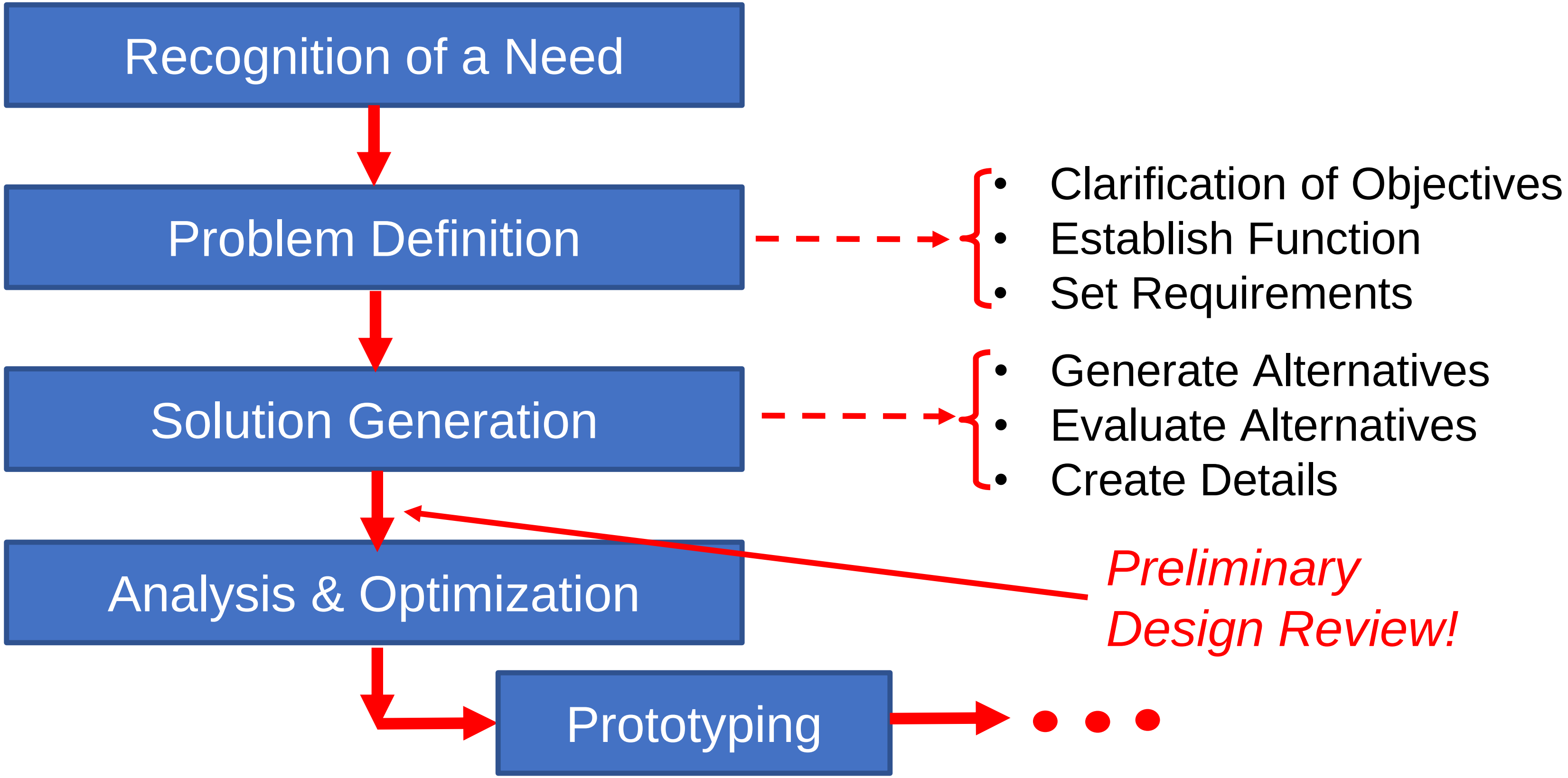
CS/EE/ME 75(a)

