CS/EE/ME 75(a)

Oct. 16, 2019

Today:

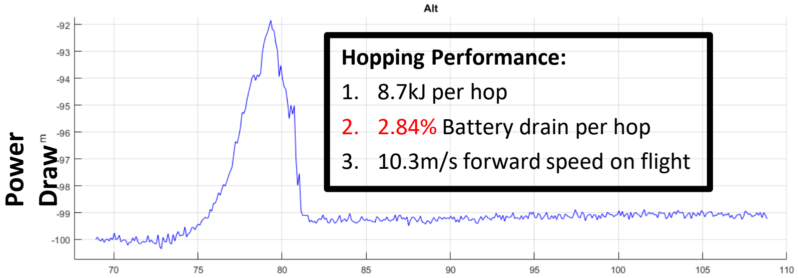
- Teaming & Projects!
- Systems Engineering Concept: Structured Design Artifacts
  - GoTChA Chart
  - Objective Tree
  - System Architectures
- Homework

Drive-o-Copter

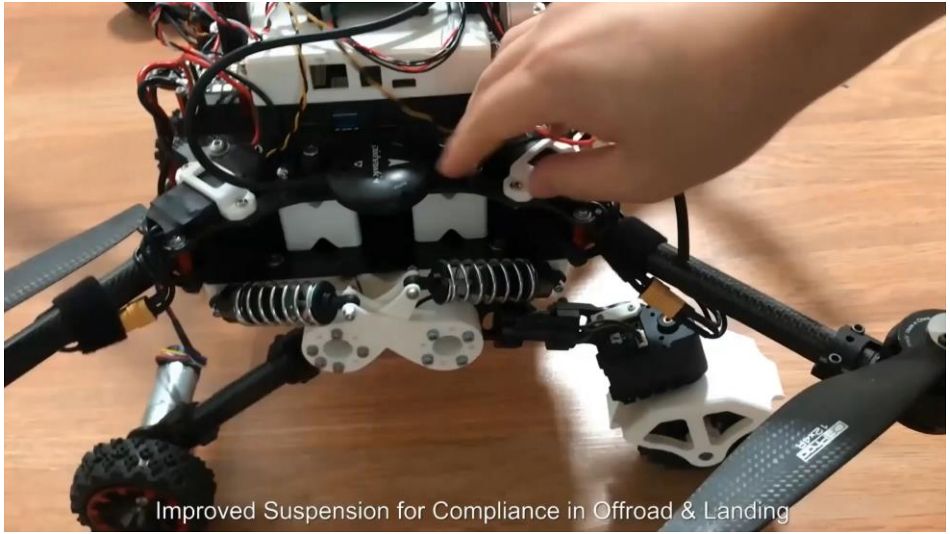
Principle: primarily a driving machine which can "hop" or fly as needed

- Solves dust problem by ground transit
- "Easy-Swap" chasses
- **ConOps:** 8 km travel, 12 hops, 1 hour autonomous operation

4WD "Swerve" Steer version



Hopping to a higher-level Platform



Drive-o-Copter Project Goals

(for students at 6+ units)

1. Design/Build specialized Urban Circuit Version of the Drive-o-copter
2. Finalize Sensor Suite
3. Bring up JPL autonomy package on Drive-o-Copter
4. Take-off and landing control
5. Test Extensively
6. Stretch goals
    - Hybrid Locomotion Planning

Resources: Arnon Lowenstein (lewinstein@gmail.com), Drew Singletary (*asinglet@caltech.edu*), Anushri Dixit (*adixit@caltech.edu*) , Amanda Bouman (*abouman@caltech.edu*)

Drive-o-Copter Project Goals

(for students at 6+ units)

