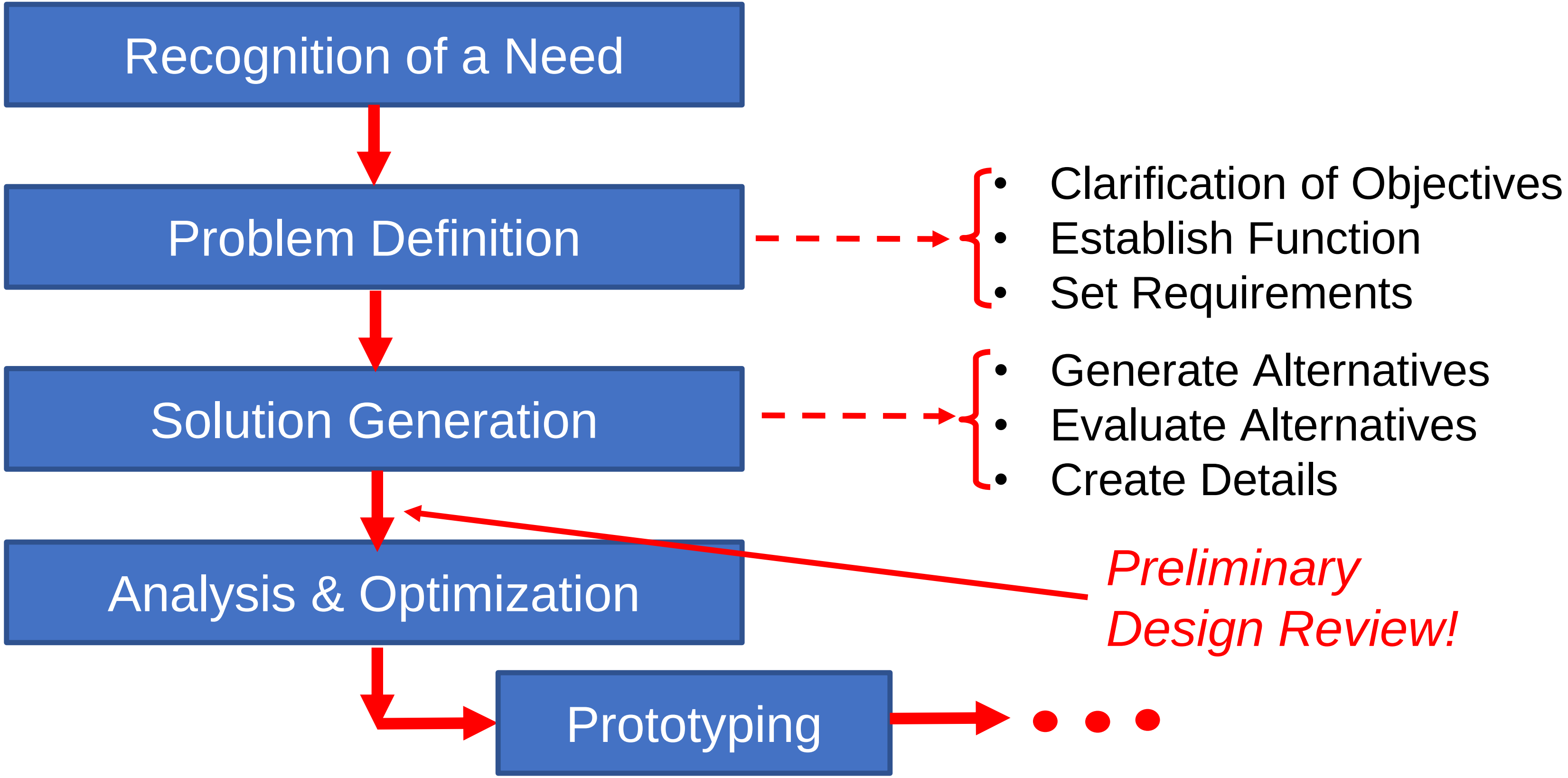
CS/EE/ME 75(a)

Nov. 6, 2019

Today:

- Evaluation (continued)
- Preliminary Design Review
- Prototypes
- Homework

Structured Design Method(s)