Nov.20, 2019

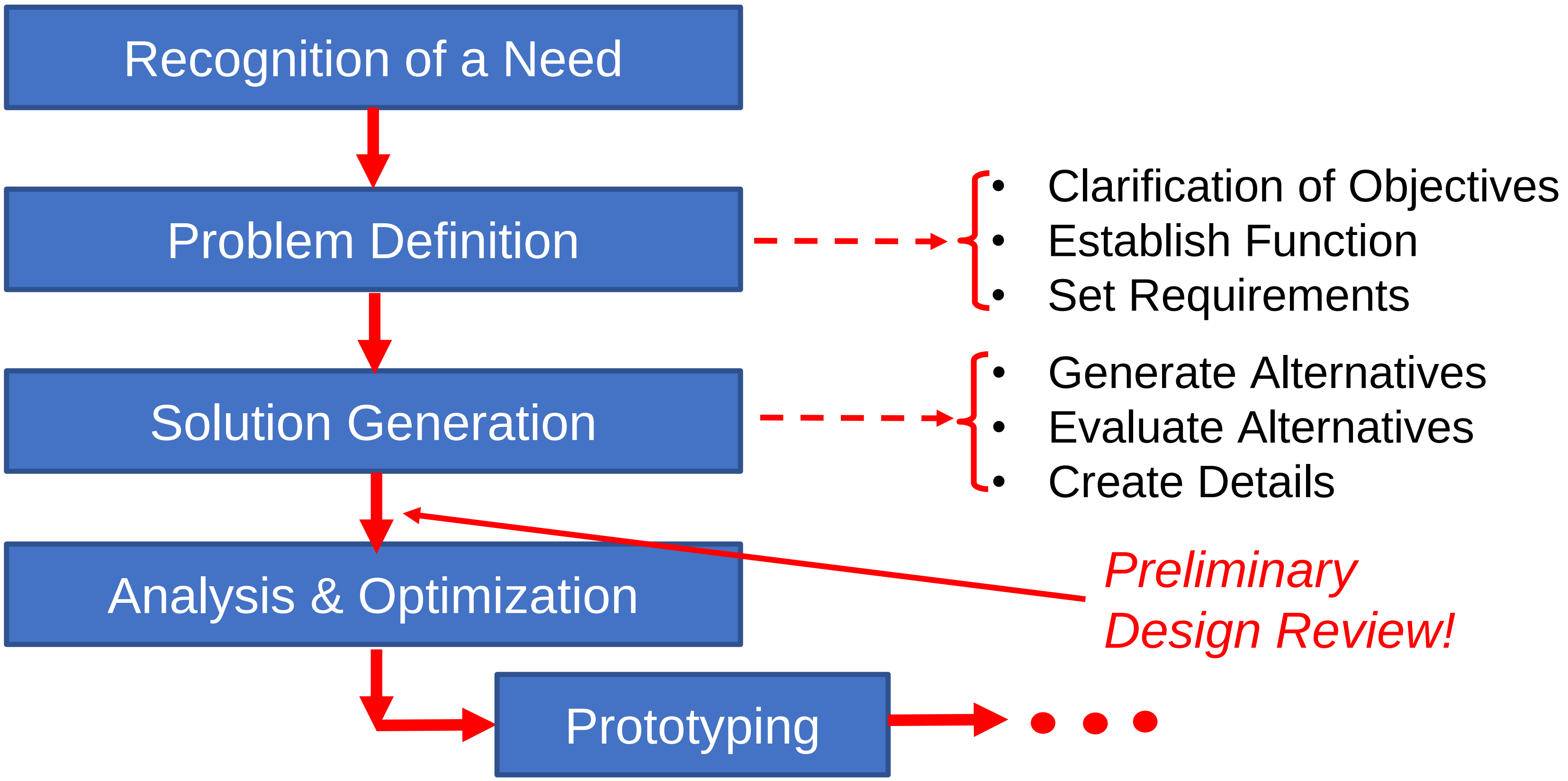
Today:

- Thanksgiving week?!
- PDRs
- What’s next?
  - Prototyping, testing, ambiguity resolution
  - CDR