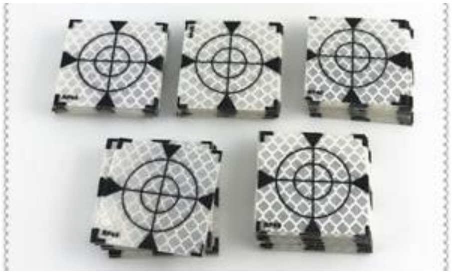
1. Design/Build specialized Urban Circuit Version of the Drive-o-copter
   - Finalize design of new chassis
   - Complete computer & electronics design integration (where located)
   - Determine battery location & wiring
2. Build (largely 3-D print) prototype with dummy loads for sensors
3. Test operation

Resources: Arnon Lowenstein (lewinstein@gmail.com), Drew Singletary (*asinglet@caltech.edu*), Anushri Dixit (*adixit@caltech.edu*) , Amanda Bouman (*abouman@caltech.edu*)

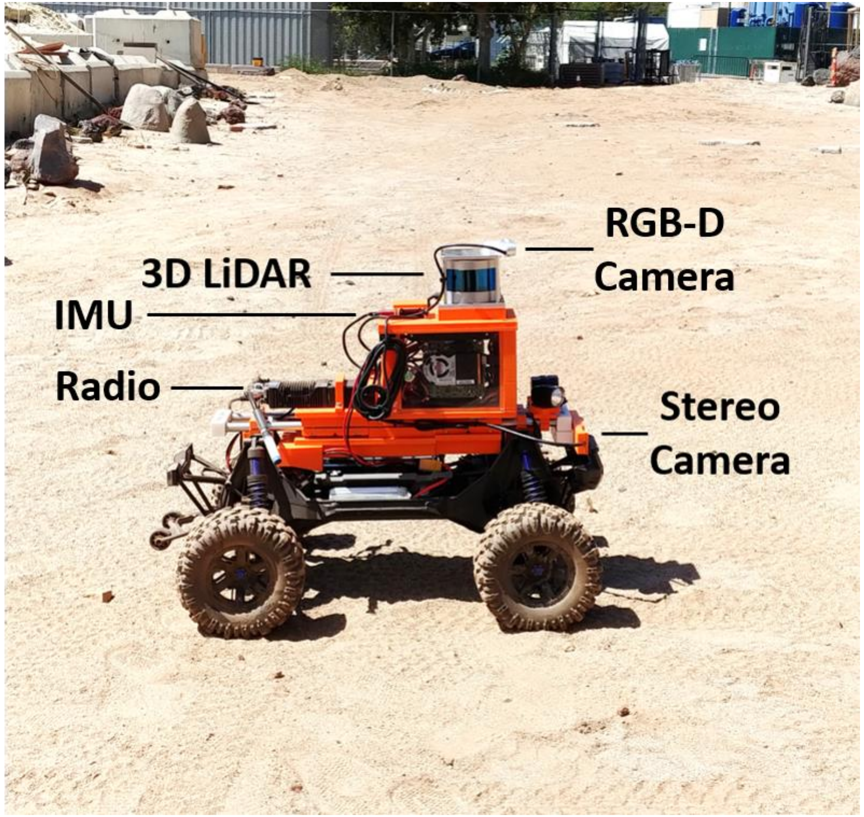
Extreme Localization

Assume: A Total Station is used to localize the robots on the first “leg” of their operation in tunnel/bunker/cave

1. Investigate: How can we “extend” the accuracy of the Total station deeper into the challenge environment
    - Multi-leg total station?
    - Radio beacons that connect to total station?
    - How to automate
    - How to deliver
2. If feasible, Design/build prototype



Resources: Joel


RGB-D
Camera
3D LiDAR
IMU
Radio
Stereo
Camera

Automated RC Car Project
Goals

1. Redesign Super-structure so that it is less top heavy
2. Add Sensors to wheels for “odometry”
3. Build 2nd car copy
4. Develop odometry estimate using the wheel sensors
5. Improve steering control at high speeds and during backup
6. Stretch goals
   - Add sensor to suspension
   - Develop whole body estimator
   - Develop high speed navigation based on “perception aware” planning principles

