LIFE CYCLE CONCERNS

18-849b Dependable Embedded Systems

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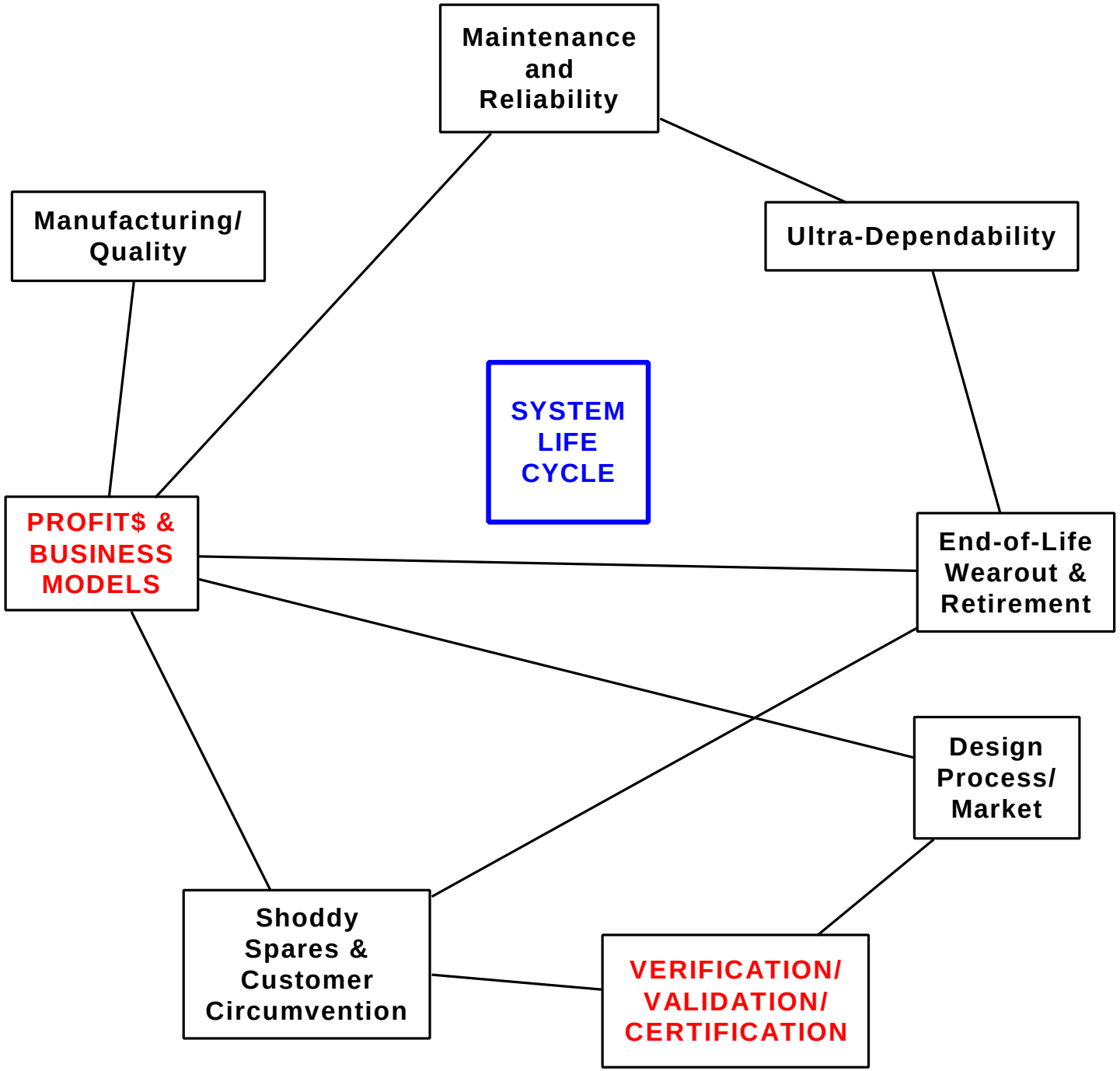
Required Reading: **Goldberg, "The Advent of 'Green' Computer Design"**
***IEEE Computer*, Sept. 1998, pp. 16-19**