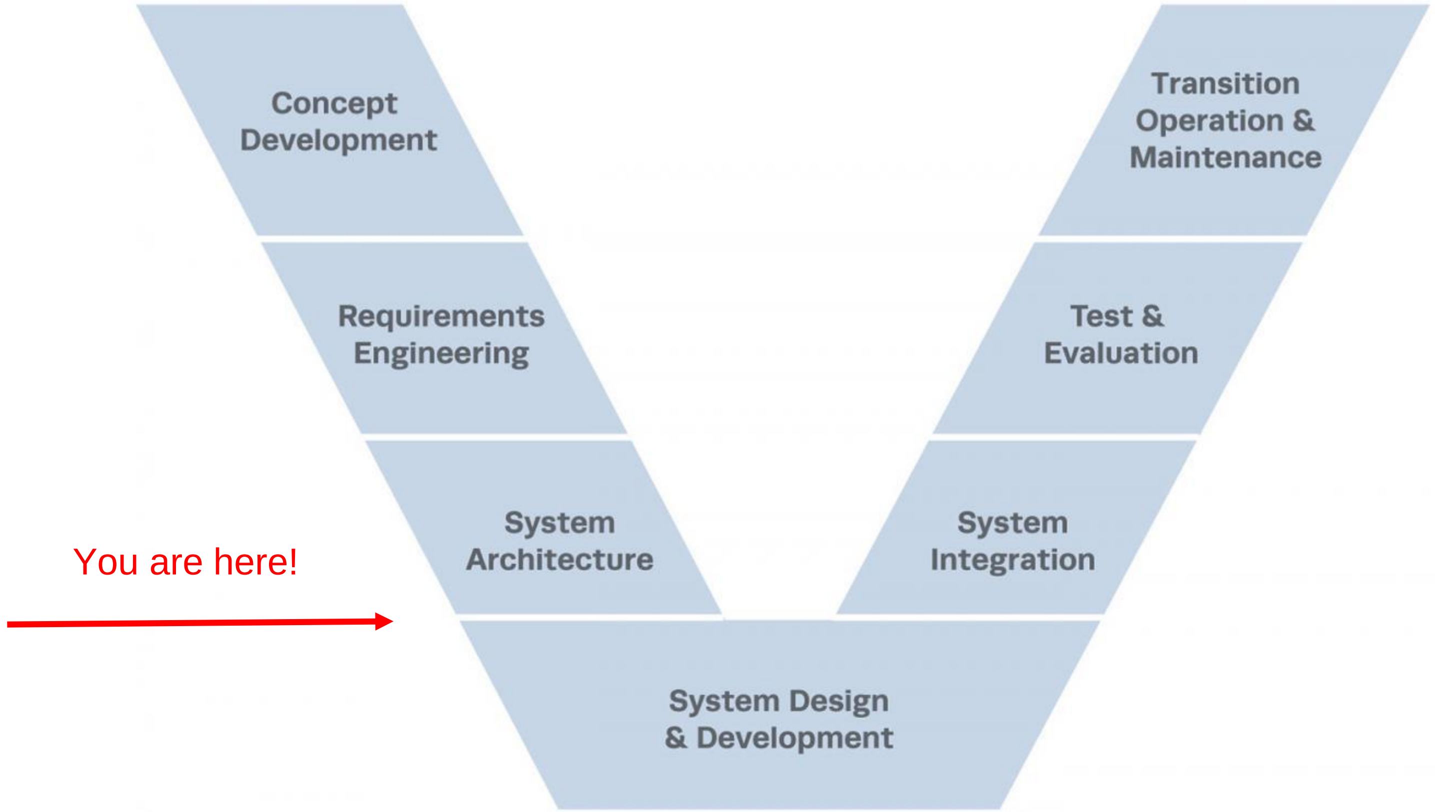
Structured Design Method(s)



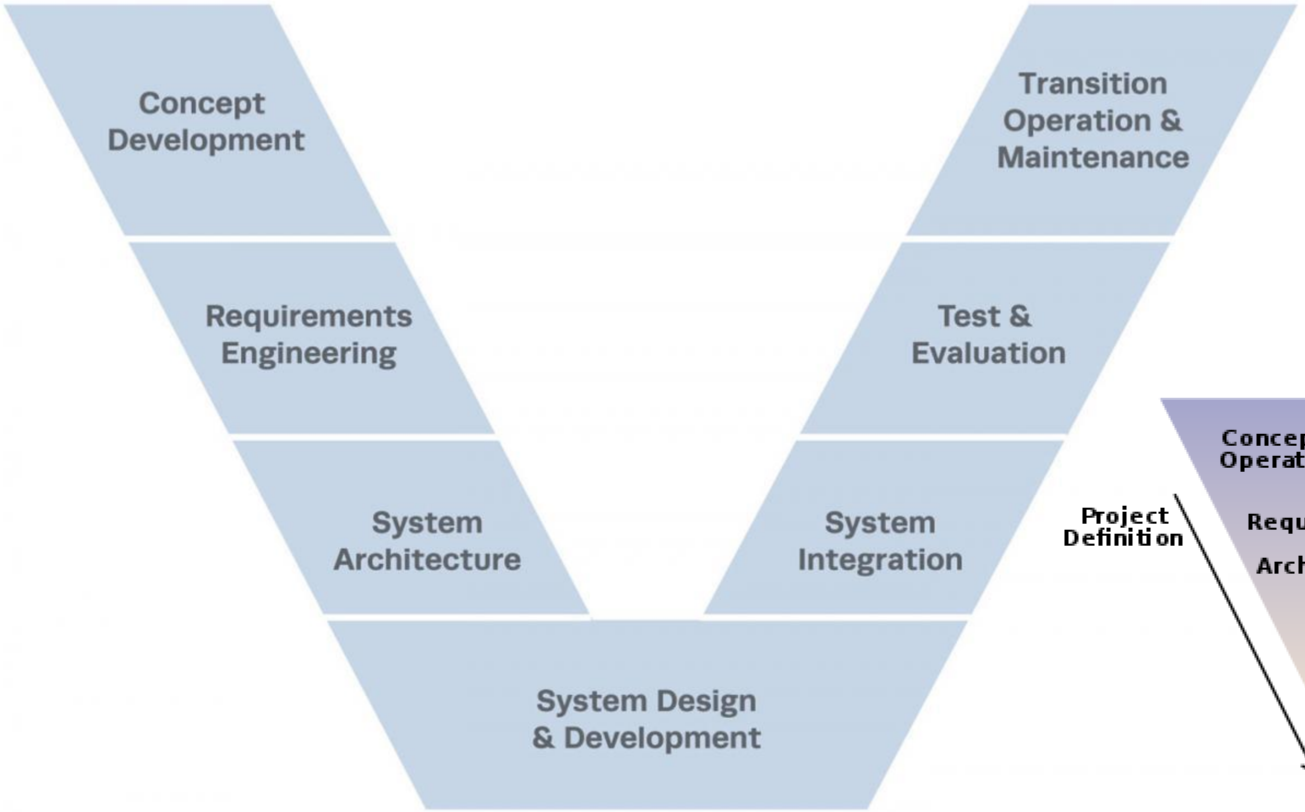
Structured Design Method(s)