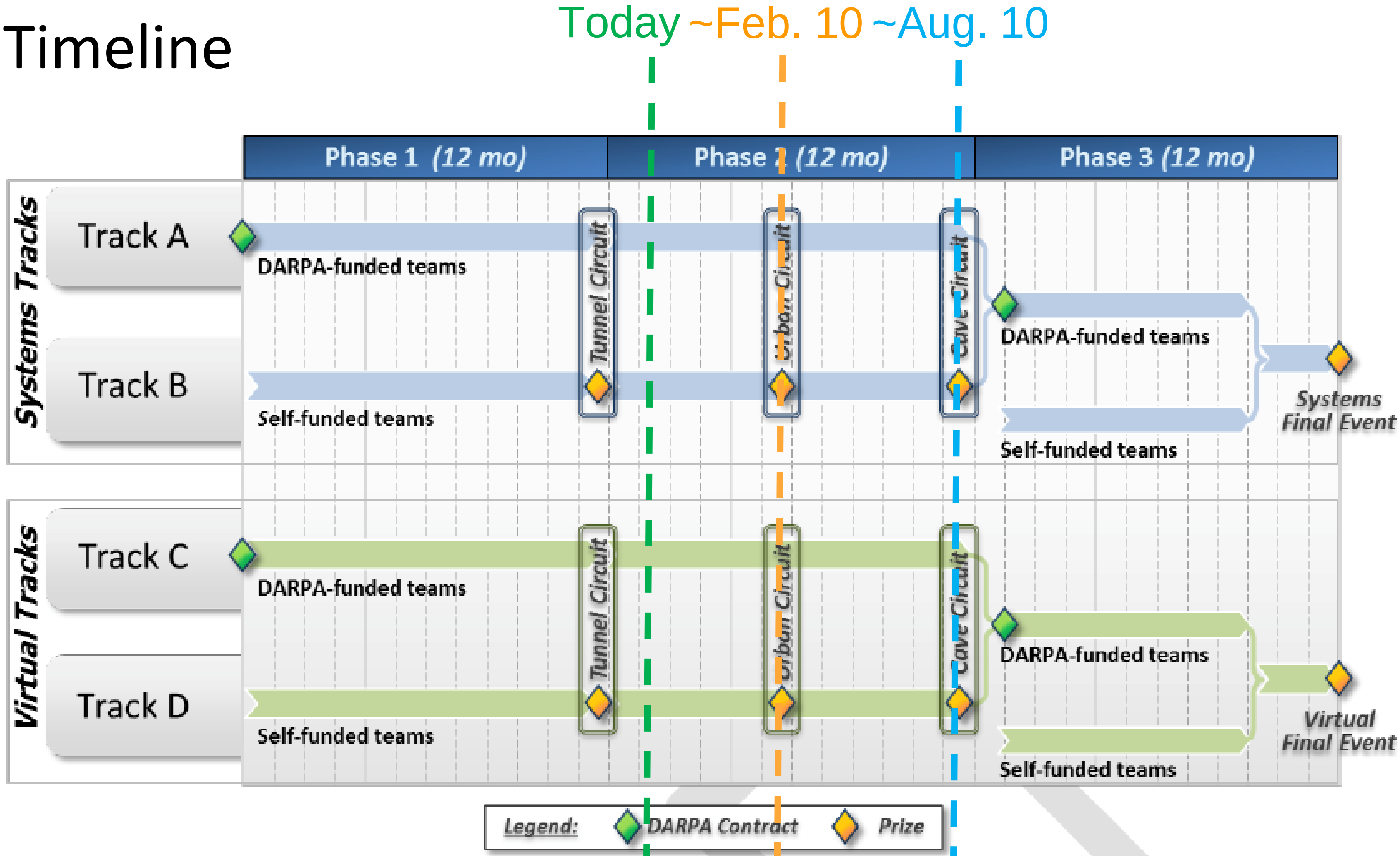
Resources: Jake Ketchum (*jketchum@caltech.edu*) , Anushri Dixit (*adixit@Caltech.edu*), Nikhilesh Alatur (*nikhilesh.alatur@jpl.nasa.gov*)

