A Holistic Approach to Systems Development

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Outline

- Holistic and Iterative Systems Design Process
- Approach
- Summary
Goals of a Holistic / Iterative Systems Design Process

• **Goals**
  – Look at the design process as a whole
  – Who and what should be involved and considered?
  – What is the right approach?
Holistic and Iterative

• Holistic
  – Looking at the entire system life-cycle
  – Expertise from multiple disciplines
  – Broad consideration of many design factors
  – Cost and schedule are part of the design process
  – Parties involved/considered
    • SMEs, End Users, Stakeholders, People Potentially Impacted

• Iterative
  – Multiple design cycles
  – Ensure sound design in each cycle given the maturity level
  – Spending more time on early design cycles
  – Reduce cost in the long run
  – Final design more solid
  – Each design cycle: Cost and schedule are as important as other design factors
Approach – Factors to be Considered

• Starts Large and Ends Small
• Converging on an Optimal Design
• Human-Centered Design
• All Disciplines are Equally Important
• Concurrent Engineering
• Documentation
• Cost as a Design Factor
• Safety as a Design Factor
• Roles of the Government and Contractors
Approach – Factor 1: Starts Large / Ends Small

- At the Beginning - Starts Large
  - Look at the system as a whole
  - With easily achievable goals
  - Reduce errors due to losing focus of the whole picture

- At the End - Ends Small
  - System naturally evolves in complexity as the design matures
  - Gradually adding finer and finer details
Approach – Factor 2: Converging onto an Optimal Design

- Continuous process
- Most effort spent early on (starts large / ends small)
- Iterative
- Design fidelity increases as design matures
- Simulate (low fidelity simulation)
- Emulate (higher fidelity simulation w/ hardware emulation)
- Stimulate (human-in-the-loop)
Approach – Factor 3: Human-Centered Design

• Designers should design for the humans
• Goal – Enable humans to accomplish the mission safely and effectively
• Who are the humans?
  – End users
  – Designers
  – Stakeholders
  – Maintainers
  – People indirectly affected by the system
  – Etc.
Approach – Factor 4:
All Disciplines are Equally Important

- Human-centered design doesn’t mean the human factors discipline is the most important
- Disciplines should be involved in the design:
  - Subsystem vendors, configuration management, operations research, manufacturing engineering, simulation/modeling, cost engineering, hardware engineering, software engineering, test and evaluation, human factors, electromagnetic compatibility, integrated logistics support, reliability/maintainability/availability, safety engineering, test equipment, training systems, design-to-cost, life cycle cost, application engineering
  - etc.
Approach – Factor 5: Concurrent Engineering

- Key: Frequent Quality Communication Among Designers
- Each designer needs to know
  - What others are doing?
  - What assumptions others make?
- Not easy, an art in itself
- Enhance communication using Technologies
Approach – Factor 6: Documentation

• Taking good notes in each design cycle
• Document and share
  – Lessons learned
  – Assumptions
  – Design specifics
• Share among the entire design team
• Documentation also serves as reference for future projects
• Best: Having a software tool that enables everyone to document and share their design findings throughout the project
Approach – Factor 7: Cost

• A major design factor
• Cost and Schedule are interrelated
• Life-cycle cost is the most important. Need to consider:
  – Production/Maintenance/Training
  – System Reusability and Disposal
• Dilemma of the government yearly budget cycle
• Extensive use of Modeling/Simulation, Mockups, Human Subjects
• Use your creativity and engineering judgment to reduce cost
• 6 major cost factors
Approach - Factor 7A: Cost and Schedule are Interrelated

- Cost and schedule estimation be part of a design cycle
- Should be done at the beginning of a cycle
- Use cost and schedule to define the end of a cycle
- Should incorporate some flexibility in the estimation
Approach - Factor 7B: Emphasizes on Life-cycle Cost

• Very important but often neglected
• Production/Maintenance/Training also part of the design
  – SMEs of these areas should participate in the early design
  – Maintenance and Reliability are tied. A well-designed system that anticipates reliability reduces maintenance cost
  – Training:
    • Well-designed system is easy to use and requires less training
    • Proper function allocation between user and machine will reduce the need for training
• Reusability and Disposal
  – Consider reusability of subsystem components after retirement by other systems (old or new) during/after design
  – Proper disposal of used components to reduce environmental cost