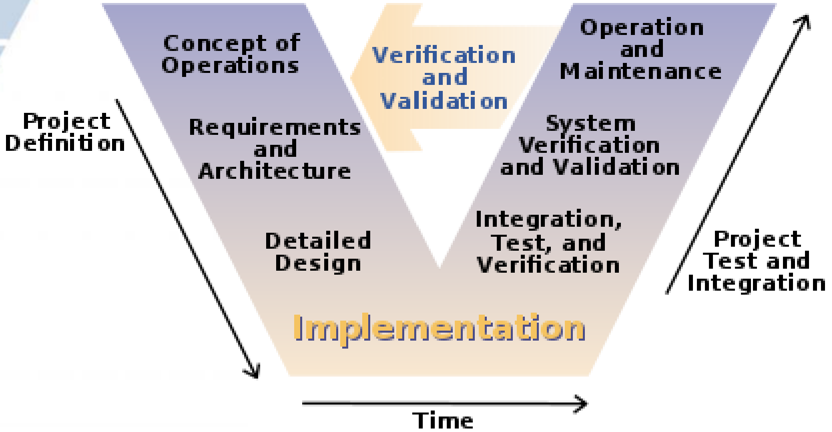


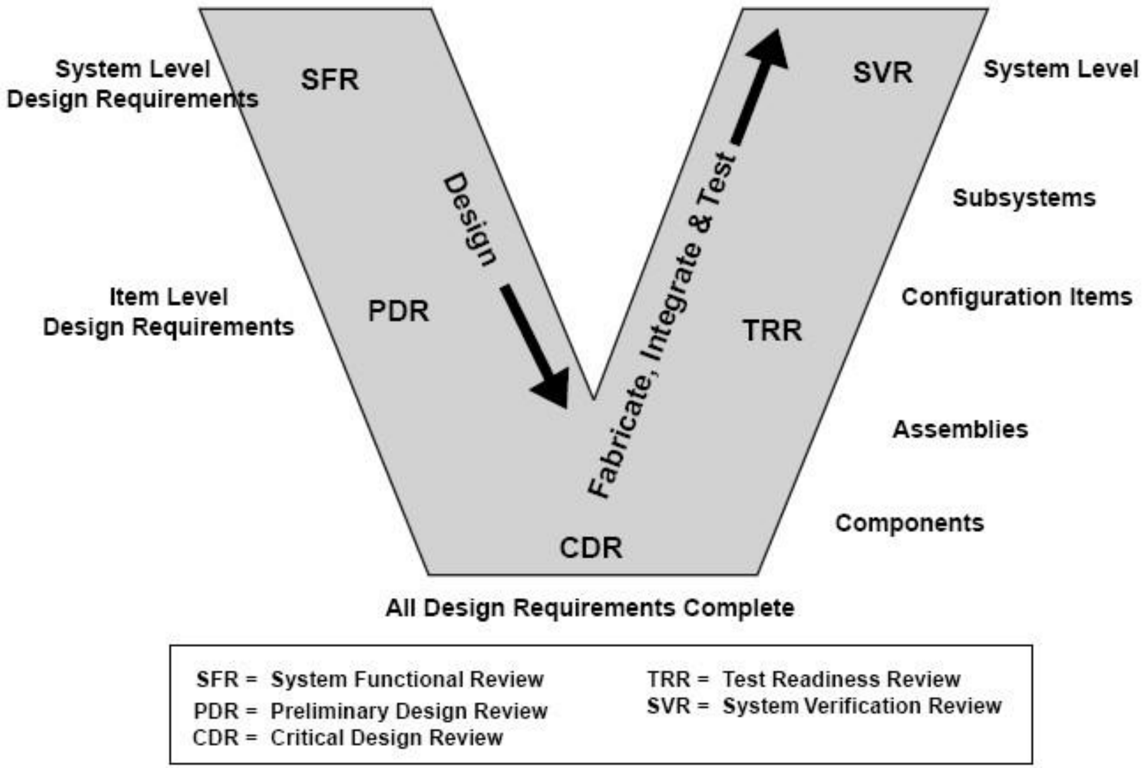
The "V" Model of Systems Engineering



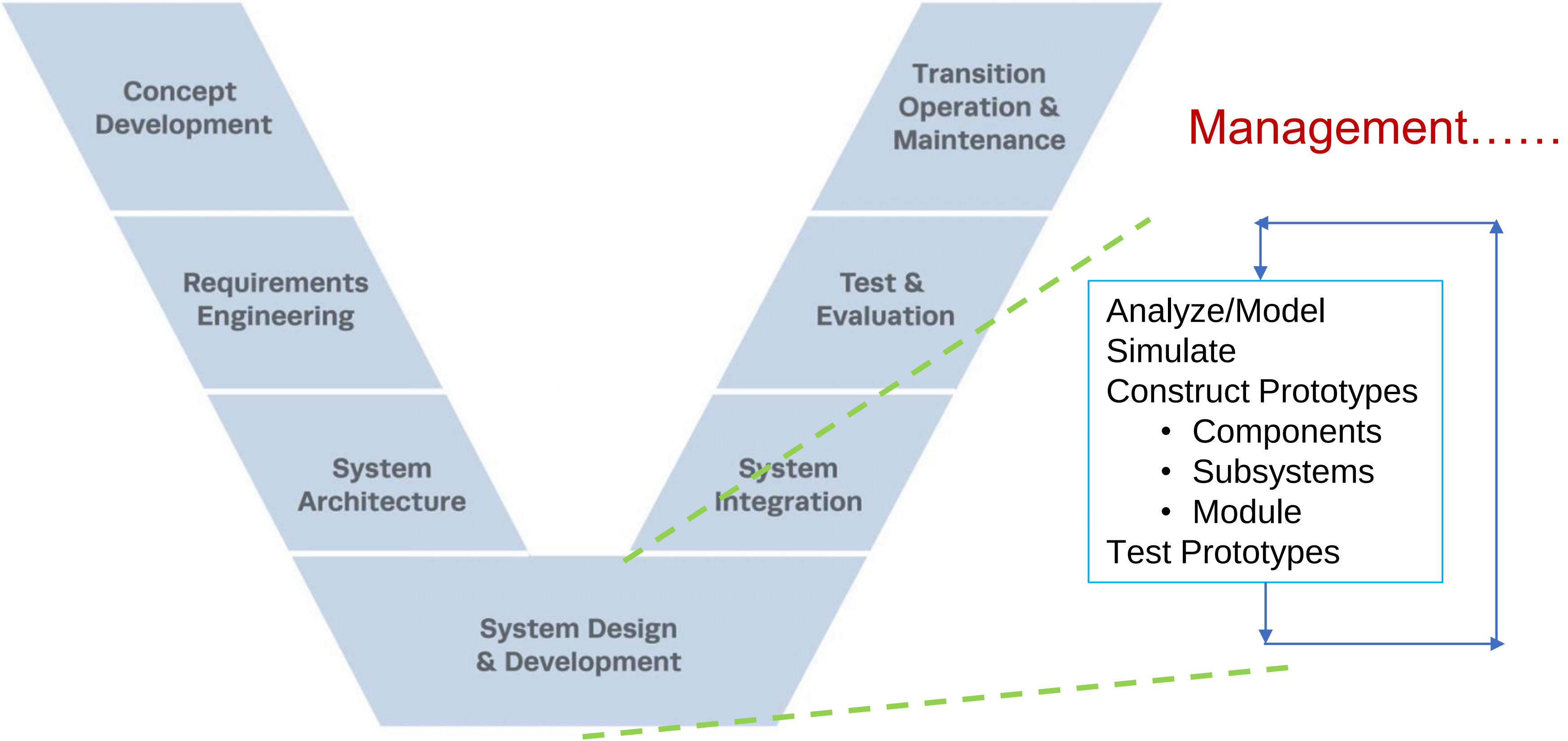
The “V” Model of Systems Engineering






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

The “V” Model of Systems Engineering



Management of Systems Engineering

A big topic, but very much common sense. We will only “scratch the surface”