Automated RC Car Project
Goals

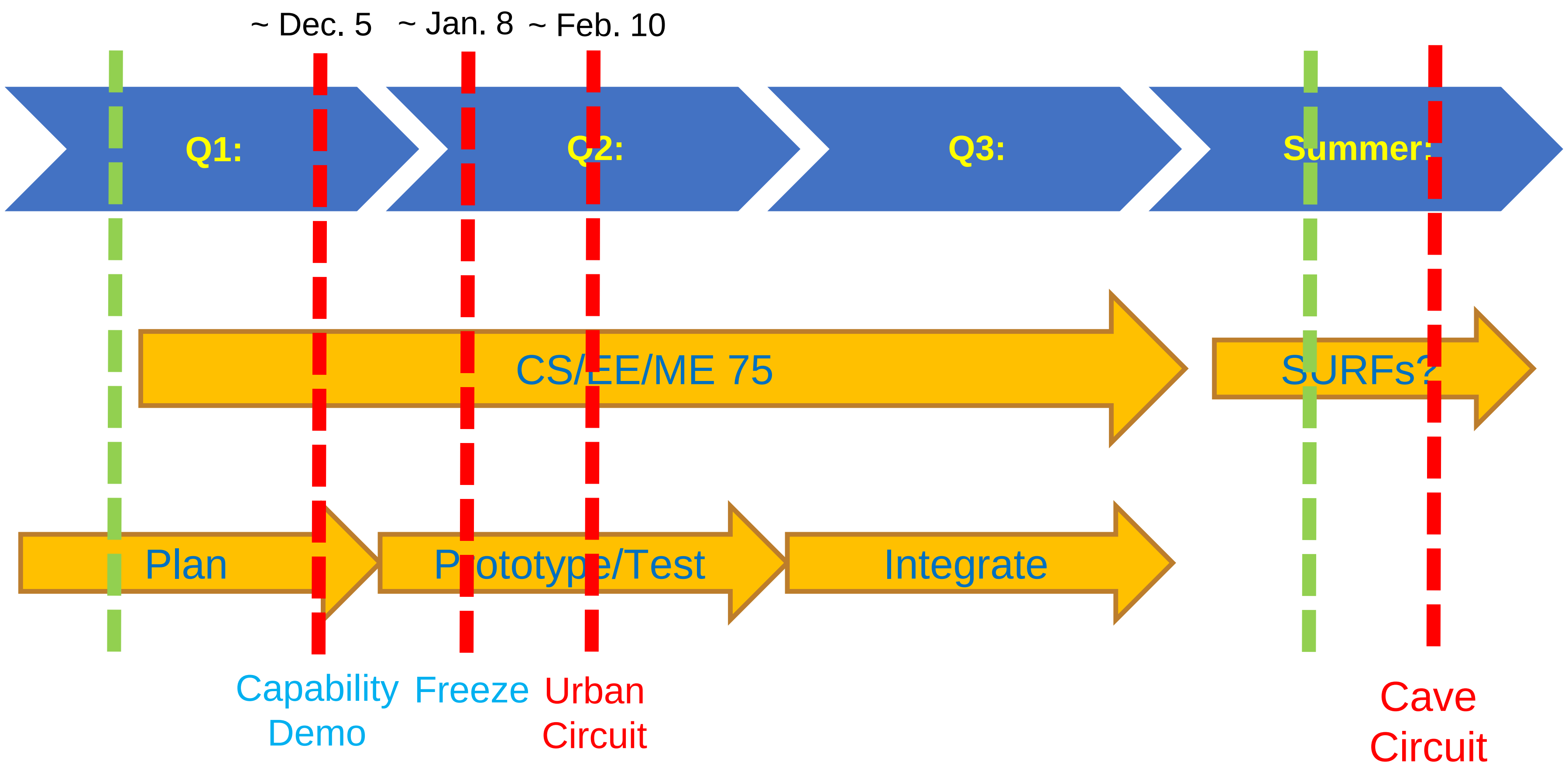
1. Redesign Super-structure so that it is less top heavy
    - Study the current RC car to understand the key components
    - Redesign the placement distribution of sensors, computers, communication, and possibly battery.
    - 3D print and build new prototype structure
    - Assemble new “mock-up” of redesigned car. Build a new copy, or reconfigure the old car?