“Waste is just really a design flaw and we have to be pushing on manufacturers and product designers to design things which are easily recyclable”
-- Kate Krebs, executive director of the National Recycling Coalition
• Government budget cycles are:
  – Yearly
  – Relatively consistent funding level
  – Rarely have an overall budget
• Saving money near term results in expensive long-term life-cycle cost
• Uncomfortable with long initial design cycles (perceived as unproductive)
• Designers need to preach the advantages of considering the life-cycle cost
Approach – Factor 7D: Extensively use Modeling, Simulation, and Mockups

• **Computer Simulation and Mockups**
  - Both are equally important
  - Easy and low cost to make design changes
  - Great for What-if studies
  - Design should first be done with M&S / mockups before any hardware is built

• **Models/Tools Validation, Verification, & Accreditation**
  - Models should be validated before use
  - Should use existing models as much as possible
  - Keep track of model uncertainties during design
  - Can be expensive but in most cases still much cheaper than building hardware especially during early design
Approach - Factor 7E: Hardware / Human-in-the-Loop

• Hardware-in-the-Loop
  – Hardware prototyping will be needed as the design matures
  – Use Emulation to reduce cost
    • Software Emulation
    • Hardware Emulation: use existing hardware for subcomponents, etc. (use your creativity)

• Human-in-the-Loop (HITL)
  – Human is the real thing (the highest fidelity)
  – Use human models wherever appropriate
  – Cost Control:
    • Use peers in the early design stages
    • To reduce bias: don’t use designers working on the particular design as subjects
    • More relevant subjects in the latter stages (relevant subjects tend to be more expensive)
Approach - Factor 7F: Don’t Reinvent the Wheel

- Make best use of existing models/tools, COTS hardware/software, and proven technologies as much as possible
- Take advantages of components used in previous projects, especially during initial prototyping
- Piggy-back on studies for other current projects
Approach – Factor 8: Design with Safety in Mind

• Design for Safety
  – Design with the safety of the eventual users and affected parties in mind

• Safety for Design
  – During the design stage, safety of the people involved in the design is equally important
  – Never compromise on safety by cutting cost!
Approach – Factor 9: Roles of Civil Servants and Contractors

• A complex but important issue
• Government carrying out good resource (personnel and facilities) estimation
  – Done in the early design stage
  – Make use of M&S for concepts exploration
• Use contractors when the number of Civil Servants (CS) are not sufficient or lacking certain skills to do the work
• Contractors and CS should work closely together
• Contractor/CS roles and responsibilities should not be divided by a simple straight line. That hinders creativity.
Summary

- Introduces a Holistic and Iterative Design Process
- Continuous process but can be loosely divided into four stages
- More effort spent early on in the design
- Human-centered and Multidisciplinary
- Emphasize on Life-Cycle Cost
- Extensive use of modeling, simulation, mockups, human subjects, and proven technologies
References

11. “Practical Human Factors Integration – Lessons Learned from a Case Study of a Large Project Implementation,” Ian Rowe, Associate Director, Ove Arup and Partners.
Questions and Comments
System Life Cycle

- Stage 1: Need Definition and Planning
- Stage 2: Design
  - Multiple design cycles in each design phase
  - Number of design cycles in each phase varies
  - Ensure design meets mission objectives in each cycle
  - Phase 1: Initial Design
  - Phase 2: Detail Engineering Design
  - Phase 3: Final Design
  - Always a little bit of other phases in each phase but detail varies
- Stage 3: Operation/Maintenance/Training
- Stage 4: System Retirement
First Design Phase – Initial Design

• Need to Spend Plenty of Time on Initial Design
• Defining Operational Needs
  – Place the definition on everyone’s desktop
• Operation Concept Development
  – Developing Operational Scenarios
  – Extensive Use of M&S, and Mockups
  – Integrated Simulation with Models
  – Don’t forget the humans (users, stakeholders, HITL)
  – Functions Allocation
  – Identifying Enabling Technologies
  – Risks Analysis
  – Trade Studies
  – System Interface Requirements
  – Prototyping
  – Design Concepts Validation
• System Architecture Development
  – An outcome of the Operation Concept Development

• Requirements Development
  – When initial design is complete
Second Design Phase – Detail Design

- Hardware-in-the-loop
- Human-in-the-loop
- Continue Use of M&S and Mockups.
- Integrated Simulation
- Design for Production
- Design for Maintenance
- Design for Training
- Design for Reusability and Disposal
- Subsystems Testing
- Integrated Testing
Third Design Phase – Final Design

- Full Scale Integrated Testing
- System Demonstration
- Production and Deployment
- Training
- Maintenance
- Final Documentation
- Design debriefing – discuss lessons learned