Pugh Analysis, Pugh Matrix

	Baseline	Alternative Solution		
Criteria	**Current Solution**	**Alternative 1**	**Alternative 2**	**Alternative 3**
Feasibility	5	1	1	1
Cost	4	-1	-1	0
Long Term Benefit	1	0	-1	1
Maintainability	3	0	0	-1
Availability of Resources	2	1	0	-1
Sum of all Positives		7	5	6
Sum of all Negatives		4	5	5
Sum of all Neutrals		0	0	0
Total		**3**	**0**	**1**

Weighted Objectives Method

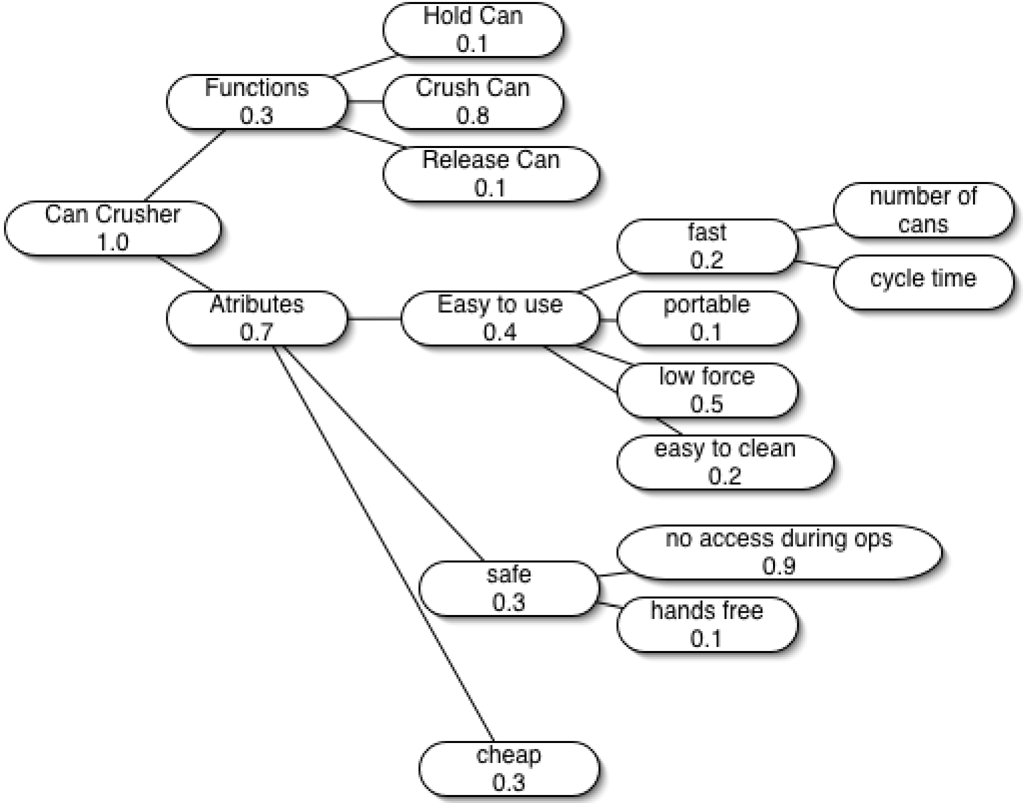
- provides a way to systematically evaluate and compare concepts

- Procedure
    - List the design objectives
    - Rank-order the list of objectives
    - Assign relative weightings to the objectives
    - Evaluate and compare the relative utility values of the alternative designs

Ranking and Weighting Objectives

- This part of the process is highly subjective
- Ranking can be done using a pair-wise comparison
  - This becomes more cumbersome with more objectives
- Weighting can be done based on the ranking
  - This is even more subjective
- A simple way to perform these steps is to examine the objective tree and weight each level and sub-level.
  - The ranking and weighting will drop out of this examination

Weighted Objective Tree



Weighting Matrix

Attribute	Level 1	Level 2	Level 3	Total
Hold Can	0.3	0.1	1	0.03
Crush Can	0.3	0.8	1	0.24
Release Can	0.3	0.1	1	0.03
Fast	0.7	0.4	0.2	0.056
Portable	0.7	0.4	0.1	0.028
Low force	0.7	0.4	0.5	0.14
East to Clean	0.7	0.4	0.2	0.056
Limit Access	0.7	0.3	0.9	0.189
Hands Free	0.7	0.3	0.1	0.021
Cheap	0.7	0.3	1	0.21

