An Introduction to a Top Down Design Process
Agenda

- Why You Should Be Concerned
  - Problems With Product Development
- Introduction to a Systems Approach
  - What Engineers Should Do
- The Three Pillars of Management
  - Project Leadership
- The Three Levels of Abstraction
  - Decomposing Designs
- Graphical Specifications
  - Better Than Natural Language Documents
- The Experiment
  - Need for Volunteers
Why You Should Be Concerned

- Customer Unhappiness Eventually Leads to Regulation
  - Human Safety Problems Accelerate the Process

- Quality Movements Now Enforce “Design Controls”
  - ISO-9000
  - FDA CGMP

- Safety Critical Software Will Be Next
Development Stress Creates Product Risks

- Development Projects Are Subject to Numerous Constraints
  - Cost
  - Schedule
  - Time-to-Market
  - Technology Limitations

- Unforeseen Problems Compromise Product Quality
  - Surprises Create Opportunities for Confusion

- Lack of Visibility on Impacts of Key Decisions Promote Disaster
  - “It sounded like a good idea at the time...”
Bad Management Causes Problems

- Many Projects Are **Behind** Schedule/Over Budget
  - Management **Dictated** Cost/Schedules
  - Lack of **Planning**
  - Failing to Stay on **Top** of Projects

- Requirements **Creep** Is a Major Source of Project Problems
  - Especially for **Software**

- Lack of Good Historical Project Cost **Metrics**
### 20th Century Engineering

**Process Problems**

- **Most Project Management And Planning Methods Are** **Activity Based**
  - Difficult to **Maintain** in the Presence of Dynamic Changes

- **Most Product Design Tools Are** **Bottom up** or Implementation Oriented
  - Fail to Capture All Requirements

- **Natural Language Specification Methods Are** **Ambiguous**
  - Difficult to Capture Complex Product Behavior
Why Development Continues to Become Harder

- Lack of a "Systems" Approach to Product Development
- Complexity of Technology
- Interdisciplinary Products
- More Competition
Why There is a Fog

Everything Exists Only in the Heads of the Engineers!

- Early Phases Lack **Documentation** Everyone Can Understand
- High Levels of **Abstraction** Are Difficult for Many People to Grasp
- Lack of Clear **Plans** Make Coordination Difficult
Accelerated Product Development™ System

INTRODUCTION

TO

A SYSTEMS APPROACH
Definitions

- **Science**
  - The Ability to Create **Mathematical Models** of Natural Behavior

- **Mathematics**
  - The **Language** of Science

- **Engineering**
  - The Ability to **Apply** Science and Mathematics to Solve Problems
  - Ability to **Model** Designs
  - Prove It Will Work Before It Is Made

- **Design**
  - The **Creative** Process Which Defines a Man Made Device
  - Does Not Necessarily Require **Engineering** Skills
Engineering Definitions

- Product Architecture
  - The Process That Leads to the Creation of Documentation Necessary to Define the Product Function, Behavior and Performance Requirements

- Design Engineering
  - The Process That Leads to the Creation of Documentation Necessary to Define How the Product Is Made
What Do Engineers Do?

- **Use** Science and Mathematics to Solve Problems
- Make **Paper** for Someone **Else** to Use
The Way Engineers Are Taught to Think

Bottom Up Approach

Define A Design

Analyze Performance

Re-Design “Do Loop”
Inventors Syndrome

Define a Solution

Look for a Problem
The Top Down Approach

- Necessity Is the Mother of Invention
- Find a Need and Fill It
- “Never Invent Something Unless You Have a Customer Ready to Buy It”
  » T.A. Edison
- The Architect Model
Architects See The Big Picture at the User Level
Architect Creates Overall Design Concepts
Engineers Make It Work

Building Codes

Math Models

Engineering Calculations

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Architect Shares Plans With Everyone
General Contractor Plans And Directs The Job
Specialists Implement The Design
Inspectors Check Everything Against The Codes
The Result
A Model for a Solution

- **Architect (Product Architect)**
  - Integrates Function, Esthetics, Performance