The Org Chart

Milestones/Capabilities Table

Task Tables

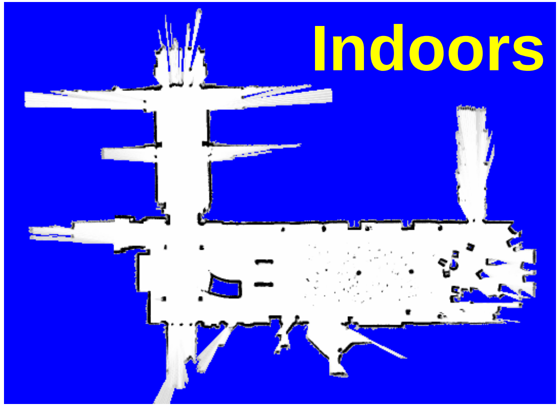
Next Class Frontier: the Autonomy System

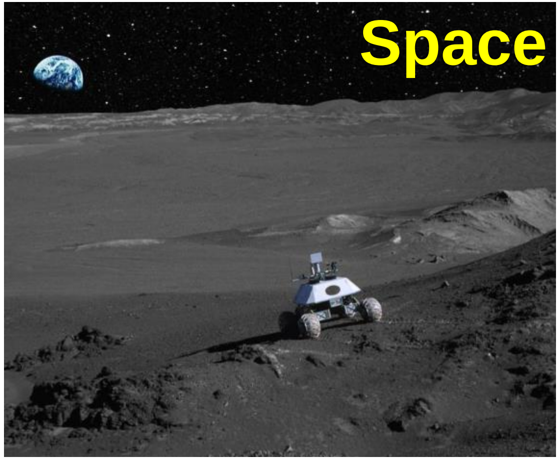
Need to know:

- Basics of mapping, localization, SLAM
- Basics of motion planning—the cost map
- ROS
- Implementing a robot control system in ROS
- System interfacing

Robot *Localization*

(where am I?)