	CONCEPT VARIANTS							
SELECTION CRITERIA	A	B	C	D	E	F	G	REF.
Ease of Handling	0	0	–	0	0	–	–	0
Ease of Use	0	–	–	0	0	+	0	0
Number Readability	0	0	+	0	+	0	+	0
Dose Metering	+	+	+	+	+	0	+	0
Load Handling	0	0	0	0	0	+	0	0
Manufacturing Ease	+	–	–	0	0	–	0	0
Portability	+	+	–	–	0	–	–	0
PLUSES	3	2	2	1	2	2	2	
SAMES	4	3	1	5	5	2	3	
MINUSES	0	2	4	1	0	3	2	
NET	3	0	–2	0	2	–1	0	
RANK	1	3	7	5	2	6	4	
CONTINUE?	Yes	Yes	No	No	Yes	No	Yes	

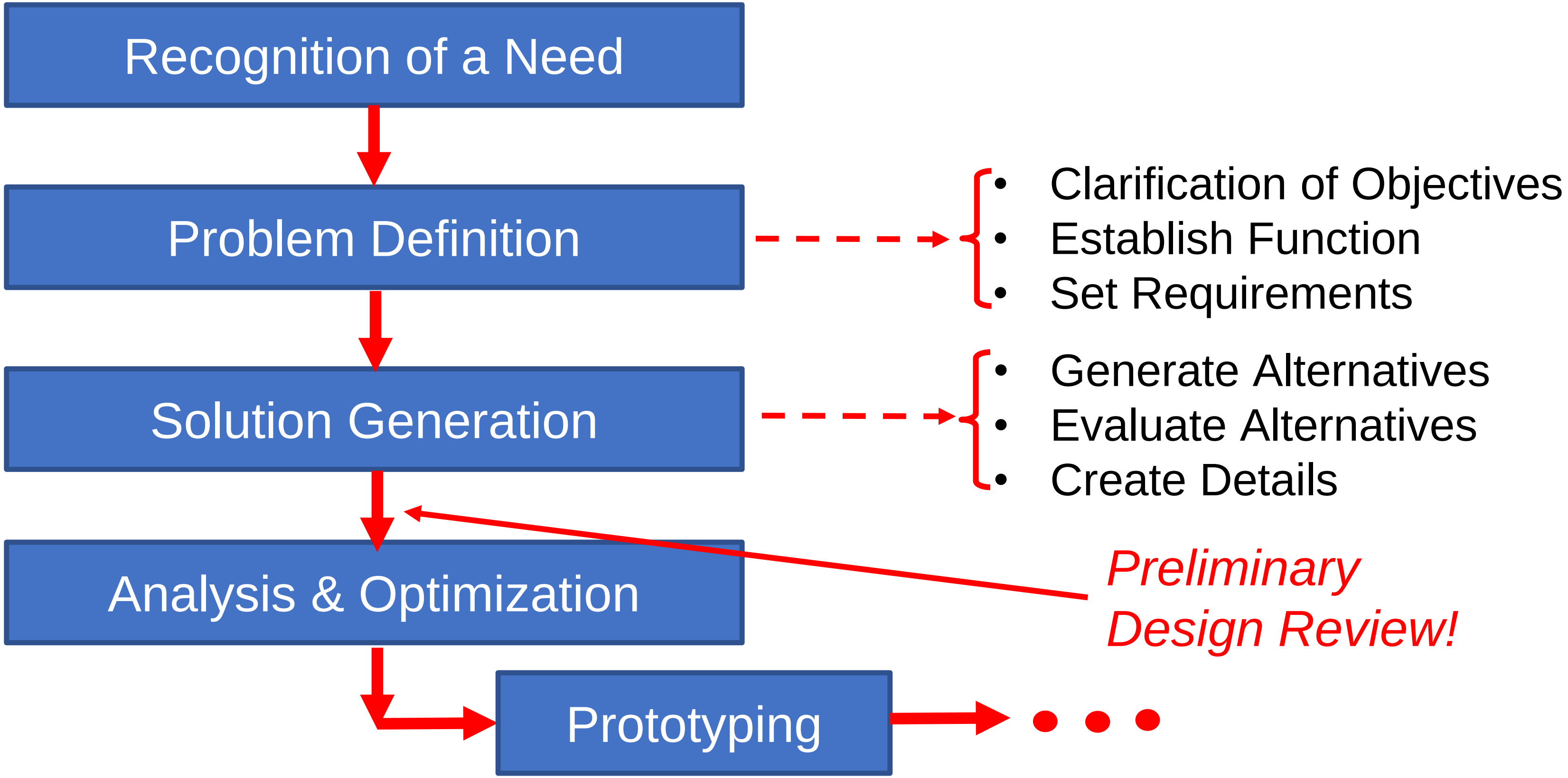
Putting it all together