- **Engineers (Product Analyst)**
  - Designs Structures to Meet Codes

- **A Single Set of Plans Can Be Read by Everyone**

- **General Contractor (Project Manager)**
  - Plans and Executes Job

- **Specialists (Design Engineers) Build/Install Components**

- **Inspectors (Test Engineers) Check Each Step Against Codes**
The Architect Model Works Well If There Is a Customer to Talk to
  » Contract Development Work

Private Venture Development Work Requires a Surrogate Customer
  » Provided by a Joint Effort With Marketing

Must Define Customer Characteristics
  » Demographics
  » User Requirements
  » Customer ROI
APD<sup>sm</sup> System
is Founded on 3 Pillars

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Introduction to the Systems Approach

PRODUCT DEVELOPMENT MANAGEMENT

PROJECT MANAGEMENT
- COST
- SCHEDULE
- PERFORMANCE

PRODUCT ARCHITECT
- FLOW DOWN
- PARTITION
- INTEGRATION
- VERIFICATION

PRODUCT ANALYSIS
- MODELING
- ANALYSIS
- SIMULATION

LIFE CYCLE MODELS
- PHASE REVIEWS
- PRO-FORMA'S
- CHECK LISTS
- DELIVERABLE ITEMS
- RISK ANALYSIS

REQUIREMENTS ANALYSIS
- REQUIREMENTS MANAGEMENT
- TRADE OFF STUDIES
- DESIGN RULES
- DESIGN AUTHORITY
- RISK ANALYSIS

MODEL DESCRIPTIONS
- MODEL VALIDATION
- PERFORMANCE ANALYSIS
- TOLERANCE STUDIES
- CONFIDENCE LEVELS
- BEHAVIOR SIMULATION

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Management Visibility and Control

- Provides Management with Better **Visibility and Control**
- Life Cycle Planning Templates for **Rapid** Planning and Estimating
- Integrates All **Organizations** Into the Development Process
- **Reduces** Items That “Fall Through The Cracks”
- Measures Percentage **Completion** Not Just Costs
- Early Visibility on **Risks and Tradeoff’s**
- Promotes **Faster** Decision Making
- Simple but **Effective** Documentation and Review Methods
- Facilitates Development Team **Communications**
- **Improves** the Managerial Process
Product Architecture

- Requires a **Life Cycle View** of the Product
- Makes **Visible** Product Function, Behavior and Performance
- Promotes **Alternatives** and Enhances Creativity
- Gets the Design **Right** the First Time
- Reduces Design **Iterations**
- **Shortens** Design and Testing Time
- Allows **Parallel** Development Processes
- **Reduces** Quantity and Skill Levels During Implementation Phases
- Forces **Integration** of Marketing and Engineering Functions
Modeling and Analysis

- Validates Requirements
- Proves Product Will Work Before It Is Made
- Reduces Test and Evaluation Time and Cost
- Verifies Production Design Margins
- Verifies and Validates Designs Outside the Testable Envelope
- Reduces Time to Solve Production and Quality Problems
How Products Requirements Can Be Modeled

- Function
  - What It Does

- Behavior
  - How It Does It

- Performance
  - How Well It Achieves Function and Behavior
How Products Can Be Decomposed

- **Black Box**
  - Internal Workings Are \textit{Unknown}
  - Must Be \textit{Modeled} by External Properties

- **Gray Box**
  - Function, Behavior and Performance Can Be \textit{Specified}
  - \textbf{Physical} Implementation May Be Unknown

- **White Box**
  - Physical Design Is \textit{Known}
  - Multiple Functions May Be Implemented by \textit{Same} Physical Objects
Levels of Abstraction
Functional Vs. Physical