Resources: Jake Ketchum (*jketchum@caltech.edu*) , Anushri Dixit (*adixit@Caltech.edu*), Nikhilesh Alatur (*nikhilesh.alatur@jpl.nasa.gov*)

Timeline

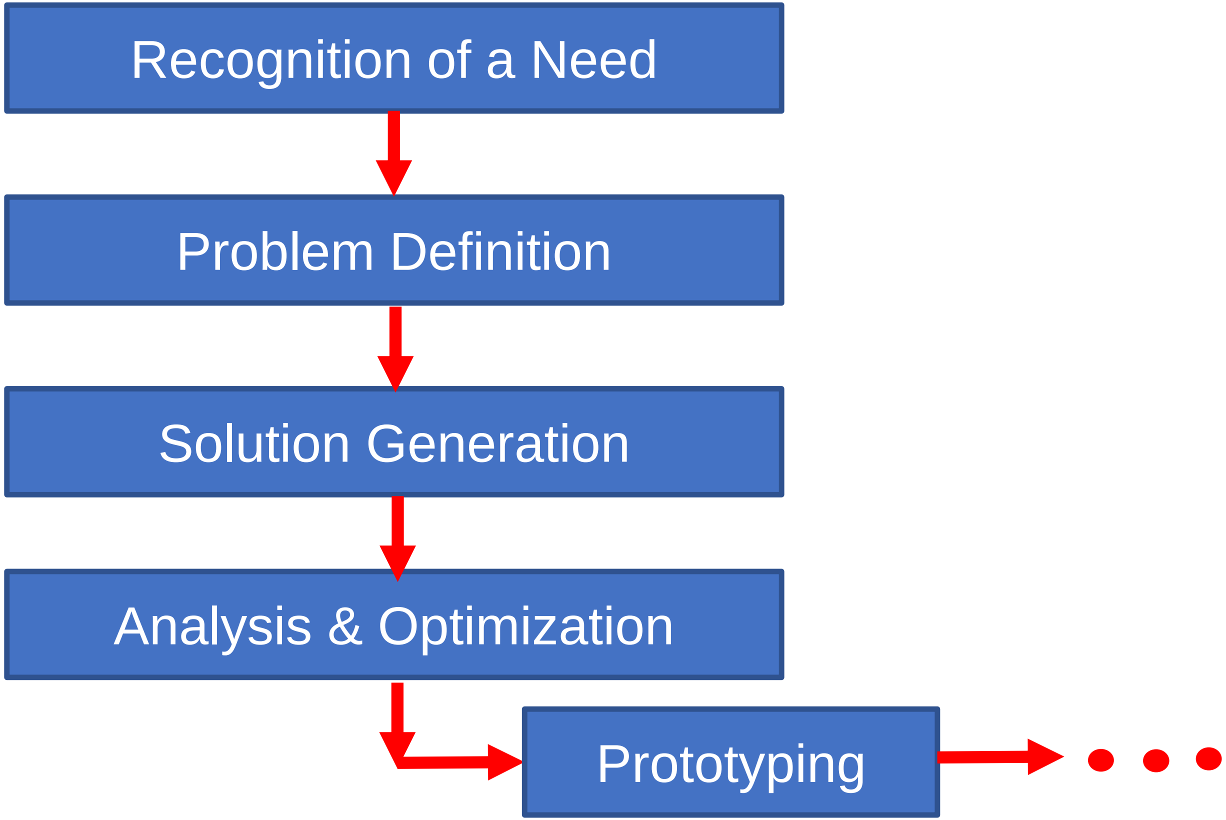

Today
~Feb. 10
~Aug. 10
Phase 1 (12 mo)
Phase 2 (12 mo)
Phase 3 (12 mo)
Systems Tracks
Track A
DARPA-funded teams
Track B
Self-funded teams
Tunnel Circuit
Urban Circuit
Cave Circuit
DARPA-funded teams
Self-funded teams
Systems Final Event
Virtual Tracks
Track C
DARPA-funded teams
Track D
Self-funded teams
DARPA-funded teams
Self-funded teams
Virtual Final Event
Legend:
DARPA Contract
Prize

CS/EE/ME 75(a,b,c)



Structured Design Method(s)

Design is a process that has a general structure.

