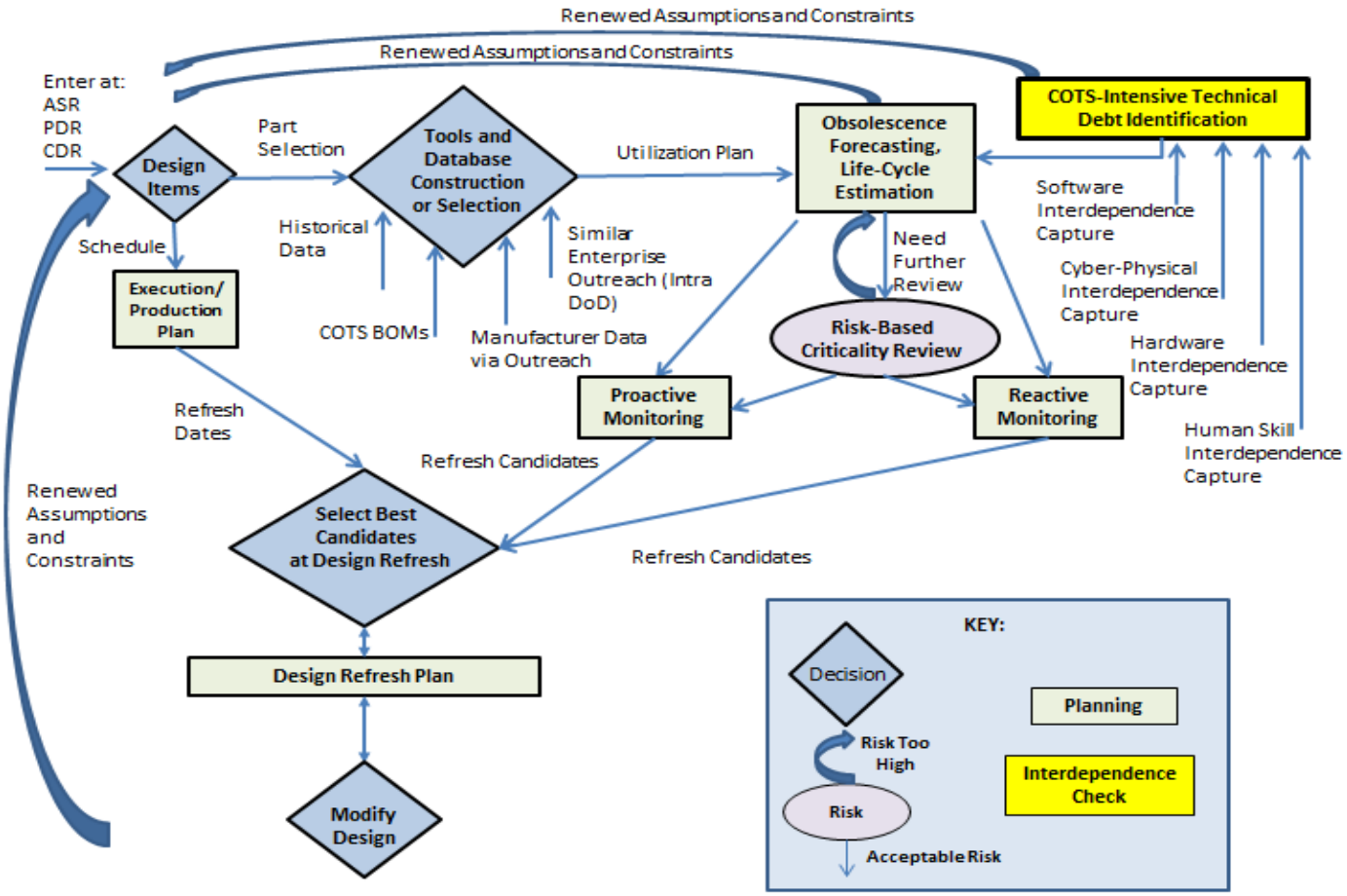


RQ5: COTS obsolescence management approaches?

- 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

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

COTS TD Management Activities

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.

