01. The Design Process
NASA ESMD Capstone Design

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Why Use Such a Long, Structured Approach?

- It avoids embarrassment when a better solution is found far into the project
- The disciplined approach leads to more creative solutions and time saved in the long run

(From Lumsdaine et al., 2006)

Why Use Such a Long, Structured Approach?

- It saves costs
  - Changing concepts on paper is inexpensive
  - Changes during prototyping are more costly
  - Changes at production ramp-up are very expensive
  - Changes due to warranty claims and recalls are extremely expensive and can affect market share and the reputation of the company

(From Lumsdaine et al., 2006)
**Objective**

- A system is designed, built and operated so that it accomplishes its purpose safely in the most cost-effective way possible considering performance, cost, schedule, and risk

The cost of a system is the value of the resources needed to design, build, operate, and dispose of it. Because resources come in many forms—work performed by personnel and contractors; materials; energy; and the use of facilities and equipment such as wind tunnels, factories, offices, and computers—it is convenient to express these values in common terms by using monetary units (such as dollars of a specified year).

Effectiveness is a quantitative measure of the degree to which the system’s purpose is achieved. Effectiveness measures are usually very dependent upon system performance. For example, launch vehicle effectiveness depends on the probability of successfully injecting a payload onto a usable trajectory. The associated system performance attributes include the mass that can be put into a specified nominal orbit, the trade between injected mass and launch velocity, and launch availability.
What is Cost-effectiveness?

- **Cost-effectiveness**
  - The cost-effectiveness of a system combines both the cost and the effectiveness of the system in the context of its objectives.
  - While it may be necessary to measure either or both of these in terms of several numbers, it is sometimes possible to combine the components into a meaningful, single-valued *objective function* for use in design optimization.
  - Even without knowing how to trade effectiveness for cost, designs that have lower cost and higher effectiveness are always preferred.


The Dilemma

- **At each cost-effective solution**
  - To reduce cost at constant risk, performance must be reduced.
  - To reduce risk at constant cost, performance must be reduced.
  - To reduce cost at constant performance, higher risks must be accepted.
  - To reduce risk at constant performance, higher costs must be accepted.

Pre-Phase A: Design Problem Analysis

◆ Goals
  - Design Project Proposal

◆ Steps
  - Team Organization
  - Quantitative Design Constraints
  - Project Analysis Statement
  - Project Planning
  - Design Evaluation Plan
Pre-Phase A: Design Problem Analysis

◆ Tools
  - Weighted User Requirements
  - Design Objectives with Targets
◆ Reviews
  - Project Concept Review

Phase A: System Level Conceptual Design

- Concept Benchmarks
- Functional Description
- Design Concept Keys
- Technology Readiness Assessment
- Pugh Evaluation
- QFD
- Design Evaluation Plan
- Best System Concept Proposal
- System Design Review
- System Requirements Review
Phase A: System Level Conceptual Design

Goal
- Best System Concept Proposal

Steps
- Design Evaluation Plan (from Pre-Phase A)
- Design Concept Keys
- Pugh Evaluation
- Technology Readiness Assessment
- QFD

Tools
- Concept Sketches
- Concept Benchmark
- Functional Description

Reviews
- System Requirements Review
- System Design Review
Phase B: Parameter Level Design

- **Goal**
  - Parameter Level Design Proposal

- **Steps**
  - Detailed Design Concept Drawings
  - Bill of Materials
  - Construction/Assembly Drawings
**Phase B: Parameter Level Design**

- **Tools**
  - Parameter Analysis
  - FMEA
  - Simulation
  - Functional Testing
  - DfX

- **Reviews**
  - Design Objectives Review
  - Product Design Review

**Phase C: Optimized Parameter Design**

- Refined Parameter Design
- System Optimization
- Prototype Testing
- Design Objectives Review
- Detailed Design Drawings
- Production Specifications
- Production Plan
- Detailed Design Drawings and Specifications
- Critical Design Review
- Production Readiness Review
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Phase C: Optimized Parameter Design

◆ Goal
  - Detailed Design Drawings and Specifications
◆ Steps
  - Detailed Design Drawings
  - Production Specifications
  - Production Plan

◆ Tools
  - System Optimization and Tradeoffs
  - Prototype Testing
◆ Reviews
  - Design Objectives Reviews
  - Critical Design Review
  - Production Readiness Review
Phase D: Fabrication, Assembly, and Testing

- **Goal**
  - Final System Delivered

- **Steps**
  - Fabrication
  - Assembly
  - Testing
### Phase D: Fabrication, Assembly, and Testing

- **Reviews**
  - Test Readiness Review
  - System Acceptance Review
  - Operational Readiness Review