1. Choose the criteria for comparison (leaves of the objective tree)
2. Develop relative importance weighting (based on objective tree)
3. Select the alternatives to be compared (from pruning the initial concepts)
4. Evaluate alternatives (relative comparison +,–,0)
    - Pick one to be the datum or baseline concept, and compare all designs to that one
5. Compute the satisfaction

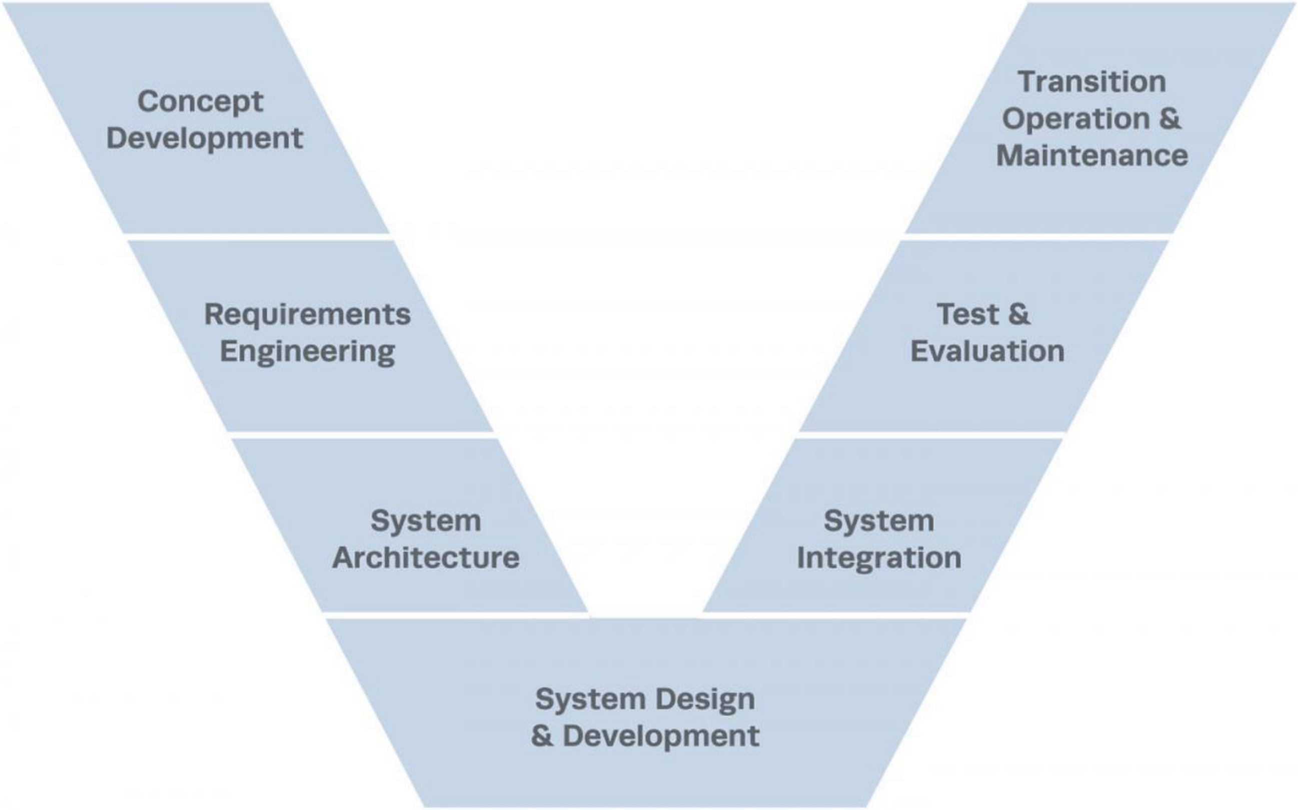
Table 8.2 The basic structure of a decision matrix

