# ENGR 310

Lecture 20

4 April 2008

# Exam: April 7

- Closed book, closed journal, closed neighbor, open mind
- 4” x 6” reference card allowed
- Timed
- Short Answer questions
- Covers the course learning objectives
  - www.coe.montana.edu/engr310

# What is Engineering Design?

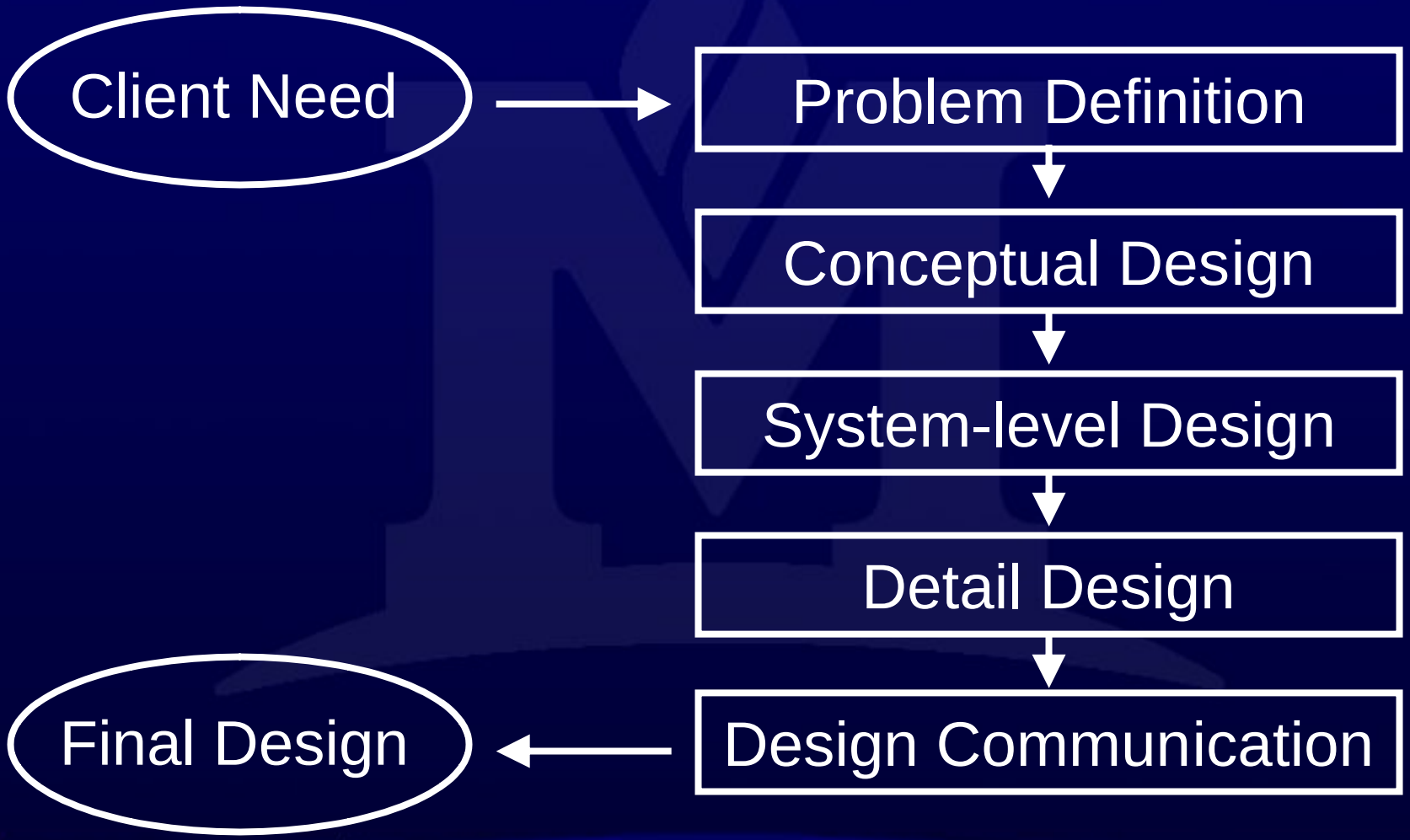
"…systematic, intelligent generation and evaluation of specifications for artifacts whose form and function achieve stated objectives and satisfy constraints."

-Dym & Little, 2004

# Design in Engineering is:

- Ill-structured → cannot apply a formula
- Open-ended → >1 solution possible
- Complex
- Must integrate many pieces.
- Must integrate with environment

# An Engineering Design Process



client's statements

Problem Definition

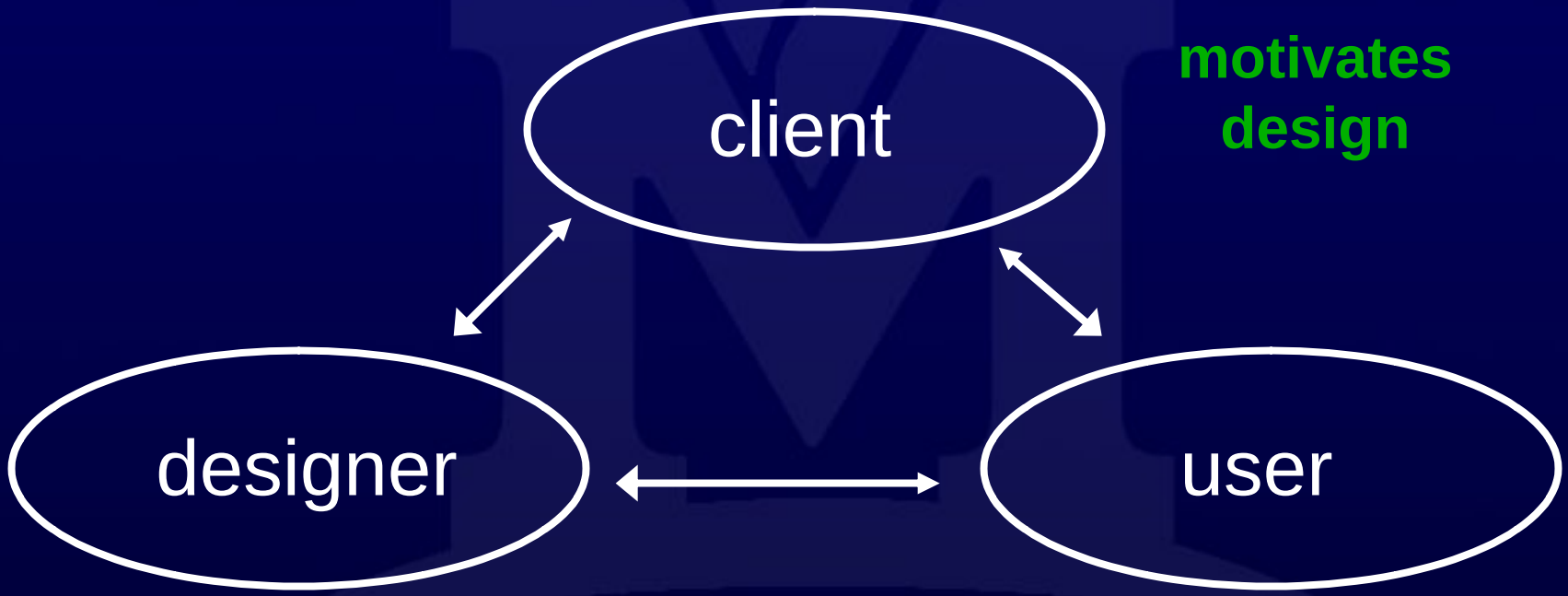
**statement of:**

**objectives**
**constraints**
**requirements**
**functions**

Gather information to develop a statement of client wants in engineering terms:

1. Clarify objectives
2. Establish user requirements
3. Identify Constraints
4. Define desired functions

# Who Sets Objectives and Constraints?

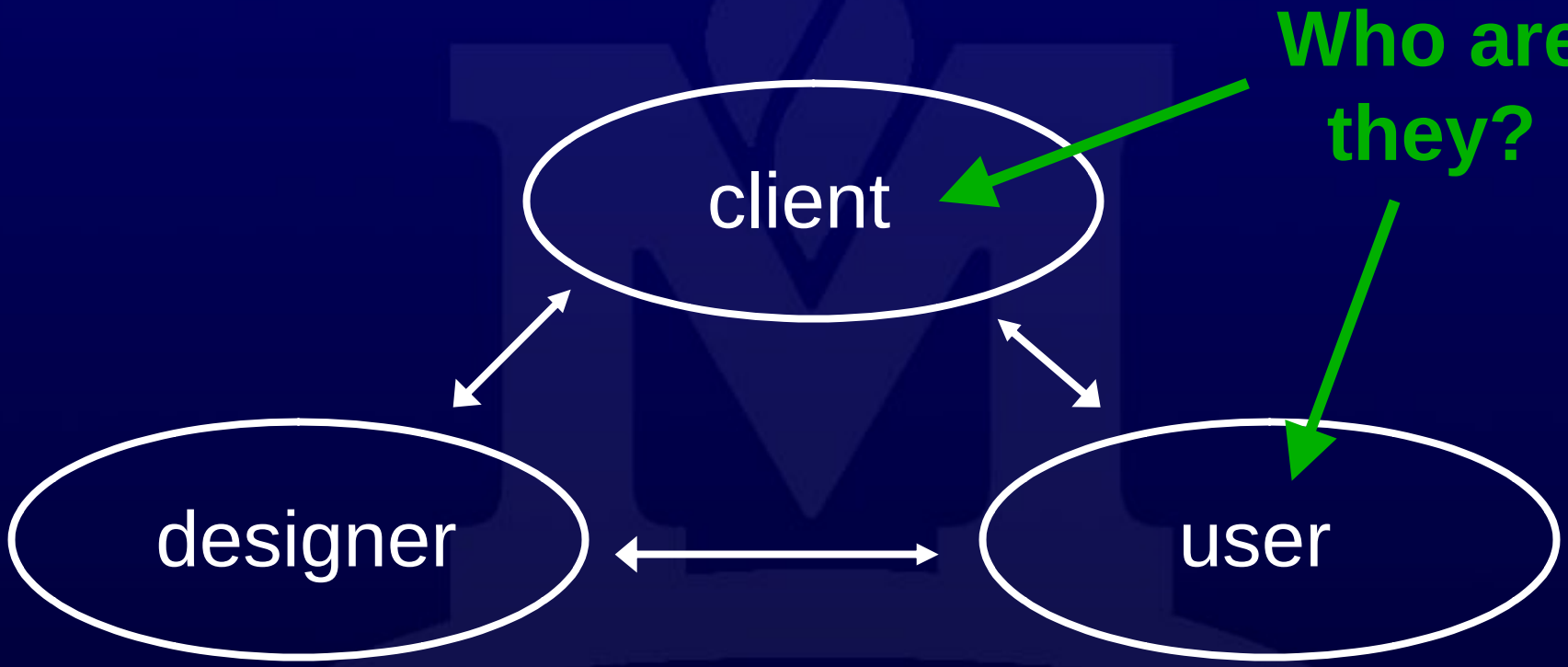



**motivates design**

**creates design**

**uses designed artifact**

# First step



# Clarify the Design Problem

# Most initial attribute lists are a mix of:

- Objectives
- Constraints
- Functions
- Means (or implementations)

# Objective Tree

Helpful to organize objectives into a hierarchy.

Add Constraints (but differentiate).
No functions or means!

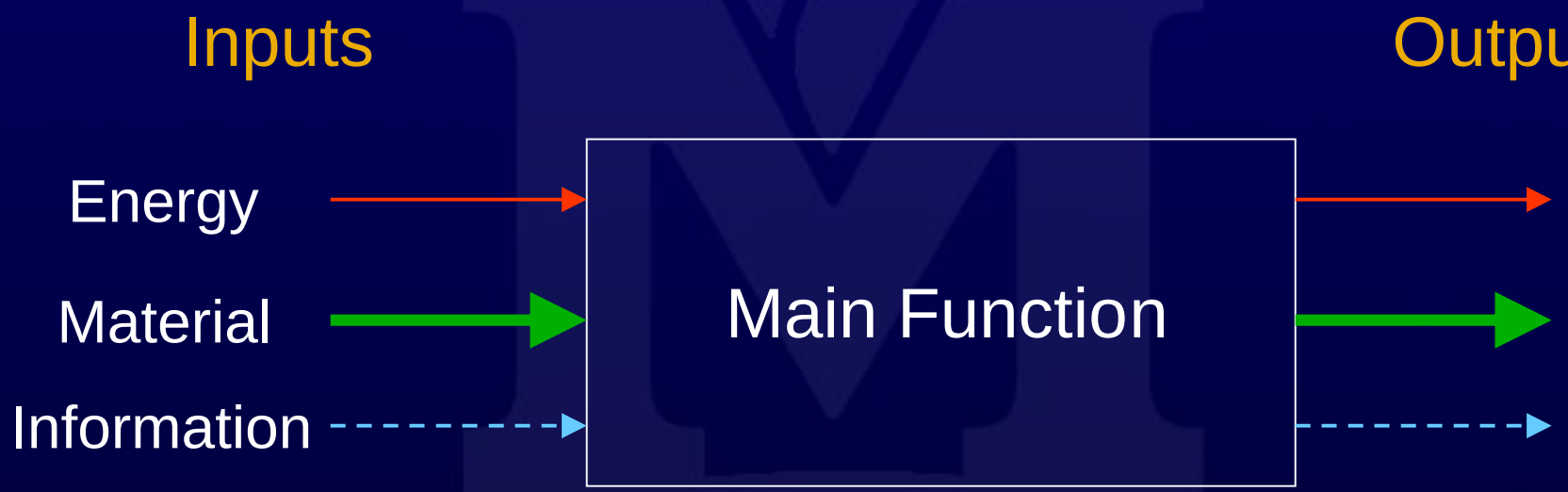
# Functions & Specifications

**Functions** = what system must do to achieve objectives

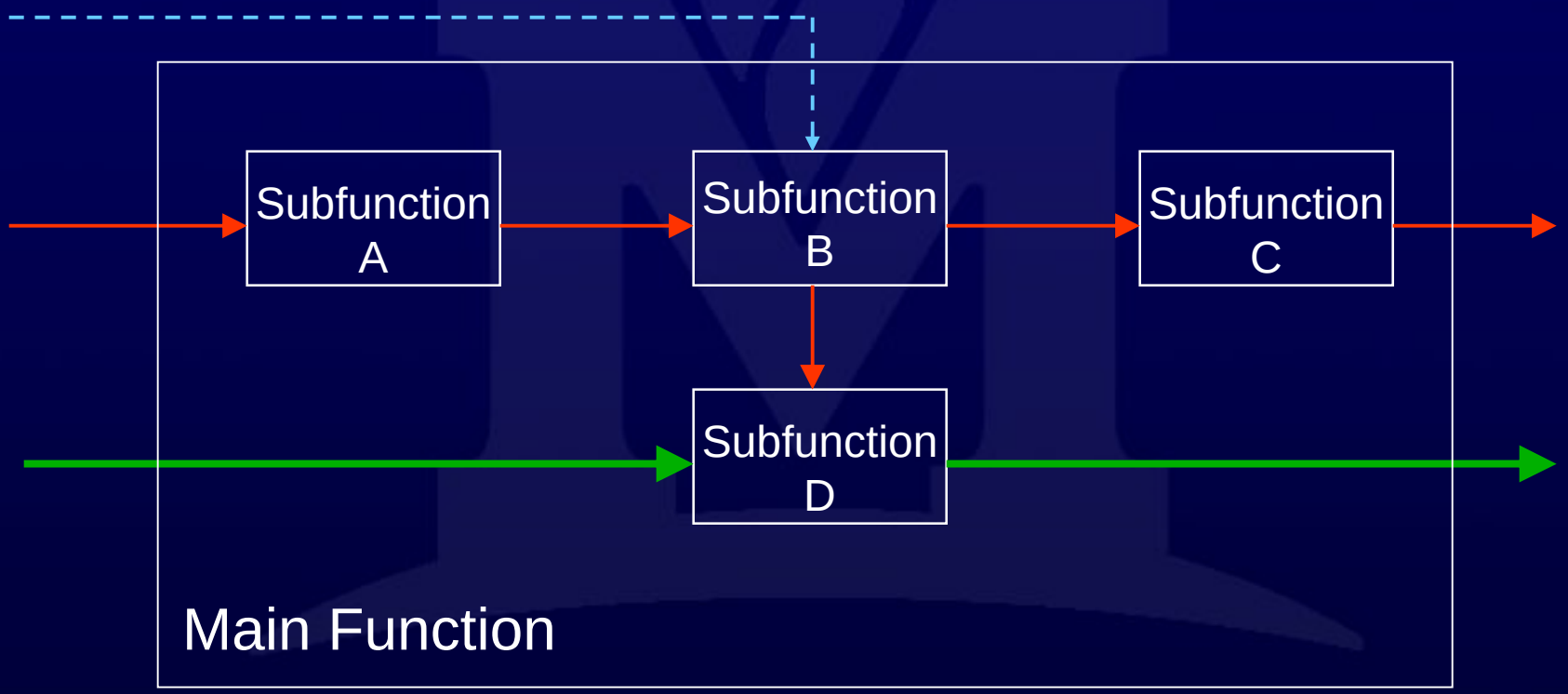
**Functional Specifications** = how well system must do it