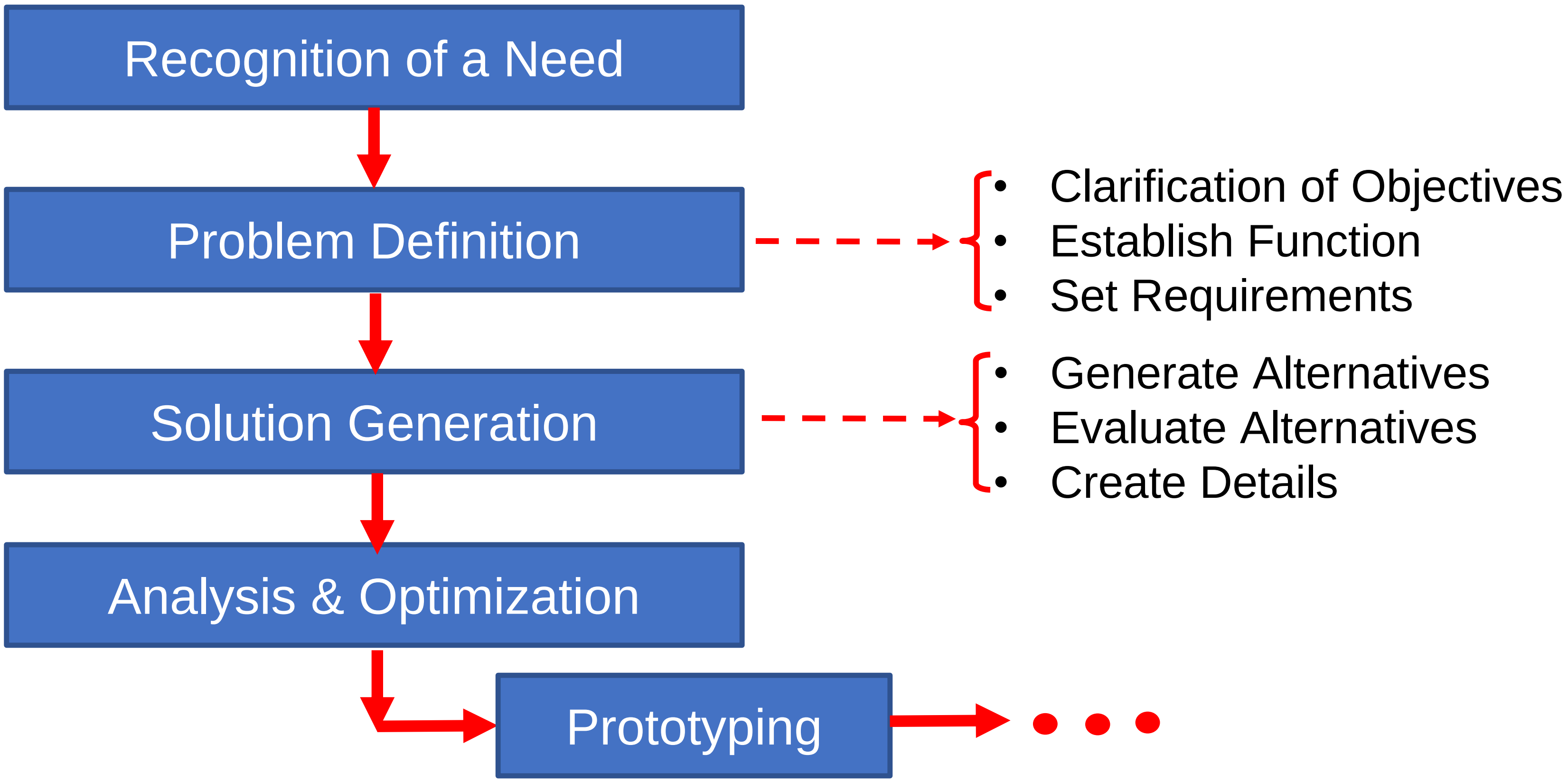


Structured Design Method(s)

