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

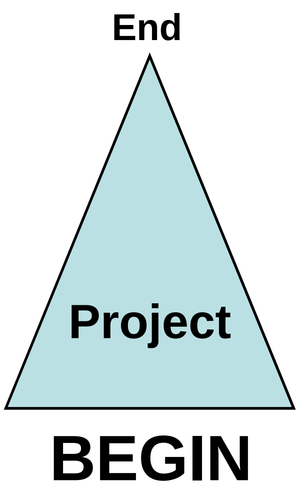
- **Holistic**
  - **Looking at the entire system life-cycle**
  - **Expertise from multiple disciplines**
  - **Broad consideration of many design factors**
  - **Cost and schedule are part of the design process**
  - **Parties involved/considered**
    - **SMEs, End Users, Stakeholders, People Potentially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

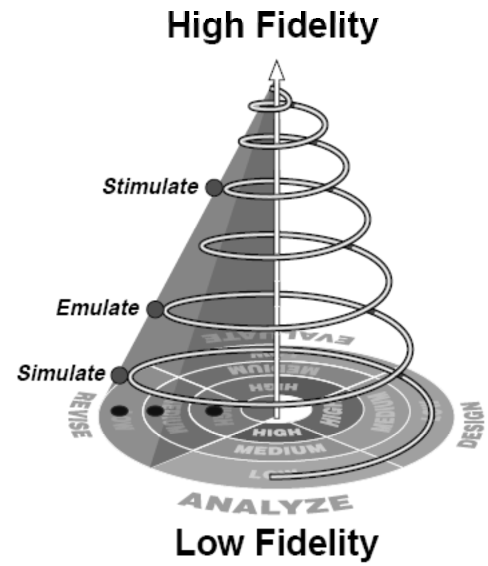
Approach – Factor 1: Starts Large / Ends Small

- **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 <u>safely</u> and <u>effectively</u>**
- **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**

Approach - Factor 7B: Life-cycle Cost (cont.)

- **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

Approach - Factor 7C: Dilemma of Government Budget Cycle

- 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

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Questions and Comments

Backups

Backups

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**

First Design Phase – Initial Design (cont)

- **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**