A Holistic Approach to Systems Development

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Outline

- **Holistic and Iterative Systems Design Process**
- **Approach (9 Factors)**
- **Summary**

Goals of the Holistic / Iterative Systems Design Process

Holistic/Iterative Systems Design Process

- Look at the design process as a whole (Holistic)
- Multiple design cycles (Iterative)
- Who and what should be involved and considered?
- What is the right approach?

Holistic and Iterative Systems Design

HOLISTIC	ITERATIVE
• Looking at the entire system life-cycle • Expertise from multiple disciplines • Broad consideration of many design factors • Cost and schedule part of the design process • Parties involved/considered – SMEs, End Users, Stakeholders, People potentially impacted	• Multiple design cycles • Spending more time on early design cycles • Ensure sound design in each cycle given the maturity level • Reduced cost in the long run • Final design more solid • Each design cycle: Cost and schedule as important as other design factors

Approach – Factors to be Considered

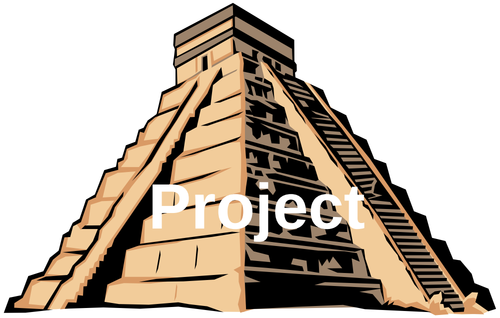
Factors for Holistic/Iterative Systems Design:

1. Starts Large and Ends Small
2. Converging on an Optimal Design
3. Human-Centered Design
4. All Disciplines are Equally Important
5. Concurrent Engineering
6. Documentation
7. Cost as a Design Factor (6 sub-factors)
8. Safety as a Design Factor
9. Roles of the Government and Contractors

Approach – Factor 1: Starts Large / Ends Small

At the Beginning - Starts Large

- Seeing the system as a whole
- Making easily achievable goals
- Focusing on the big picture to reduce error



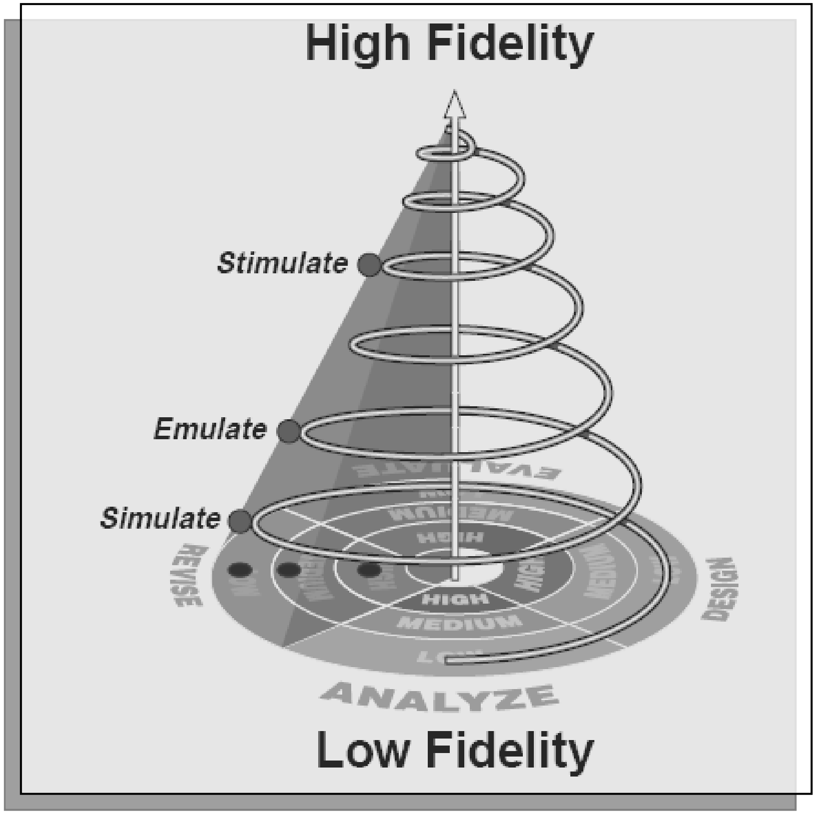
At the End - Ends Small

- Natural evolution in complexity as system design matures
- Gradually addition of finer and finer details

Approach – Factor 2: Converging onto an Optimal Design

Systems Engineering:

- 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)



"Simulation Based Acquisition: A New Approach," Lt. Colonel Michael V.R. Johnson, et al., Report of the Military Research Fellows DSMC 1997-1998, December 1998

Approach – Factor 3: Human-Centered Design

A system should:

- **Be designed for humans**
- **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 human factors is the most important discipline

Disciplines 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, . . .