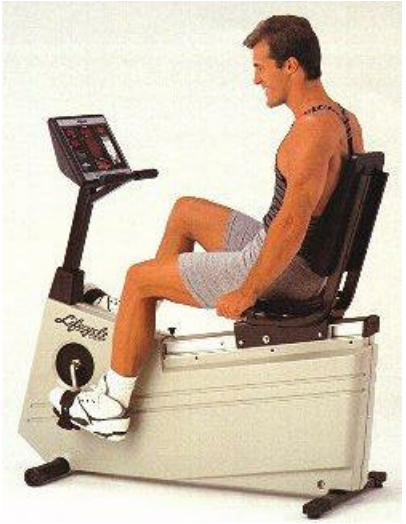
Books: **Kirk & Dell'Isola, *Life Cycle Costing for Design Professionals***
Christopher, *Logistics: the strategic issues*
Burall, *Green design*

Carnegie Mellon


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

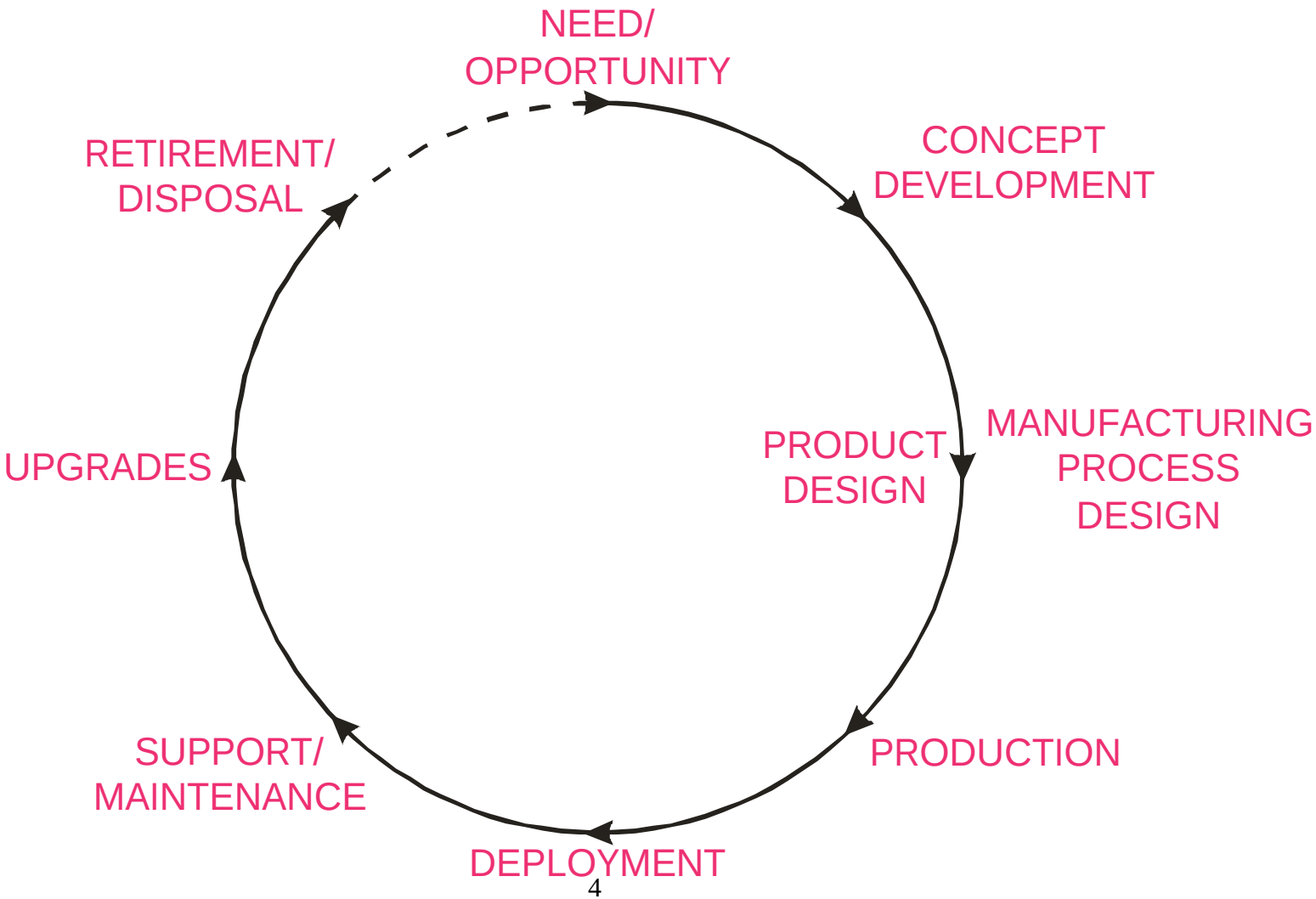
Overview: Life Cycle

- **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**



Life Cycle View -- Not Just Development

- **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**