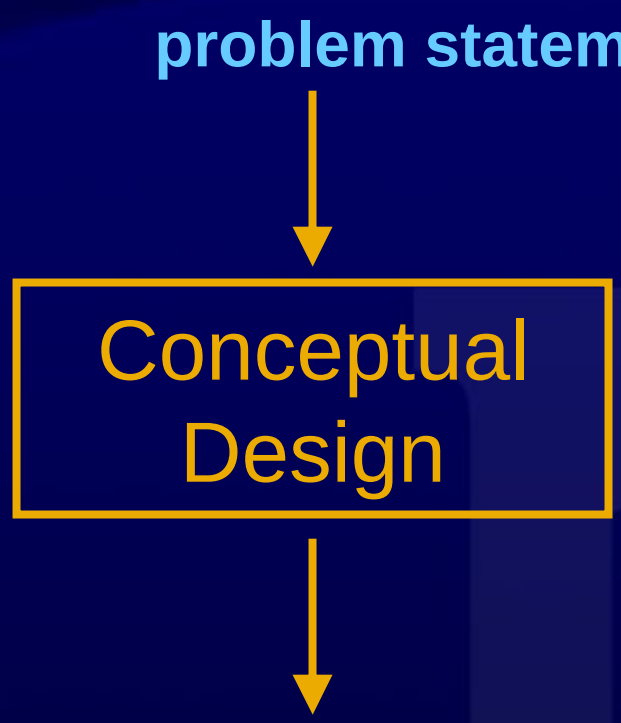
Also called “performance specifications” or “functional requirements”

# Black Box Approach



# Divide Functions into Subfunctions






Generate concepts of candidate designs:

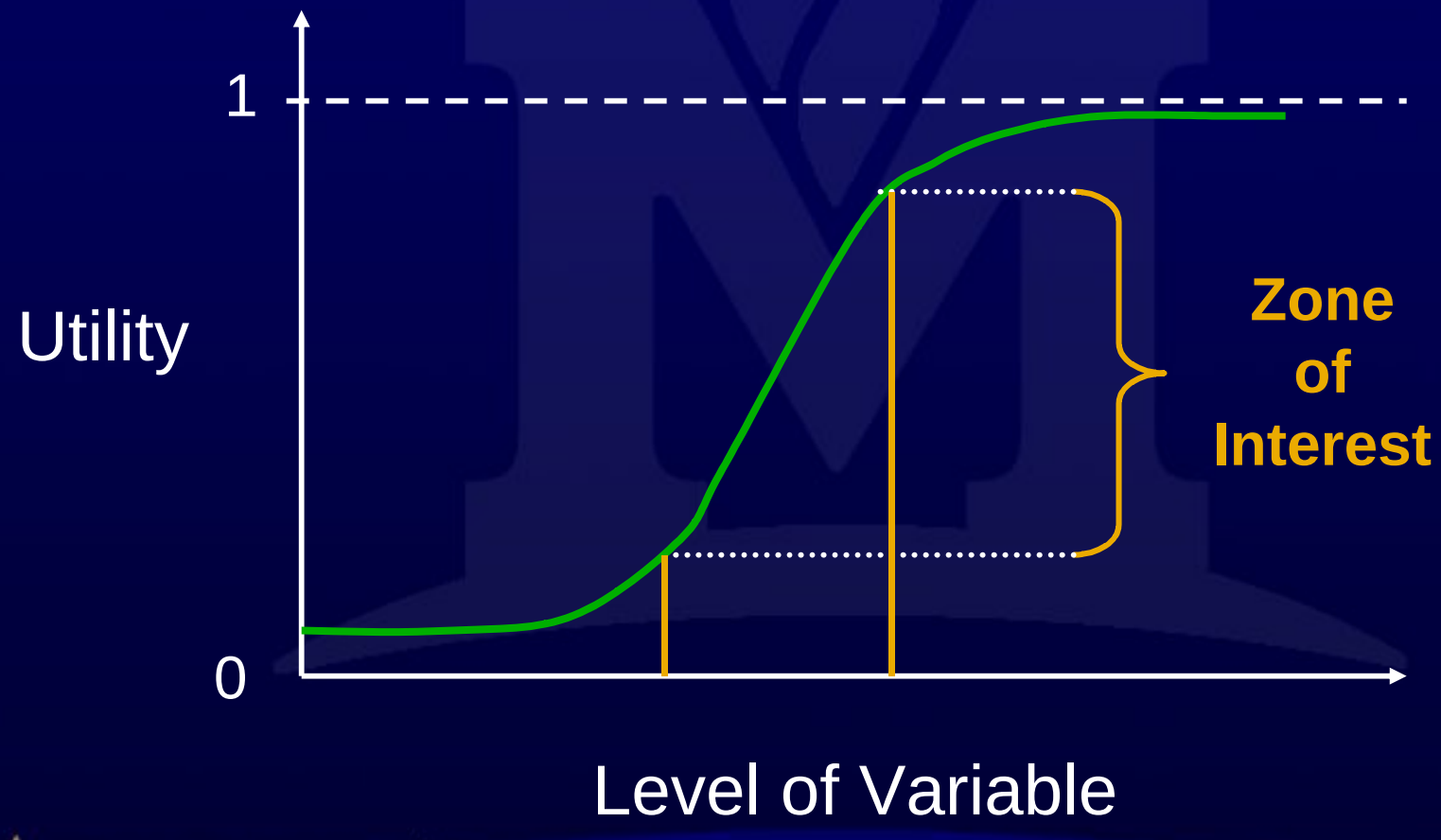
5. Establish design specifications
6. Generate ideas

# Functional Specifications

How well must the design accomplish the functions?

- Measurable
- Solution neutral
- Things client/users care about

# “Zone of Interest”



# Common Mental Blocks

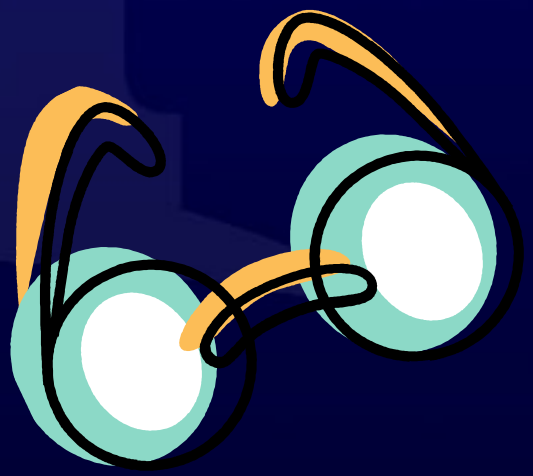
- Perceptual:  define problem too narrowly
- Fixation:  can't get past one idea
- Emotional:  anxiety, fear of failure, frustration
- Cultural:  social patterns that blind us to possible solutions
- Environmental:  distractions, poor atmosphere

# Conceptual Blockbusting

- First step is to recognize them.
- Second, use structured techniques to break out of your current thinking pattern

# Where do new ideas come from?

- Adaptations of existing ideas to new contexts
  - Generalize the problem, look for others' solutions
- Combining existing ideas
- Analogy



# Technique 1: Brainstorming

- List all ideas
  - individually first, then as a group
- No criticism or evaluation!
  - encourage crazy, outlandish ideas
  - have fun!!