CPU

Serial I/O

Memory

DAC

Source A

Sink A

Source B

Sink B

Signal #1

Data #2

Signal #2

Data #1

Physical

Functional
Core Engineering Process

Define Requirements

AND

Model Function

Model Behavior

AND

Risk Analysis

Perform Trade Off's

Model Performance

Human Interface Analysis

Define Baseline

Verification & Validation

Requirements Failure

Design Failure

At Least Level Of Decomposition
Role of the Product Architect

- **Objective Specification**
- **Design Rules**
- **Lessons Learned**
- **Manufacturing & Support Requirements**
- **Black Box Requirements**
- **Partition & Architecture**
- **Functional Decomposition**
- **Design Specifications**
- **Analysis Models**
- **Design Engineering**
- **Product Documents**
- **Manufacturing**
- **Suppliers**
- **Components**
- **Customer Support**
- **Customers**
- **Products**

**Concepts:**
- Capability
- Technology Integration
- Cost & Test Requirements
- Shipping and Maintenance Requirements
21st Century Product Design Process

BLACK BOX
- FORMULATE REQUIREMENTS
  - ELICIT
  - DOCUMENT
  - EXCEPTIONS
  - CONSTRAINTS
  - PRIORITIZE
- REQUIREMENTS ANALYSIS
  - COMPLETE
  - UNAMBIGUOUS
  - ACCURATE
  - INTER-ACTIONS
  - ENVIRONMENTS
  - SYSTEM PARAMETERS

GRAY BOX
- PARTITION
  - DECOMPOSE
  - INTER-ACTIONS
  - DEFINE ICD’S
  - BUDGETS
  - ALLOCATIONS
  - BALANCING
- TRADE STUDY
  - IMPLEMENTATION
  - COST / BENEFIT
  - RISK
  - TECHNOLOGY

WHITE BOX
- VALIDATE REQUIREMENTS
  - INTEGRATION
  - USER TEST
- VERIFY DESIGN
  - ANALYSIS
  - TEST
- BASELINE APPROACH
  - STRAW MAN
  - DESIGN SPECIFICATIONS
  - COULD HAVE RISKS/LIMITS
  - CONFIGURATION MANAGEMENT
Decomposition Process

- **Objective Specification**
- **Decomposition into Sub-systems**
  - **Product Specification**
  - **Decomposition into Assemblies**
- **Create Decomposition Math Models**
- **Integration & Verification**
  - **Fabrication & Test**
  - **Create Design Documentation**
- **Design Specification**
- **Data**
Graphical Description Language

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The Benefits

- **Reduced** Risk
  - Know It Will Work Before It’s Built
  - Find and Solve Problems on Paper
    - Not in the Lab, Factory Floor, or the Field

- **High Quality** Products
  - Meets All the Requirements
  - Fewer Design Flaws
  - Easier to Produce
  - Easier to Maintain

- **Better Competitive** Position
  - Time-to-Market
  - Product Cost
  - Product Performance
The Experiment

- At Least One Group of Volunteers Are Needed for the CPS 479 Lab Project
- Need to Fill the 3 Roles
  - Project Manager
  - Product Architect
  - System Analysts
- Will Be Trained in the “Systems” Approach
- Will Use the Approach to Conduct the Project
- Metrics on Performance Will Be Collected
  - Visibility
  - Rework
  - Quality
Qualities of a Good Project Manager

- **Highly Goal Oriented**
  - A Finisher
  - Expediter
  - Follow Up

- **Good People Skills**
  - Negotiator
  - Empathy
  - Motivates
  - Good Communicator

- **Well Organized**
  - Attention to Details
  - Foresight
Qualities of a Good Product Architect

- **Broad and Deep at the Same Time**
  - Sees the Big Picture
  - Likes the Details Too

- **Good Technical Skills**
  - Has Excellent Creative Skills
  - Mastered at Least Two Disciplines
  - Understands High Levels of Abstractions
  - A Good Communicator

- **User Oriented**
  - Life cycle Oriented
  - Understands the Application
  - Focus on the Right Product
  - Can Take Objective Feedback
Qualities of a Good Product Analyst

- **Strong Analytical Orientation**
  - Need for Quantitative Understanding
  - Uses Analysis to Find and Solve Problems

- **Good Mathematical Skills**
  - Has Excellent Analytical Skills
  - Mastered All Engineering Analysis Methods
  - Uses Automation Tools

- **Focused on Getting Results**
  - When Good Enough Is Good Enough
  - A Good Communicator