Approach – Factor 5: Concurrent Engineering

Key concept:
- **Frequent quality communication among designers**

What do designers need to know?
- **What others are doing**
- **What assumptions others are making**

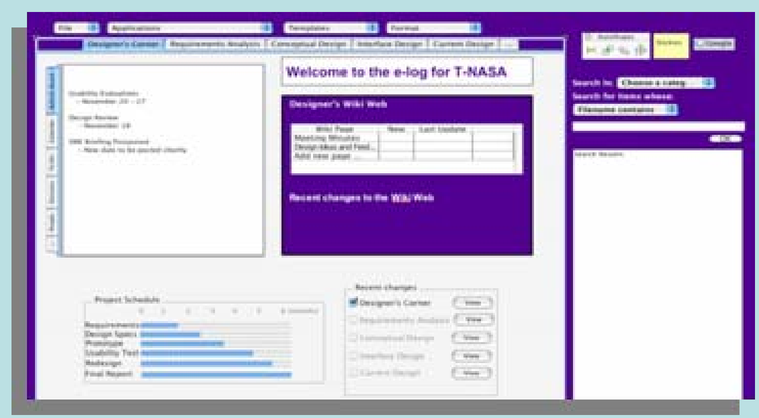
Making the communication process easier with software tools, e.g., ProE

Concurrent engineering is not easy; it's an art in itself.

Approach – Factor 6: Documentation

- **Taking good notes in each design cycle**
- **Documenting and sharing:**
  - **Lessons learned**
  - **Assumptions**
  - **Design specifics**
- **Sharing among the entire design team**
- **Using documentation as a reference for future projects**

Tips: ***Use a software tool that enables everyone to document and share their design findings throughout the project, e.g., Design Rationale Capture System***



"Capturing the Research and Development Process of Aviation Systems: Creating a Multi-Media Living Legacy," A. Andre, B. Hooey, D. Foyle, Proceedings of the 13th International Symposium on Aviation Psychology, 2005

Approach – Factor 7: Cost

COST

- **A major design factor**
- **Cost and Schedule are interrelated**
- **Emphasis on life-cycle cost**
- **Dilemma of annual government budget cycle**
- **Extensive use of modeling/simulation, mockups, human subjects**
- **Use of creativity and engineering judgment to reduce cost**
- **6 major cost factors**

Approach - Factor 7A: Cost and Schedule are Interrelated

Cost and schedule estimation …

- **should be part of a design cycle.**
- **should be done at the beginning of a cycle.**
- **should define the end of a cycle.**
- **should incorporate some flexibility.**

Approach - Factor 7B: Emphasis on Life-cycle Cost

Life Cycle Cost

- Very important but often neglected
- Important systems elements
  - Design
  - Production
  - Maintenance and Reliability: 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 reduces the need for training
  - Reusability and retirement
    - 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:

- Yearly in nature
- Relatively consistent in funding level
- Overall funding nonexistent
- Saving money near term results in expensive long-term life-cycle cost
- Long initial design cycles perceived as unproductive
- Need to promote the advantages of life-cycle cost

Approach – Factor 7D: Extensive Use of 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 using
- Use existing models as much as possible
- Keep track of model uncertainties during design
- 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
  - Hardware
  - Creativity

Human-in-the-Loop (HITL)

- Human is the real thing (i.e., the highest fidelity).
- Use human models wherever appropriate.
- Cost control:
  - Use peers in the early design stages.
  - Reduce bias by not using designers working on the design under evaluation as test subjects.
  - Use 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 advantage 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, the 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**
  - **Use of M&S for concepts exploration**
- **Use contractors when the number of Civil Servants (CS) is not sufficient or the CS workforce lacks certain skills**
- **Contractors and CS should work closely together.**
- **Contractor/CS roles and responsibilities should not be divided by a simple straight line, which can hinder creativity.**

Summary

Introduction of a Holistic and Iterative Design Process

- **Continuous process**
- **More effort spent early on in the design**
- **Human-centered and multidisciplinary**
- **Emphasis on life-cycle cost**
- **Extensive use of modeling, simulation, mockups, human subjects, and proven technologies**

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Questions and Comments

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**