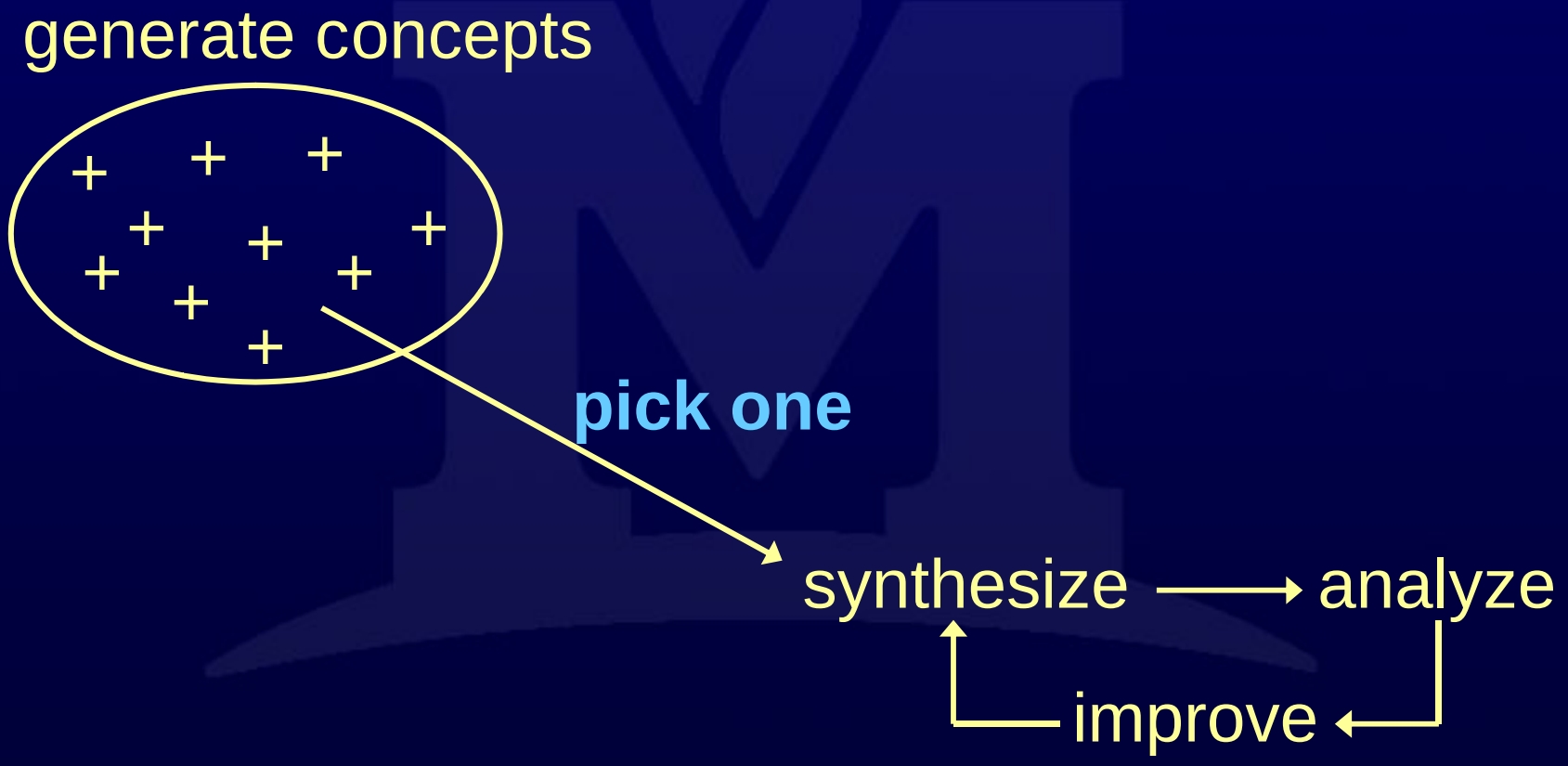
# Technique 2: Morphological Chart

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Accept Beans | Lid | Door | Gravity chute | … |
| Contain Beans | Canister | Bag | Vacuum | … |
| Grind Beans | Rotating blade | Mortar & pestle | Opposing discs | … |
| Etc. | | | | |

# Technique 3: Group Brain-writing

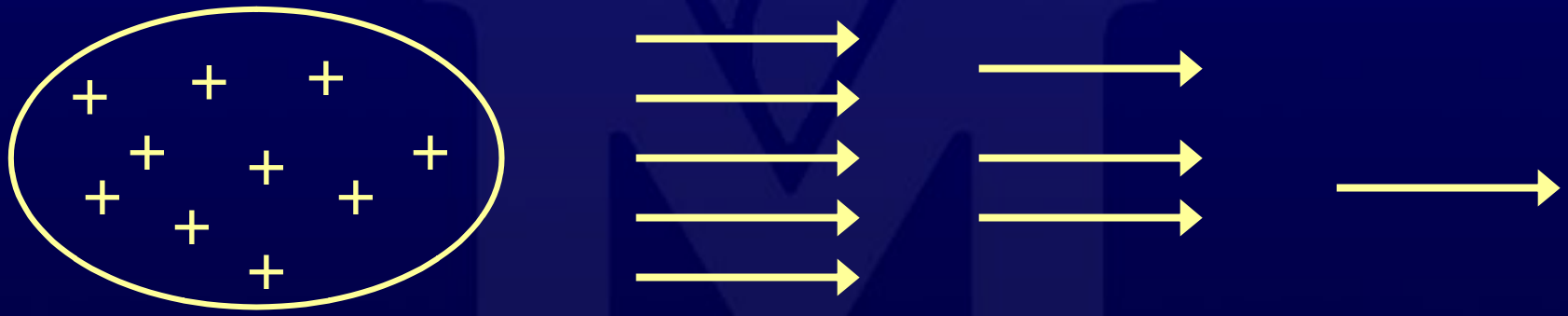
1. Decide on problem to be addressed
2. Silently, each person generates 3 ideas.
    1. Sketches + labels (minimum of words)
3. Rotate ideas to person on the right.
4. Build on the ideas just passed to you
    1. for a set period of time.
5. Repeat until ideas reach originator.
6. Review, discuss, evaluate, combine.
    1. post on the wall
7. Choose a subset to carry forward.