1	2	Alternatives			
Criteria (requirements or specifications)	Importance	Alternative 1	Alternative 2	Alternative 3	3
Criterion 1	xx	Evaluation of Alternative 1 using criterion 1	Evaluation of Alternative 2 using criterion 1	....	4
Criterion 2	yy	Evaluation of Alternative 1 using criterion 2	Evaluation of Alternative 2 using criterion 2	....	
....					
....					
	Satisfaction	Score for Alternative 1	Score for Alternative 2		5

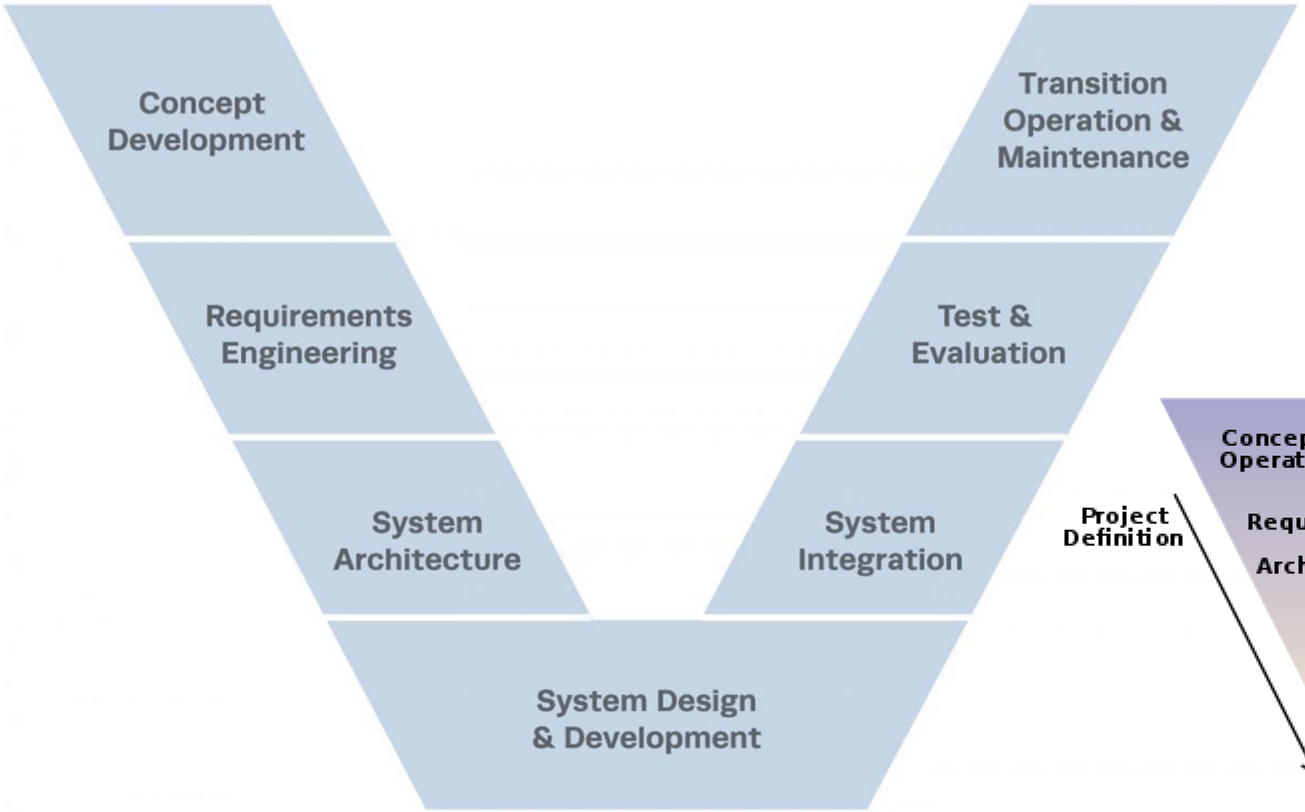
Structured Design Method(s)

