Systems Integration

4 - Manufacturing Systems

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The Manufacturing Domain

Intoduction

- ▶ Is one step in the development of a product
- ▶ A crucial step. Has its own architecture
- ▶ Stable area during decades. Changes in the last decades
    - ▶ Global communications, transportation, sources, markets and finance
    - ▶ Global manufacturing practical, and now dominant

Innovations

- ▶ Ultraquality
- ▶ Dynamic manufacturing
- ▶ Lean production
- ▶ Flexible manufacturing

Manufacturing in Context

Full Development Followed by Serial Production

- Many copies of a system after one or more prototypes
- Testing of protoypes: *qualification*. Products meets its purposed
- Prototypes may be fully tested (even destructively)
- From breadboard to final prototype in several steps
- Testing: test some samples

Incremental Development and Release

- Each prototype is fully operational but with limited functionality
- Common in software-intensive systems
- Evolutionary product, responding to customer's needs
- Cost of certification are re-incurred. Testing becomes automated

Manufacturing in Context /2

Prototype Development and Manufacturing

- One single unit delivered: prototype *and* final product
- Testing is a risk: damage during test
  - Invisible changes to the system
  - Tradeoff: not finding a defect vs defect creation
  - The architecture tells what can be tested or not

Architectural Innovations: Ultraquality

Common Perception

- Quality costs money: trade-off between cost and benefit

Quality is positive

- Quality associated with features (leather seats, air conditioning)
- Quality associated with zero defects (DeSoto story)
  - Also makes money! (for buyer and seller)
  - Reductions in inventory, warranty costs, repairs, documentation, testing
  - Zero defects: just test the functionality of first unit
- Has been achieved. No defects in satellites, chips. TV sets have yields higher than 99% (vs. 50% in the 80's)
- Consumer electronics is unrepairable (unnecessary). No repair network. No diagnostic access (less space, money, sealing: increase quality, etc)

Achieve Ultraquality

- Everyone in the production line is both a customer and a supplier
- The Five Why's. Why did this occur? Then, why did that, in turn, occur? ...
- Some of the worst failures are system failures: They come from interaction of subsystem deficiencies which do not produce end system failure by themselves, but together they can!

- Caution: if ultraquality is not achieved at one step the whole production proces may collapse!
- Immediate fixing: no inventory cushions
- Employee, customer and manager understanding and satisfaction are essential. (Strikes, boycotts...)
- Pride in work and dedication to common cause

Dynamic Manufacturing Sytems

The intersecting process and product waterfalls:
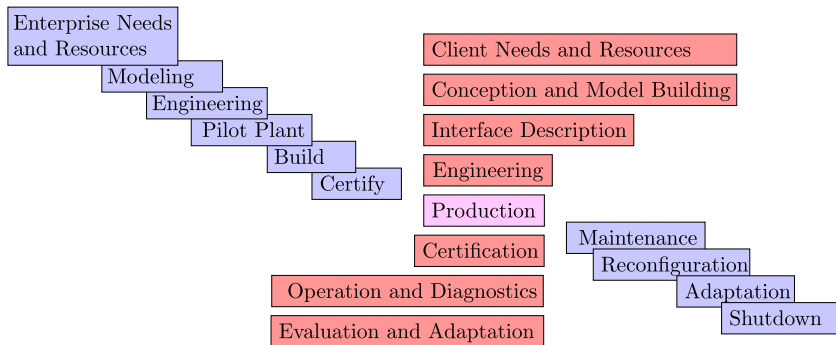
Intersecting Waterfalls

- Manufacturing waterfall longer than product waterfall, more steps, different end
- Different time scales
- Manufacture products not yet designed
- Manufacture demolition (similar to product recycling): has to be planned (high costs)

Feedback Systems

- ► Feedback from customers: maintain quality and accommodate changes in product
- ► Time constants of feedback loop
- ► Feedback control: transient and steady-state performance, delays, ringing...
- ► Nonlinear / time-variant. (Wage-reduction negotiation followed by increase in executive wages)
- ► Resonances due to improper time constants
- ► Chaotic behavior

Lean (no-fat) Production
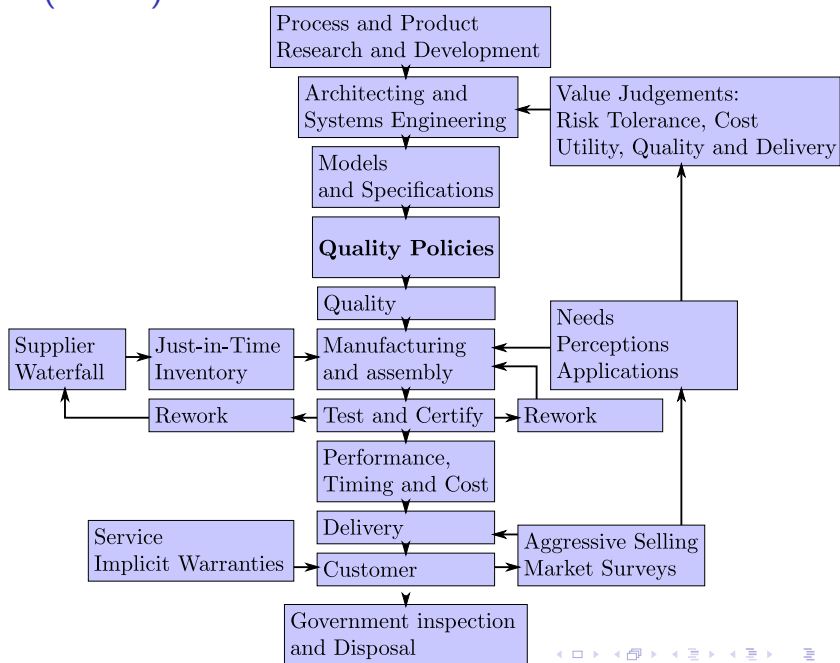
Flexible Manufacturing

- Capability of making more than one product on the same production line
- Customization on demand
- Real-time interaction between production waterfall and multiple product waterfalls
- Most companies allow flexibility inside a line of products
- Where to optimize? Low-end or high-end of the line
- System: has to be composed of subsystems the distribute cleanly over the manufacturing enterprise
- Manufacturing constraints are product constraints
- Keep low piece part count
- Keep high quality

Heuristics for Architecting Manufacturing Systems

- ▶ Product and manufacturing must match
- ▶ Keep it simple
- ▶ Partition for near-autonomy (but have feedback)
- ▶ In partitioning, choose the elements so that they minimize the complexity of material and information flow
- ▶ Watch out for critical misfits (between intersecting waterfalls)
- ▶ In making a change in the manufacturing process, how you make it is often more important than the change itself
- ▶ When implementing a change, keep some elements constant to provide an anchor point for people to cling to.

- Install a machine that even an idiot can use and pretty son everyone working for you is an idiot
- Everyone a customer, everyone a supplier
- To reduce unwanted nonlinear behavior, linearize!
- If you cannot analyze it, do not build it
- Avoid creating the same resonance time constant in more than one location in a production system
- The five why's