# “Pick Best and Iterate” Approach



# "Controlled Convergence" Approach

generate concepts



Look at sets of design ideas…

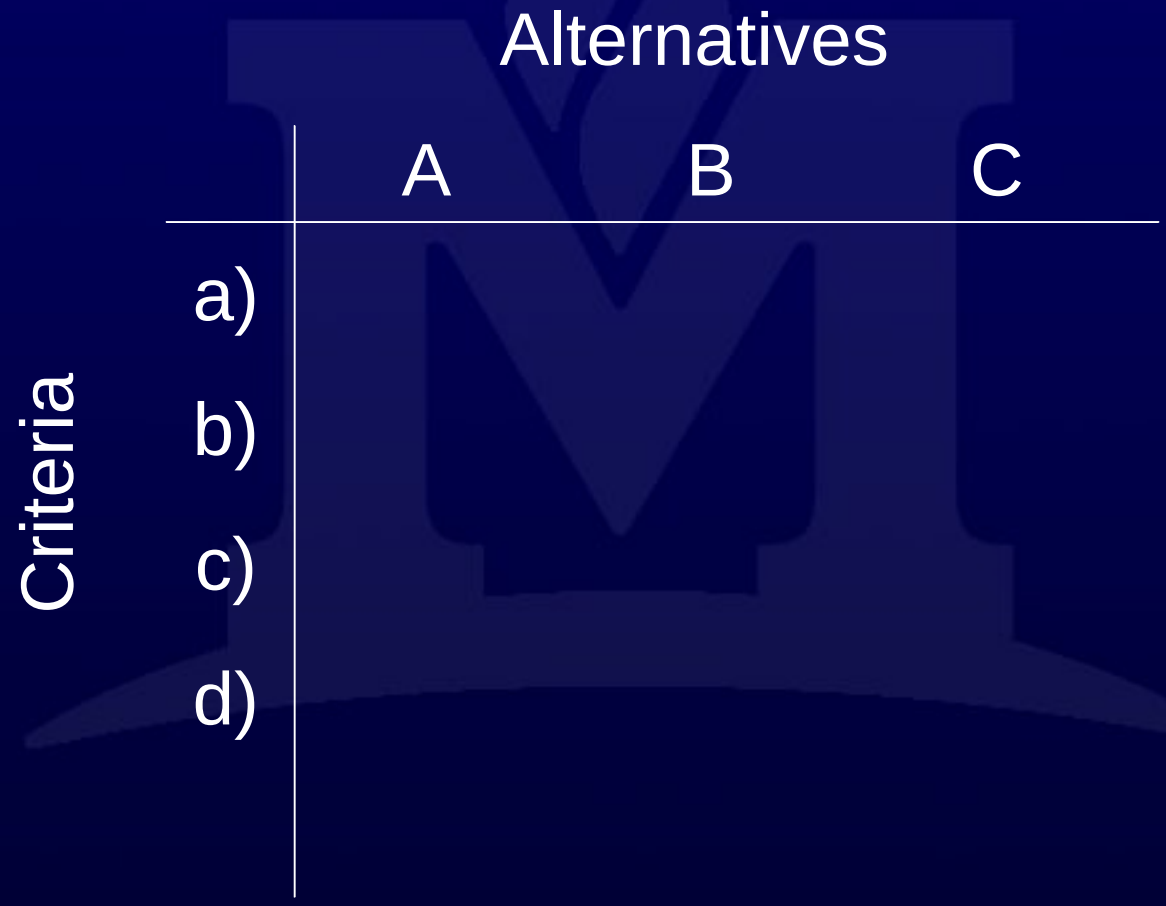
…and eliminate the worst.

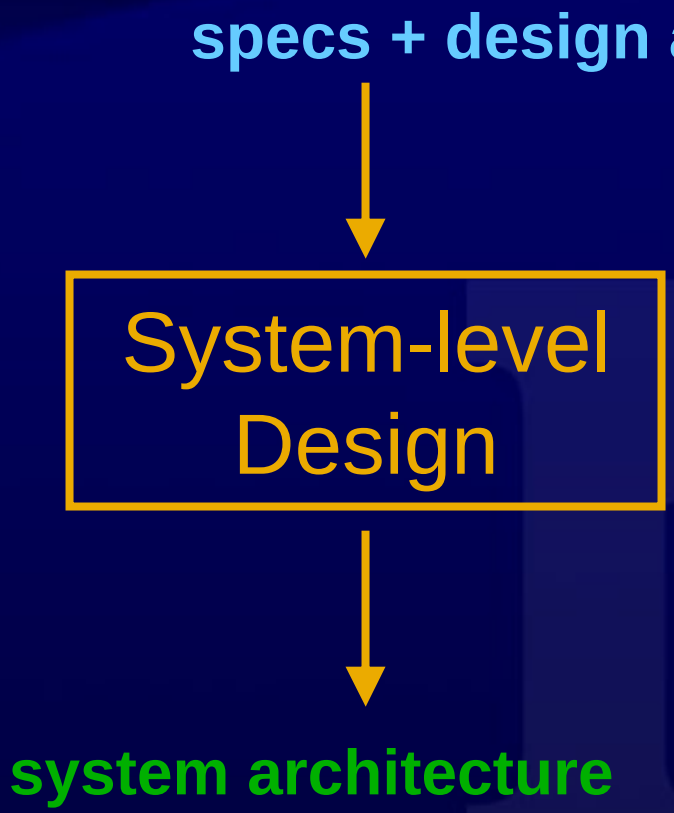
(rather than pick the best)

# Design Convergence…

…isn’t usually smooth.

# Evaluation Matrix






Identify principle attributes of leading design concepts:

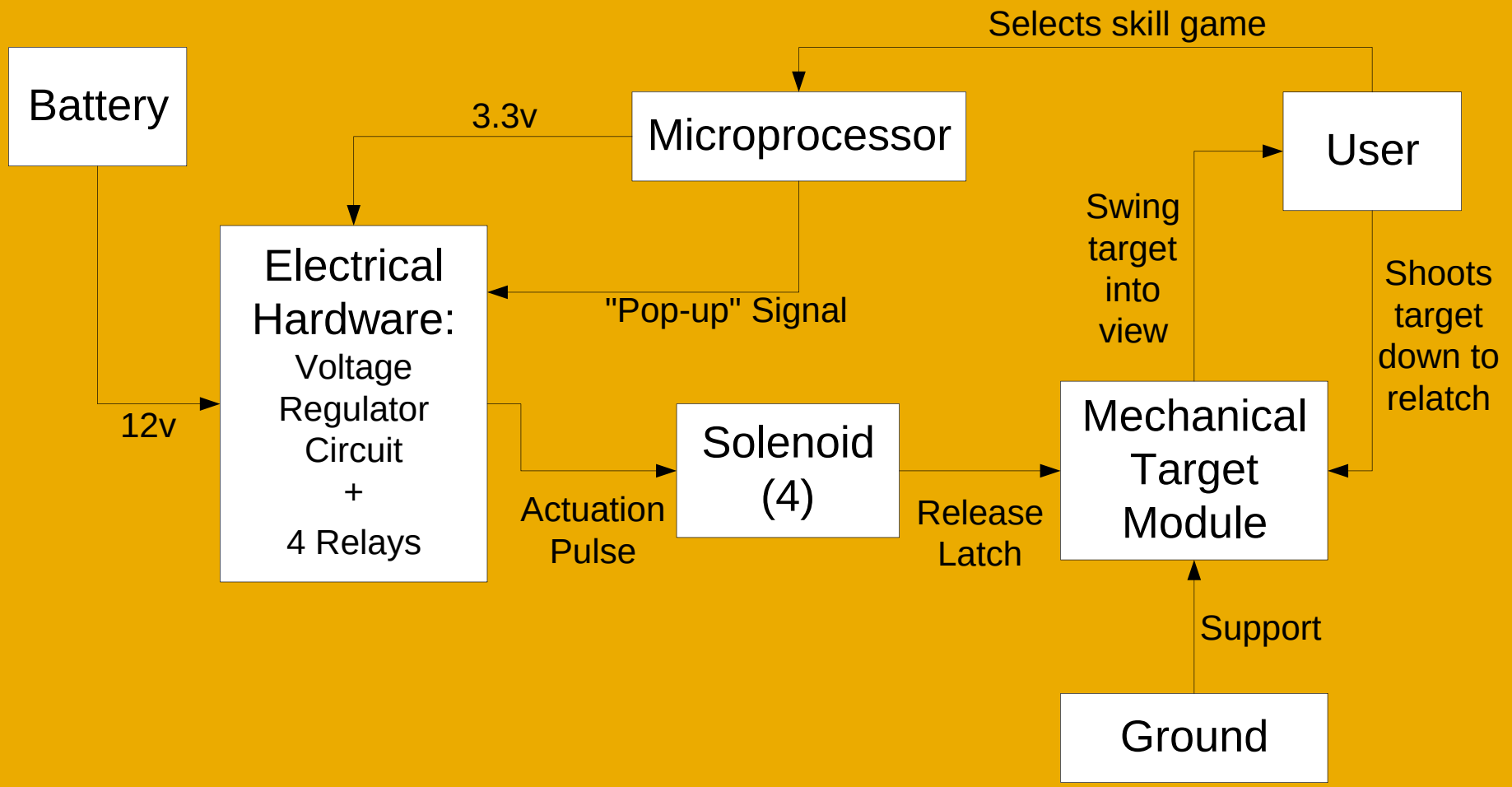
7. Establish system architecture
8. Model and evaluate alternatives
9. Converge to best alternative

# System-level Design

- Identify subsystems of the concept
- Investigate alternative configurations
- Think through interface issues, in detail
  - between subsystems
  - with user
  - with environment
- Choose configuration based on the best interfaces

