LIFE CYCLE CONCERNS

18-849b Dependable Embedded Systems
Phil Koopman
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Required Reading: Goldberg, “The Advent of ‘Green’ Computer Design”
IEEE Computer, Sept. 1998, pp. 16-19

Books: Kirk & Dell'Isola, Life Cycle Costing for Design Professionals
Christopher, Logistics: the strategic issues
Burall, Green design
SYSTEM LIFE CYCLE

- Design Process/
  Market
- VERIFICATION/
  VALIDATION/
  CERTIFICATION
- End-of-Life 
  Wearout & 
  Retirement
- Shoddy 
  Spares & 
  Customer 
  Circumvention
- PROFIT$ & 
  BUSINESS 
  MODELS
- Maintenance 
  and 
  Reliability
- Ultra-Dependability
- Manufacturing/
  Quality
Overview: Life Cycle

◆ Introduction
  • “Dotted Line” relationship to technical areas

◆ Key concepts
  • Green Design
  • Life cycle product/process engineering
  • Life cycle cost optimization
  • Logistics

◆ Tools / techniques / metrics
  • Mostly business metrics available

◆ Conclusions & future work
Optimize considering all phases of product life

- Compare to “development,” which ends when product ships
“Life Cycle Cost”

- **This is the economic/financial view**
  - Optimize total cost of ownership
    - Key factors: purchase cost, energy, maintenance, upgrades, administrative, debt service, staffing (degree of automation), downtime (opportunity cost)
  - Optimize total cost to society
    - Disposal costs, infrastructure costs

- **People’s behavior is a problem**
  - Consumers are impatient, and have cash flow problems
    - Value low purchase price even if life cycle cost is high
  - People are modeled to behave to maximize utility
    - But, may not have up-front money to invest
    - But, may not have any personal incentive to reduce societal costs
Logistics

◆ Keeping supplies flowing
  • By type of item:
    – Manufacturing components
    – Finished goods
    – Spare parts
  • By activity:
    – Delivery
    – Inventory
  • Optimize using linear programming/flow optimization

◆ Problems with support
  • Not perceived to delivery functionality ("overhead" cost)
  • Costs more to play catch-up after product is fielded
“Life Cycle Assessment”

- This is the “Green Design” interpretation
  - Analyze product design with view to ultimate impact of scrapping, disposal, or consumption
  - ISO 14000 series -- ISO 14040 Life Cycle Assessment

- Impact on embedded systems
  - IBM estimates that discarded computers will occupy 2 million tons of US landfill space by 2000. [Goldberg98]
  - Use low power design
    - Reduce energy/resource consumption
    - Reduce battery requirements (disposable & rechargeable)
  - Design for access/separability/longevity
    - Dis-assembly for recycling
    - Ready repairability
    - Better upgradability
Tools / Techniques

- CAD Tools for Green Design
  - Tracking materials through disposal
  - Design for dis-assembly as well as assembly
  - “Spreadsheet” approach to tallying total cost to environment

- Classical logistics optimization
  - Network flow problem/linear programming
Relationship To Other Topic Areas

- Not really “related” to topic areas as much as an overlay concept
  - But, must keep life cycle optimization in mind for each area

- Profits & Business Models
  - Want to optimize business profits over various life cycles
    - Product itself
    - Manufacturing process
    - Support/logistics cost
  - Business issue in terms of maximizing own profit at cost to others
    - Cost of pollution, government subsidy of technologies, resource depletion
    - Usual solution is for government to create taxes (e.g., with freon)
Conclusions & Future Work

✦ “Life Cycle” has many meanings
  • Most mature areas are life cycle cost analysis and logistics
  • Green Design is a sub-area to emphasize ecological costs

✦ This is a big, broad, nebulous area -- it’s not feasible to cover absolutely everything
  • Writeup will discuss general concepts
  • Give a few pointers to a few good starting points; not exhaustive
  • Not a lot of hard-core engineering papers available
    – Mostly management & economics
    – Green Design is an exception -- receiving engineering attention
PAPER: “Green” Computer Design

- Cool idea: “Self-dismantling computer”
- Green design is good; but there are obstacles
  - Reduce resource usage, energy usage, manufacturing waste
  - Cost of recycling can exceed cost of building new
  - Dynamic tension between building a upgradable product and making profit on selling replacement products

- No key technical contribution -- it’s a high-level “popular” discussion