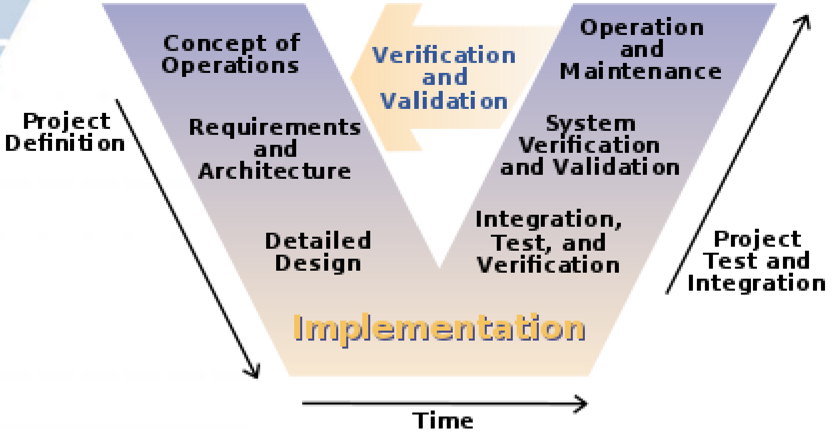


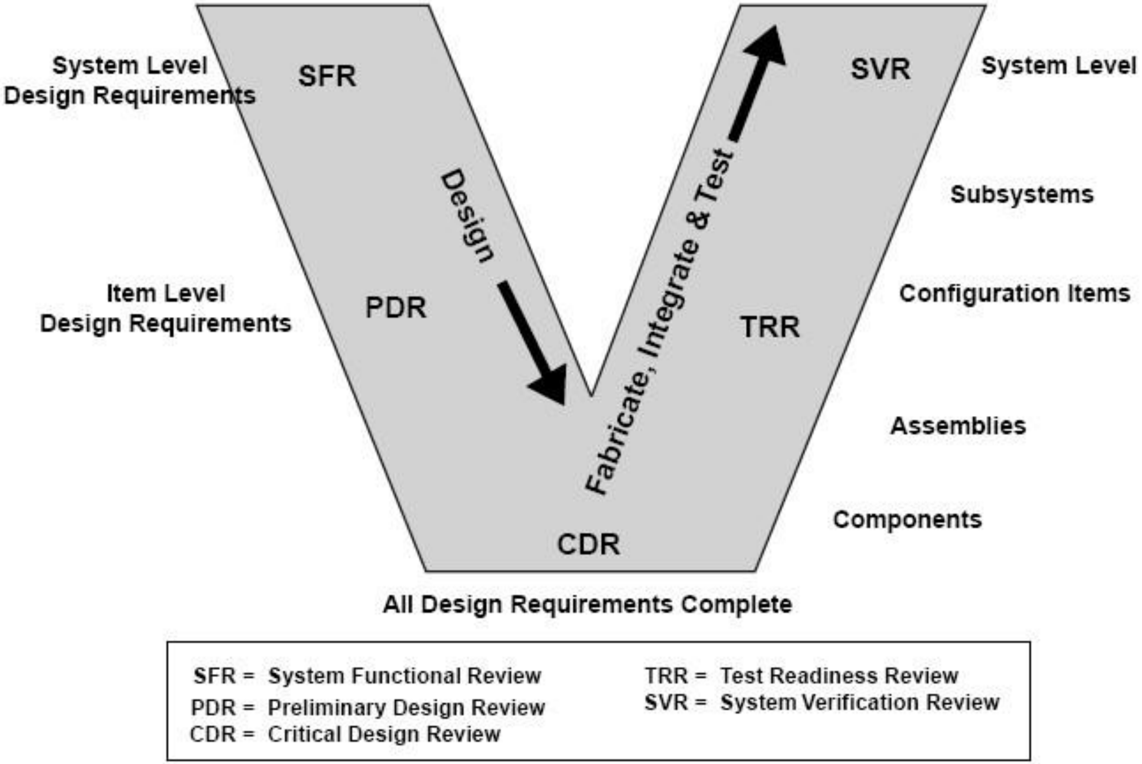
The "V" Model of Systems Engineering



The “V” Model of Systems Engineering






System Level
Design Requirements
SFR
Design
PDR
Item Level
Design Requirements
CDR
Fabricate, Integrate & Test
SVR
System Level
Subsystems
Configuration Items
TRR
Assemblies
Components
All Design Requirements Complete
SFR = System Functional Review
PDR = Preliminary Design Review
CDR = Critical Design Review
TRR = Test Readiness Review
SVR = System Verification Review