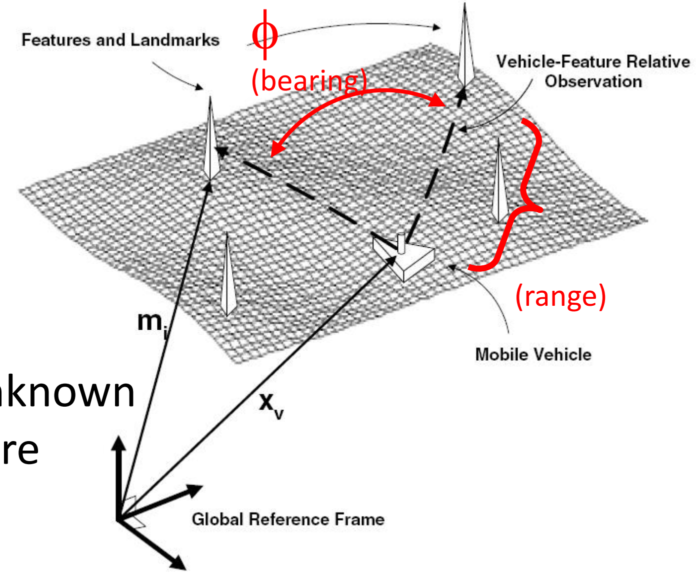


Landmark–based Localization & Mapping

Localization: A robot explores an static environment where there are known *landmarks*.

- radio beacons (Lojack)
- infrared beacons (Northstar)
- bar-code decals

Estimate the robot's position



Mapping: A robot explores an unknown static environment where there are identifiable landmarks. *E.g.:*

- doors, windows, light fixtures
- linoleum floor patterns

Build a *map* (estimate all landmark positions)

Estimation & Optimal (Kalman) Filtering

Observer

Process Dynamics — Measurement Equation

- Given $\dot{x} = f(x, u)$ $\quad y = h(x)$
- Calculate, infer, deduce the state x from measurements y
- E.g. the *Luenberger Observer* $\dot{x} = Ax + Bu + L(y - Cx)$

Estimator

- Given $\dot{x} = f(x, u) + \xi$ $\quad y = h(x) + \omega$
  - ξ represents *process noise/uncertainty* (e.g., gust or unmodeled effects)
  - ω represents *measurement noise/uncertainty*
- *Estimate* (in an *optimal)* way the state x based on
  - measurements y
  - dynamic and measurement models
  - noise model(s).

Estimation Overview (continued)

Noise & Uncertainty Models for Estimation

$$\dot{x} = f(x,u) + \xi \qquad y = h(x) + \omega(t)$$

- Set-based : $\xi \in \Xi \qquad \omega \in \Omega$
- Stochastic ξ and ω are random processes governed by $\mathrm{p}(\xi)$ and $\mathrm{p}(\omega)$

Why Estimation ?

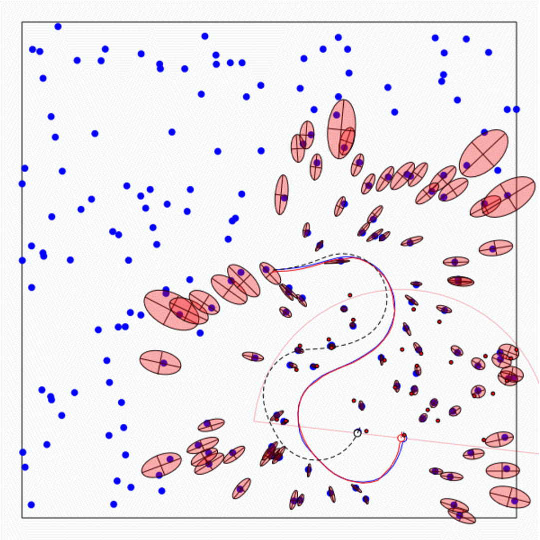
- Enables state feedback control design (separation principle)
- ***MANY*** important problems can be posed as estimation problems. *E.g.:*
  - Inertial Navigation
  - Tracking and Prediction
  - Parameter Estimation
  - Sensor Processing and Fusion

} Specialized estimation techniques & literatures

SLAM: Simultaneous Localization & Mapping

Given:

- Robot motion model: $\dot{x} = f(x, u) + \xi$
- The robot's controls, *u*
- Measurements (e.g., range, bearing) of nearby features: $y = h(x) + \omega$