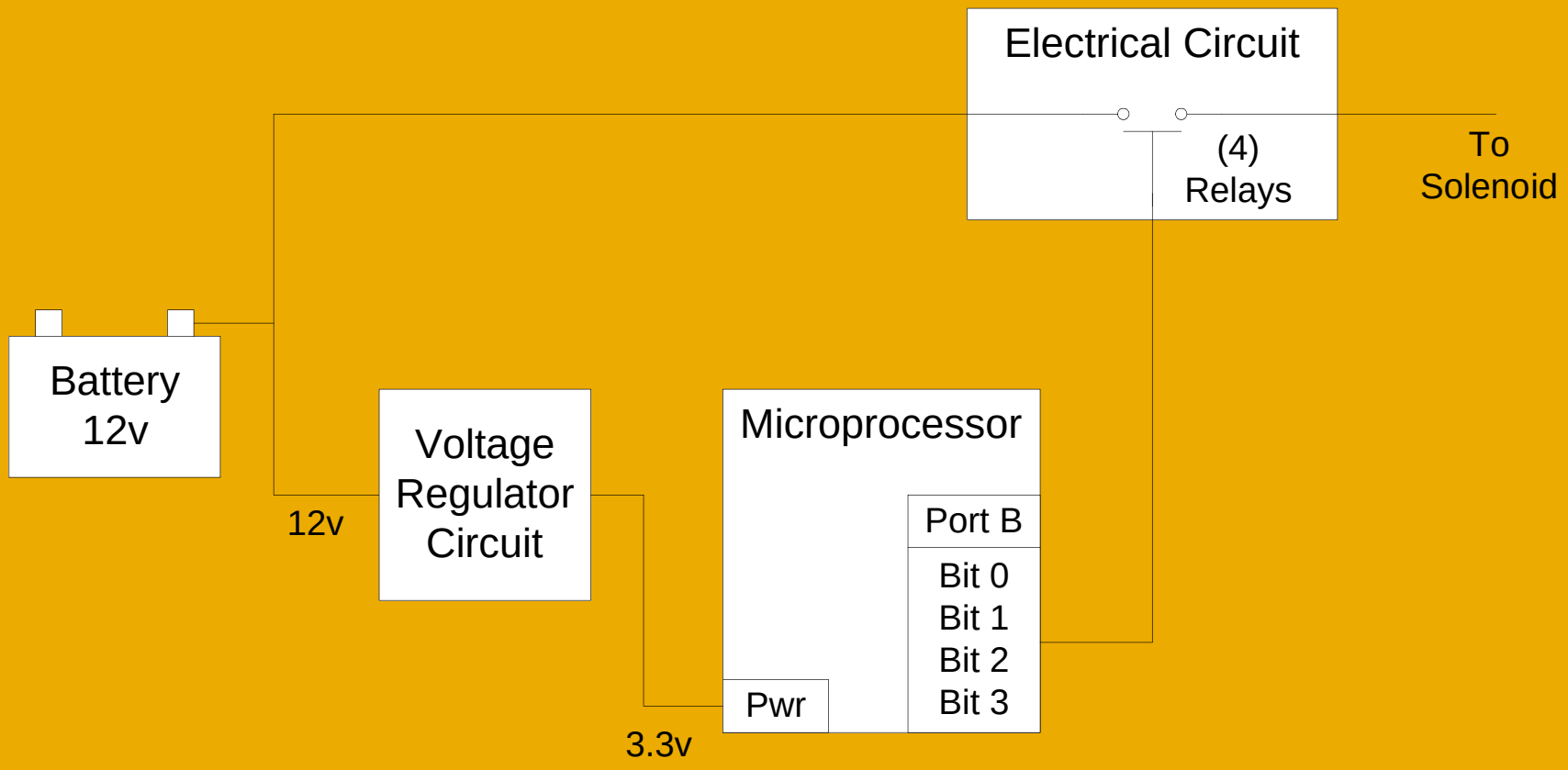
# Block Diagram

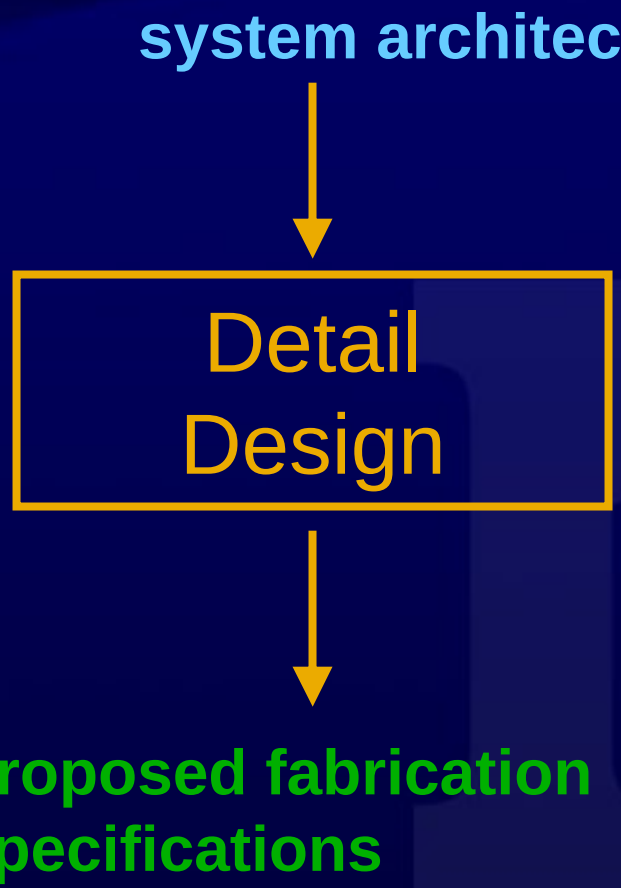
- Identifies key subsystems and interfaces



# System Architecture Plan

- Adds interface details to block diagram

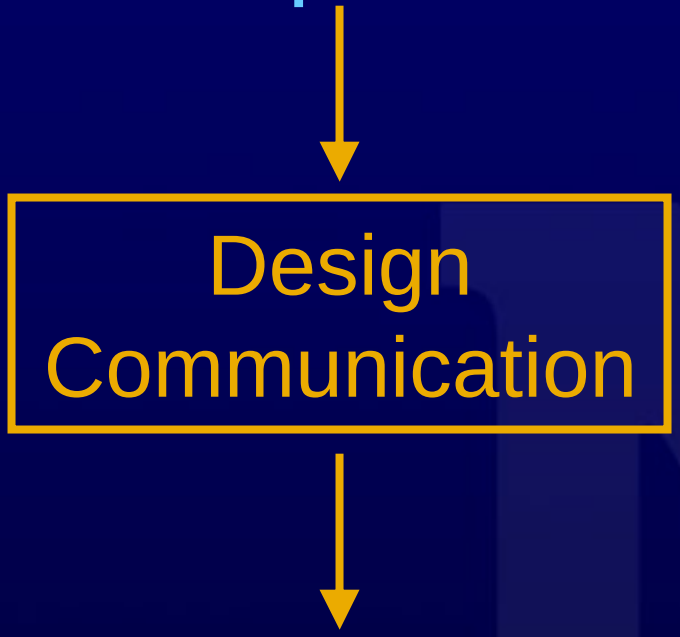





Refine and add detail to final design:

10. Create detailed drawings, etc.
11. Optimize through analysis
12. Review design.

**proposed fabrication specifications**

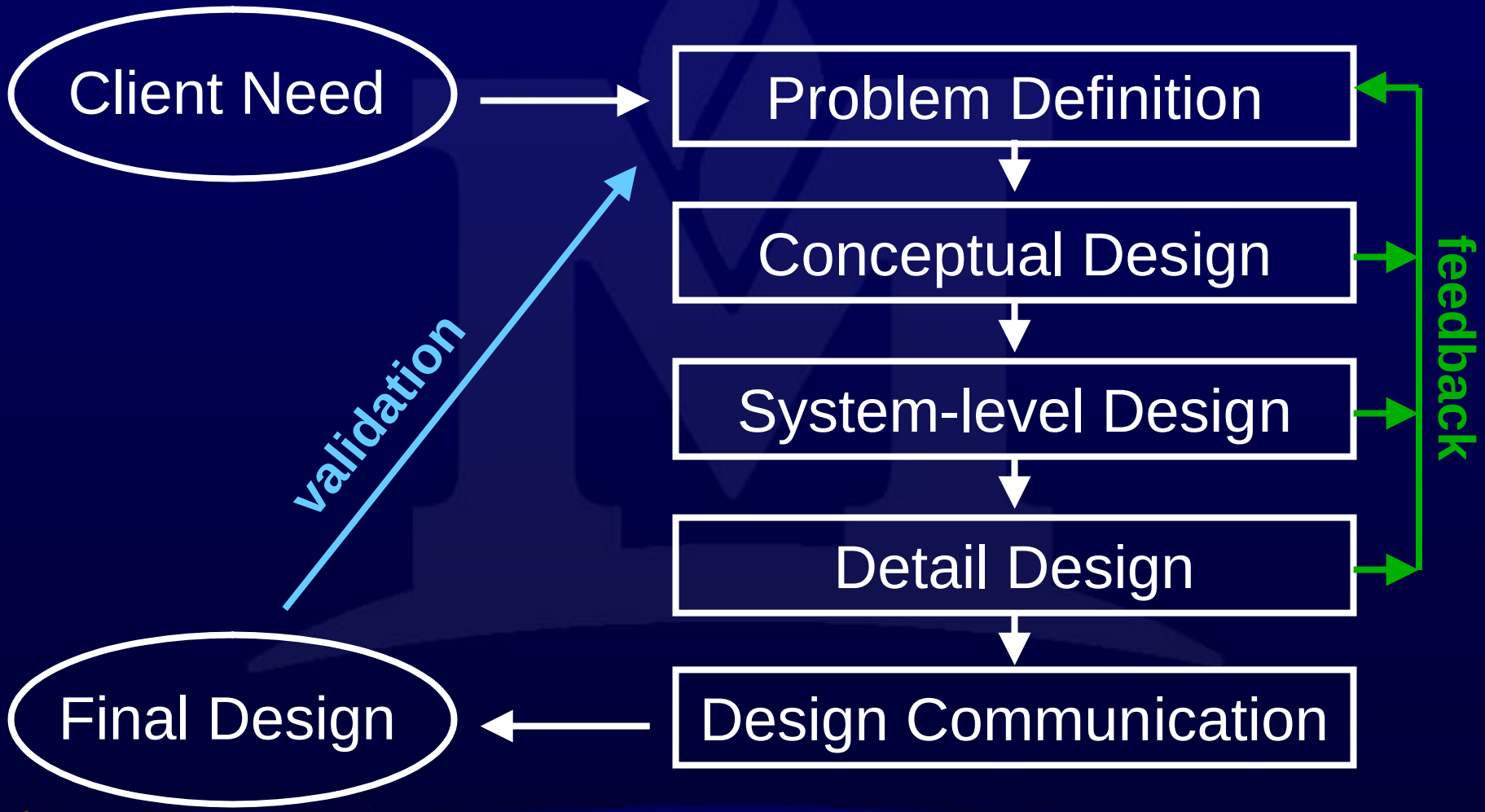



Document fabrication specifications and justification

**final fabrication specifications**

**client report**

# Iteration

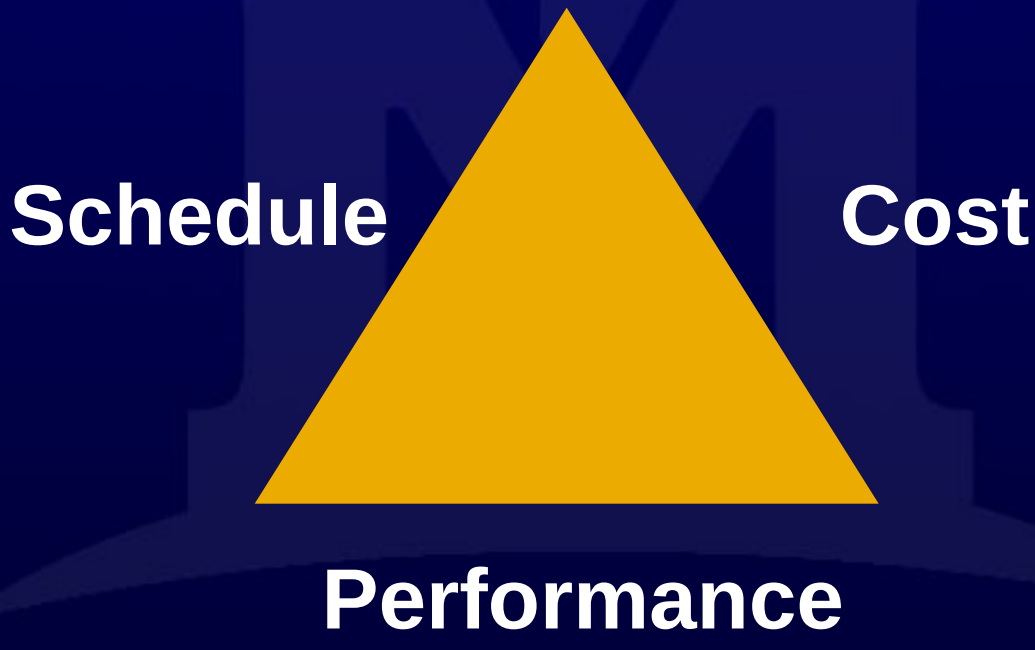

Client Need
Problem Definition
Conceptual Design
System-level Design
Detail Design
Design Communication
Final Design
validation
feedback

# The Process is Not Linear!

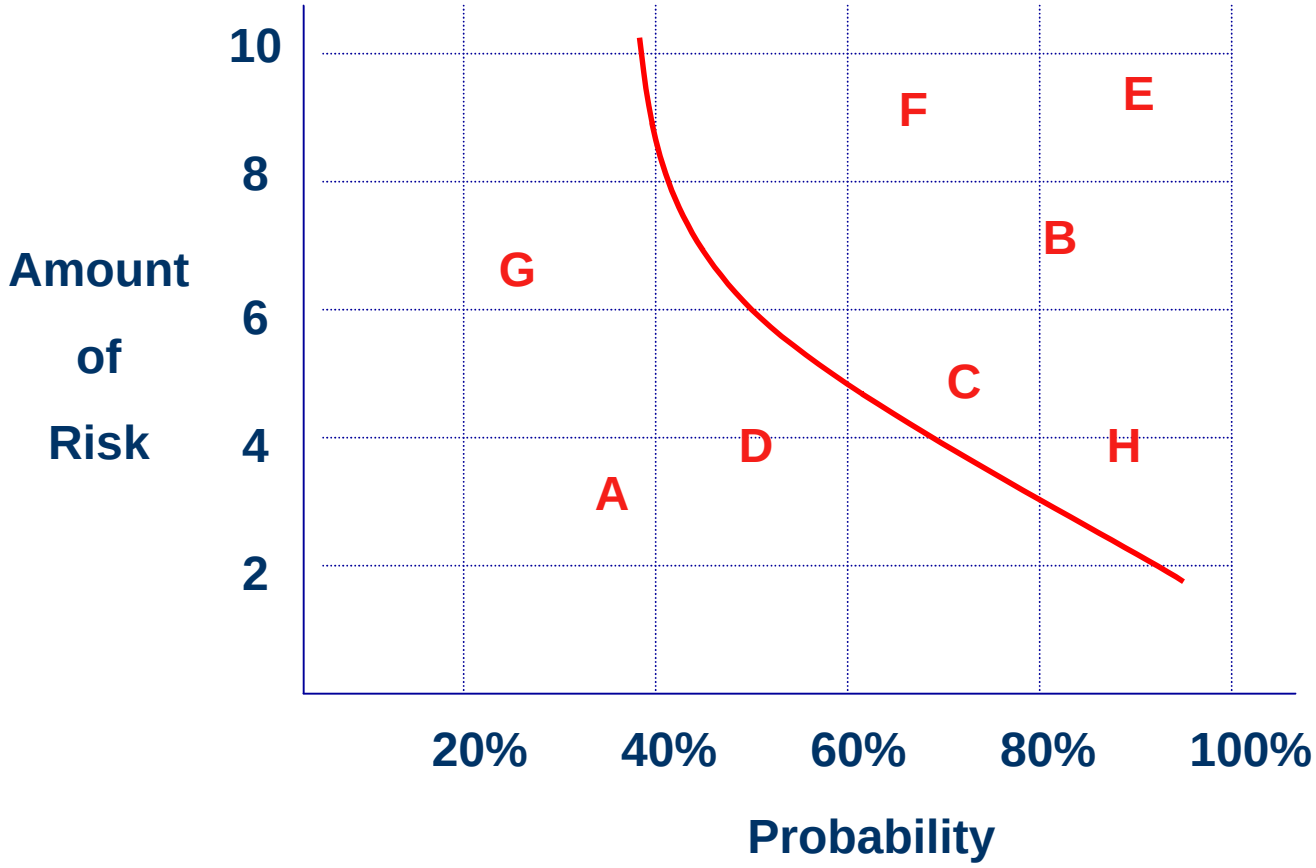
- Phases tend to overlap in practice
- Applications repeat on different:
  - subproblems
  - levels of abstraction
- Problem definition tasks appear in some form in each phase