Common Design Review Procedures

- **System Requirements Review** (SRR).
  - review system **requirements** to ensure the documented requirements reflect current knowledge of needs
  - identify requirements that may not be consistent with development constraints,
  - put the requirements document under version control to serve as a stable baseline for continued development.
- **Preliminary Design Review** (PDR)**.**
  - Reviews the **conceptual design** to ensure that the planned technical approach has a good chance of meeting requirements.
  - Identify issues which need further consideration and analysis
  - Identify Risks

Common Design Review Procedures

- **Critical Design Review** (CDR).
  - Review the **detailed design** to ensure that the proposed implementation has met the system requirements.
- **Test Readiness Review** (TRR).
  - Review preparations and **readiness for testing** of mechanical, electrical, and software configuration items, including adequate version identification of software and test procedures.
- **Production Readiness Review** (PRR).
  - Ensure that the design is completely and accurately documented and ready for formal release to manufacturing or to end-user.
- **System Verification Review** (SVR).
  - Ensure that the system works as predicted, and meets the requirements.

Preliminary Design Review

A review conducted to evaluate the progress, technical adequacy, and risk resolution of the selected design approach for one or more configuration items;

- to determine each subcomponent design's compatibility with the requirements;
- to evaluate the degree of definition and assess the technical risk associated with the selected production methods and processes;
- to establish the existence and compatibility of the physical and functional interfaces among the configuration items and other items of equipment, facilities, software and personnel;
- and, as applicable, to evaluate the preliminary operational and support documents.

(ISO/IEC/IEEE 24765 2009)

General PDR Success Criteria

- An established *baseline* design/system for implementation
  - Possible *stretch goals* are also identified
- The proposed design appears to meet the objectives, requirements, and performance goals.
- There are adequate *margins* at this stage of the design. I.e., the design is “robust”
- The design can meet interface requirements and constraints. I.e., it can fit into the system.
- Problem areas, open areas, and known risks are identified.
- There are concrete plans to resolve open issues, consistent with available resources.
- Integration and test plans are adequate.
- The project has defined plans and processes in place for managing and controlling the development and operation of the mission deployment.

Prototyping & Prototypes

Classic Definition: *“a first, typical or preliminary model of something, especially a machine, from which other forms are developed or copied.”*

System Engineering Viewpoint: The process of building a prototype should:

- Answer a question
- Reduce risk in the overall system design

Role of Prototypes in Systems Engineering:

- Embodies design/analysis thought
- Learning *Catalyst*
- Enhances Communication
- Informs Decision Making
- Milestones for schedule verification
- Obtain early feedback: Learn about user interactions, component/material choices, and features before the design becomes concrete.

Prototyping & Prototypes

Types of Prototypes: (at a high level)

Horizontal

- ***Look and Feel***: how will the potential user view the product, use the product, and integrate the product into their daily lives. User Interaction.
- **Role:** what role will the component/system serve for the user?
- ***Understanding:*** how will the component or system work?
- ***Requirement/Objective Satisfaction:*** Does the solution meet needs, requirements, objectives?

Vertical

- ***Design Alternatives:*** can two different design/physical strategies both work?
- ***Physical Dimensions & Materials:*** can I build my machine/system at the right scale and mass, and with the given materials?
- ***Performance:*** How well can a concept or design actually perform?

Horizontal: features not implemented in depth, or full functionality

Vertical: limited features, but near complete detail

Prototypes as Proof-of-X

- **Proof-of-Concept:** Are the right design choices being pursued?
- **Proof of Product:** Clarifies the physical embodiment and user utility.
- **Proof of Process:** Clarifies the production method and choice of materials.
- **Proof of Production:** Demonstrates that manufacturing method is sound.

Homework

Team Tasks: (all unit levels)

- Read CS/EE/ME75 PDR document
- Create a PDR package!
- **Schedule:**
  - **Next week: (Nov 13):**
    - No homework. Class time to answer PDR questions
    - Lecture time on SubT updates/issues/
  - **Following week: (Nov. 20):** 20 Minute PDR sessions in class, followed by short lecture

Homework

Team Tasks: (6+ unit level)

- **RC Car:**
  - Now that NUC is available, learn how to drive.
  - Layout
  - What errors should resilienc logic handle?

- **Drive-O-Copter:**
  - Finish prototypes!
  - Start on avionics specification

- **Extreme Localization:**
  - Choose final focus of team
  - What about optical markers for stair climbing?

Homework

Start organizing your team for your PDR.