Estimate:

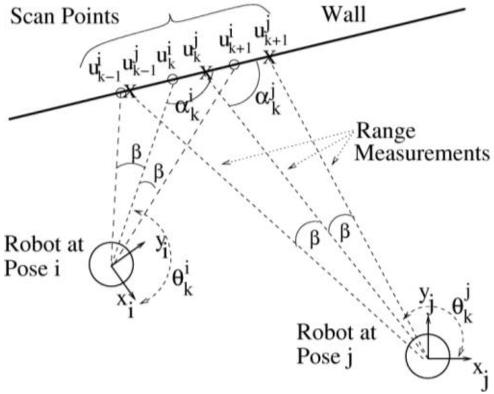
- Map of landmarks (x_L)
- Robot's current *pose*, x_R, & its path
- Uncertainties in estimated quantities

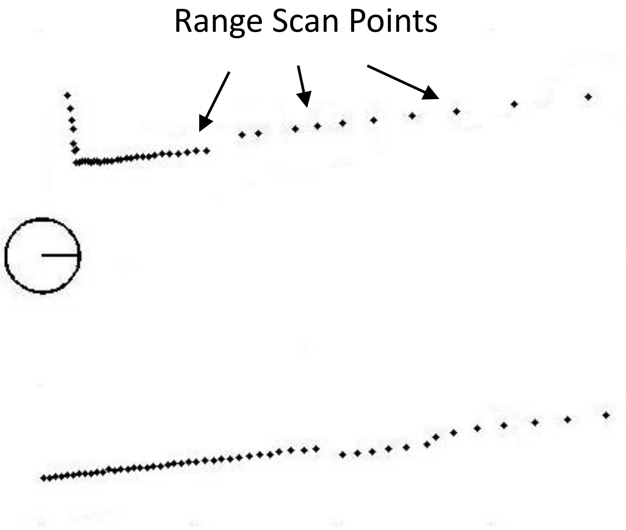
$$\vec{x} = \begin{bmatrix} \vec{x}_R \\ \vec{x}_L \end{bmatrix} = \begin{bmatrix} \vec{x}_R \\ x_{L_1} \\ \vdots \\ x_{L_N} \end{bmatrix}$$