# A Project Management Framework

# The Project Triangle

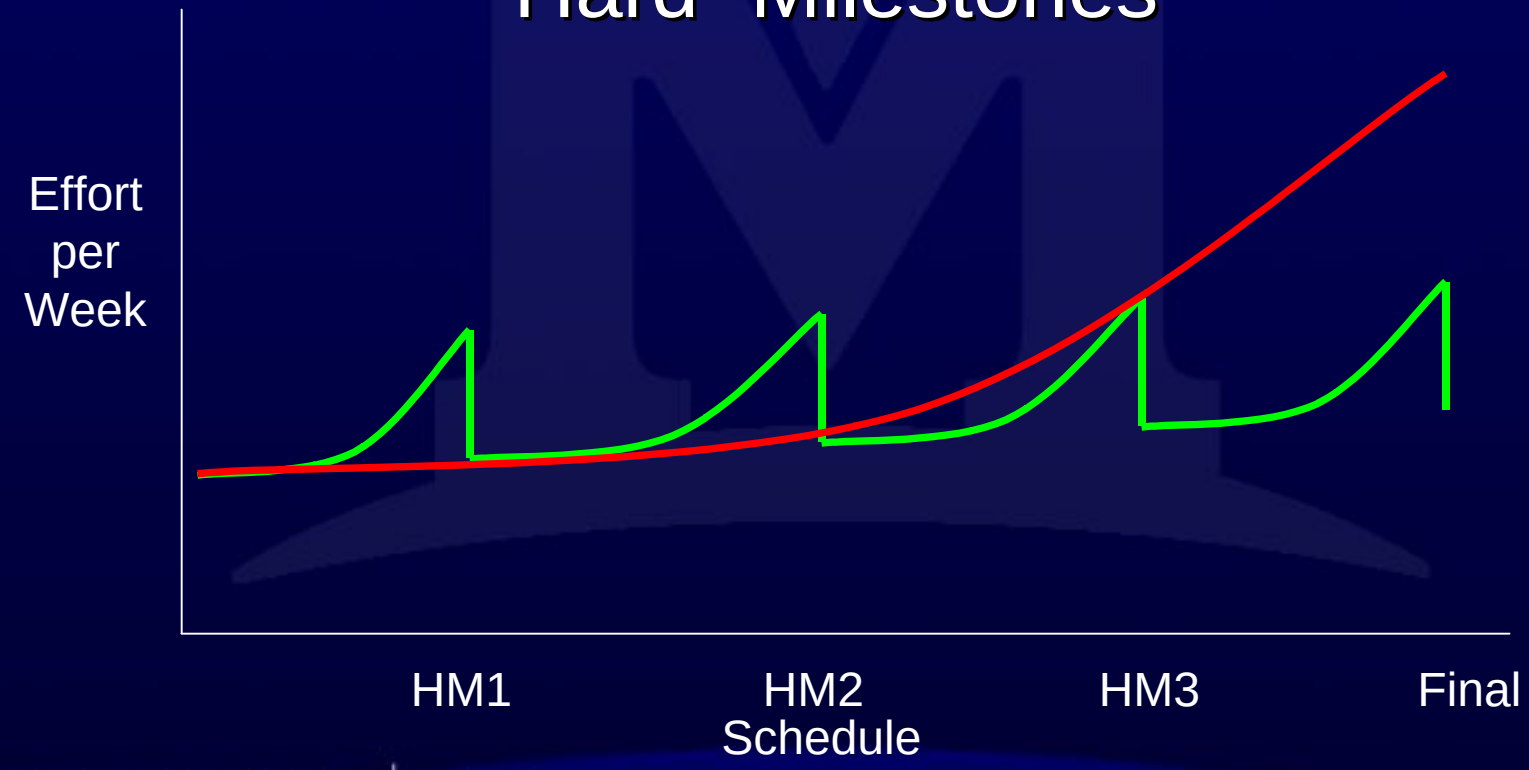


# Project Risk Chart



# Project Planning Approach

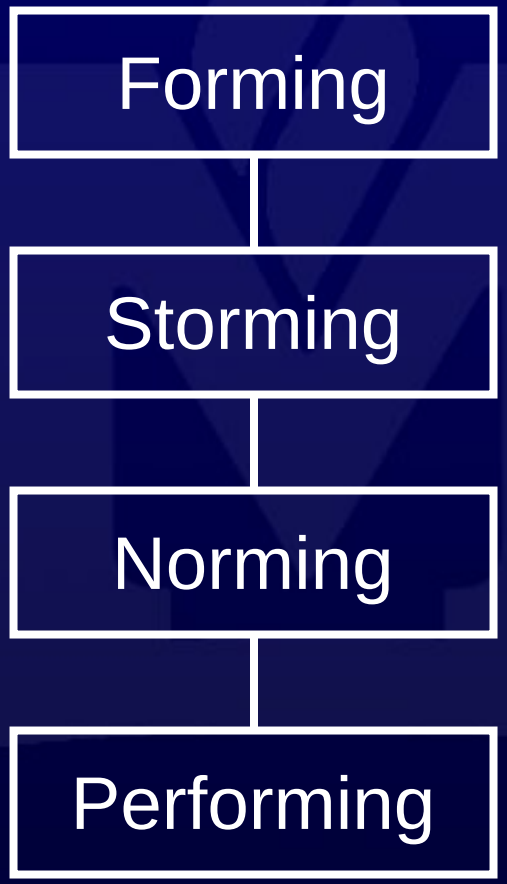
- Project Manager Sets Multiple "Hard" Milestones



# Building the Plan

1. Develop work breakdown structure (WBS)
2. Define length for each task
3. Define dependencies
4. Assign resources
5. Review for over -allocation

# Stages of Team Development



# Feedback: An essential element of design reviews

# PAUSE Principle

**Prepare** – get the facts, generate options

**Affirm** – the relationship

**Understand** – the others' issues

**Seek** – mutually beneficial options

**Evaluate** – Have we satisfied the major concerns?

# Conflict Management Strategies

Avoidance Compromise Attack

Constructive
Engagement

**Creative Solutions**

# Keys to Effective Meetings

- Prepare ahead of time.
- Have a written agenda.
- Agree on meeting's objectives.
- Start on time.
- Document decisions made.
- Don't leave without an action plan.
- Establish ground rules.
- Appoint a facilitator.

# Five Sets of Teamwork Skills

1. Interpersonal communication and collaboration
2. Understanding & communicating trade-offs and empathy for diverse perspectives
3. Planning/organization and accountability/reliability
4. Common goals/shared outcomes and conflict management, resolution
5. Willingness to learn and inclusive decision-making

# Why do design projects fail?

1. Misunderstanding what the customer needs.
2. Committing to a solution too early.
3. Lack of teamwork: esp. communication & conflict resolution across disciplines.
4. Poor system architecture, especially interfaces.
5. Poor planning.

# Good Luck on Monday!