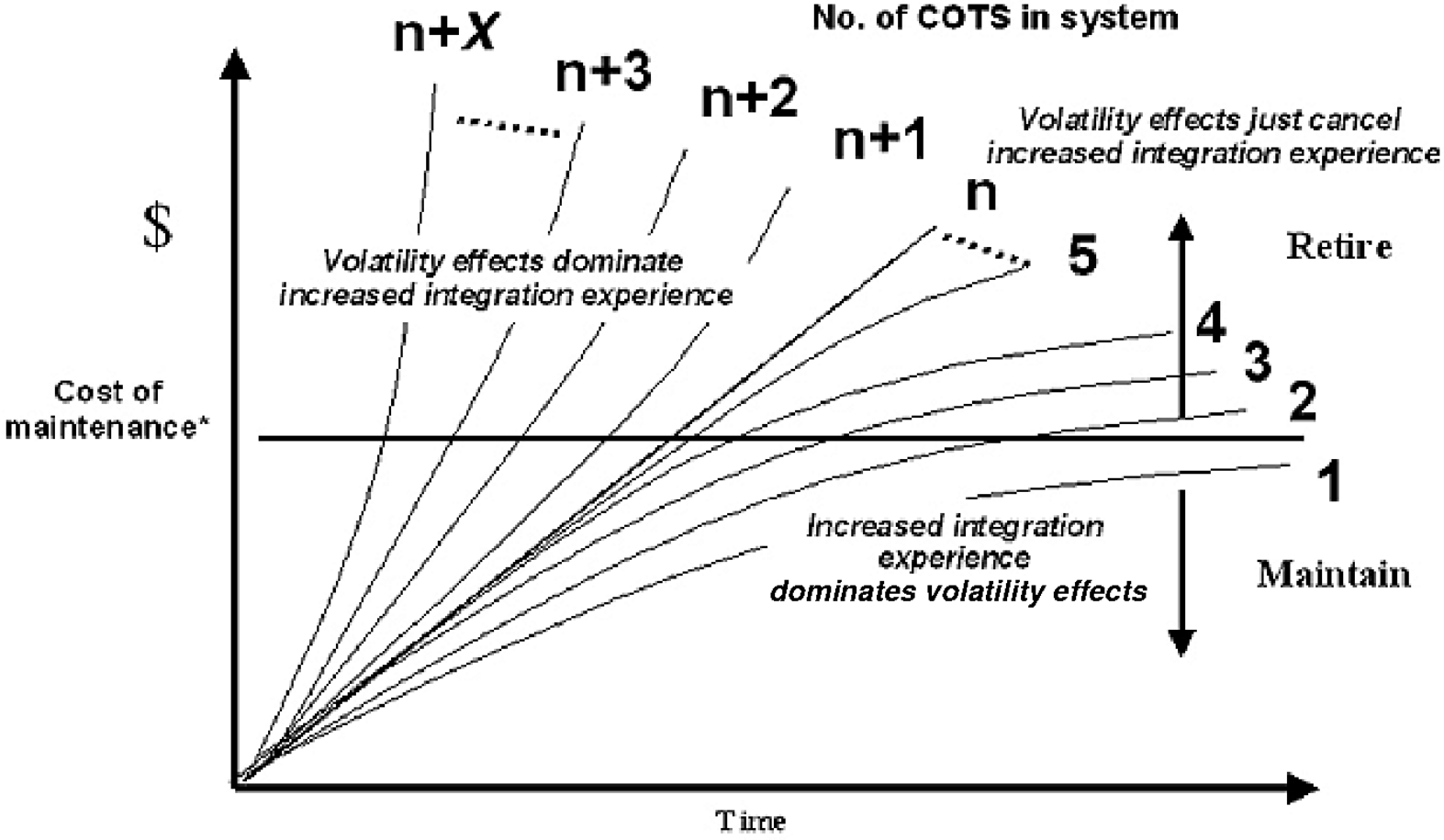
Thank You!
&
Questions?

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.

Obsolescence management approach	Integration level			
	Small	Medium	Large	Very large
Existing stock	£300	£300	£300	£300
Life time buy	£2,000	£2,000	£2,000	£2,000
Cannibalisation	£1,700	£2,500	£3,400	£4,500
Equivalent	£3,500	£3,500	£3,500	£3,500
Alternative	£10,100	£10,100	£15,200	£21,500
Authorised aftermarket	£13,000	£13,00	£19,800	£25,800
Emulation	£52,100	£193,000	£489,000	£2,690,000
Minor redesign	£50,100	£167,000	£244,000	£549,000
Major redesign	£250,000	£2,000,000	£3,400,000	£13,700,000

Example 2 - Economic Life Span of COTS-based Software Systems: the COTS-LIMO Model [Abt. Et al. 2000]



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