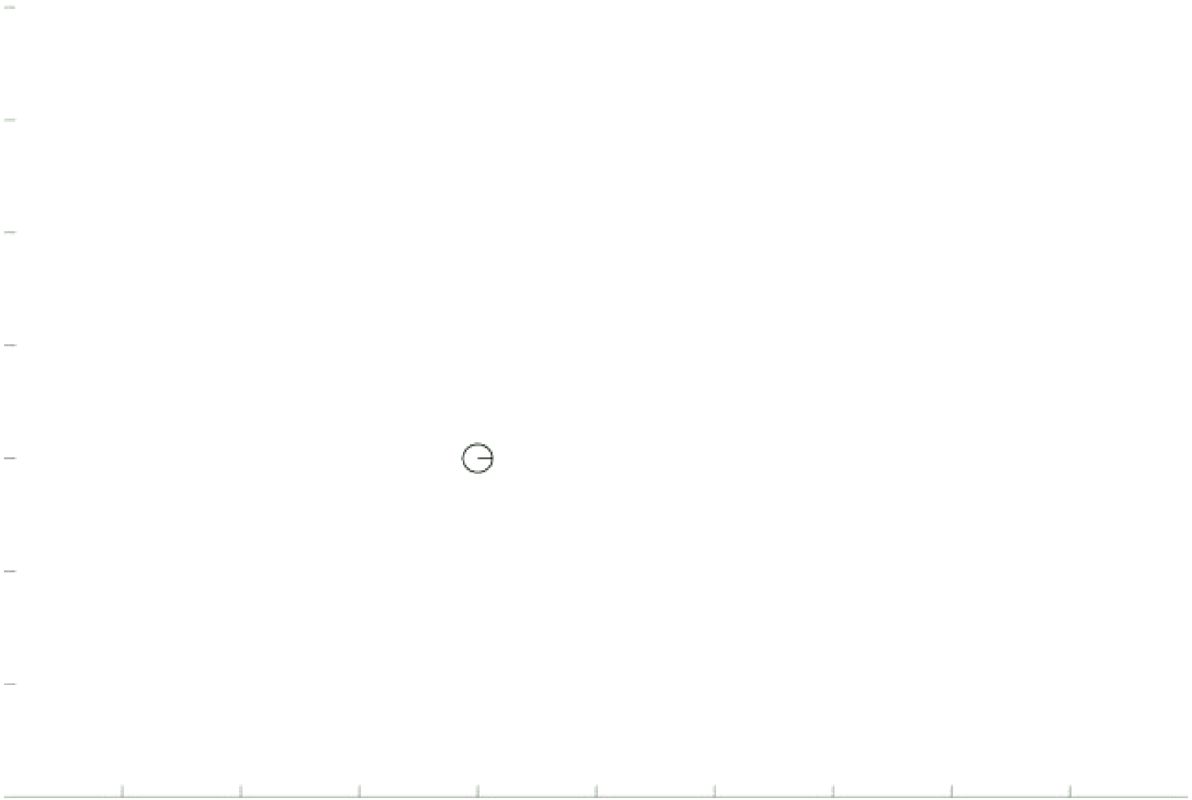
Robot state

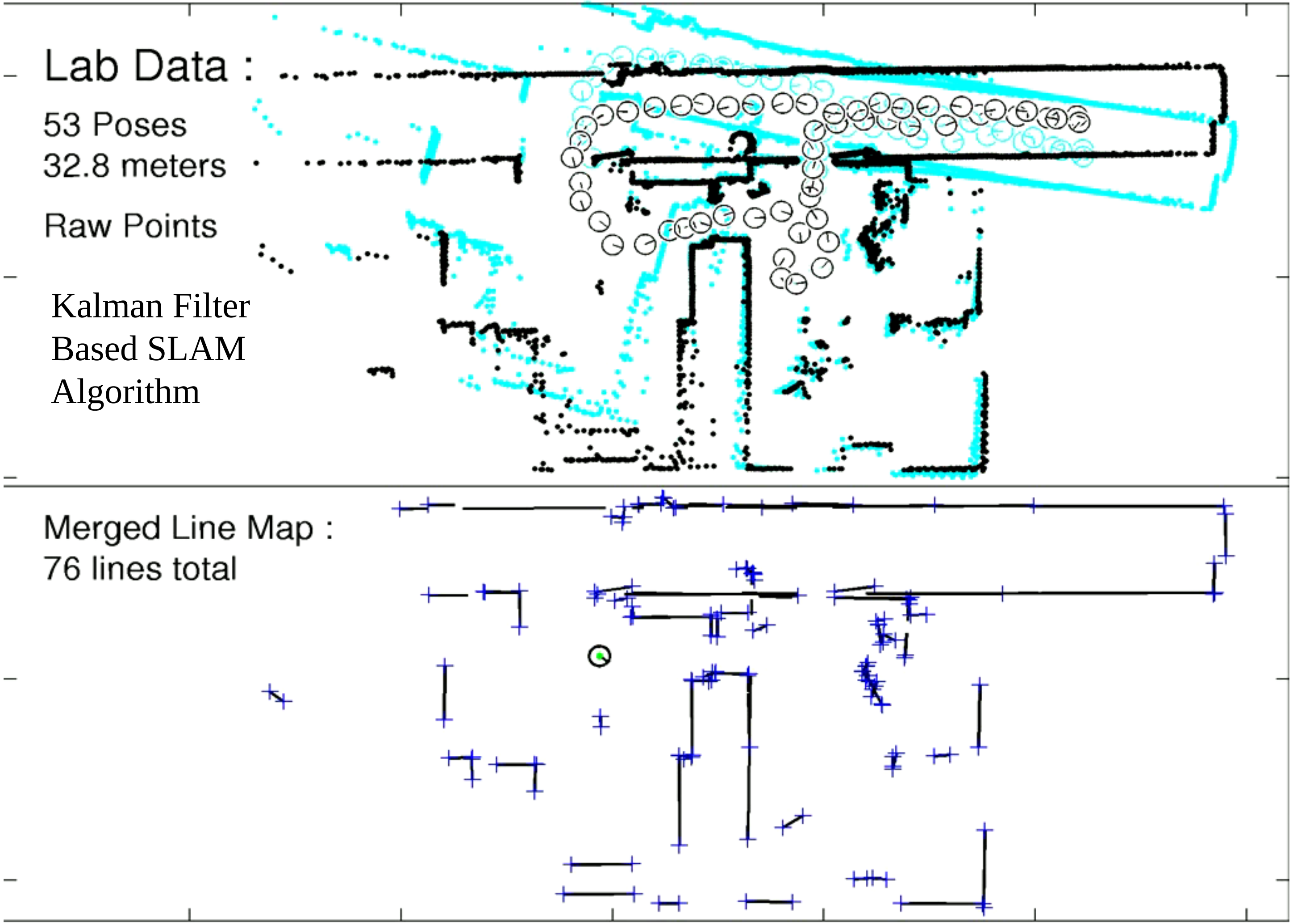
Landmark positions

Line-Based SLAM: LADAR








Lab Data :
53 Poses
32.8 meters
Raw Points
Kalman Filter
Based SLAM
Algorithm
Merged Line Map :
76 lines total

Homework

Team Tasks: (all unit levels)

- Put all electronic PDR material in your team GitLab page

Team Tasks: (6+ unit level)

- **RC Car:**
  - Choose wheel odometry sensors
  - Complete power distribution design
  - Design mountings for additional cameras
- **Drive-O-Copter:**
  - Start on avionics coordination
- **Extreme Localization:**
  - Experiment with UWB kit consider stair climbing and triangulation?