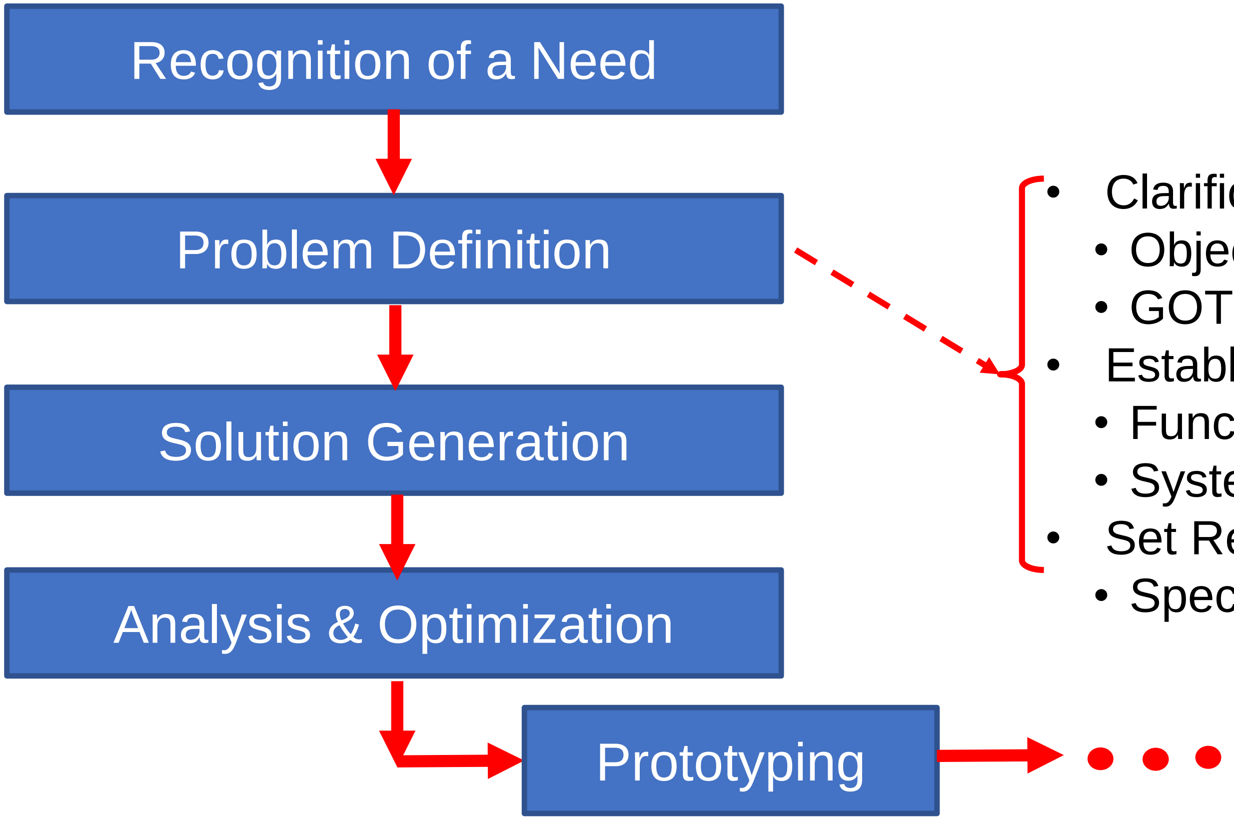
The System Engineering Process should have structure

- Structured flow of the problem solving process
- Structured components of each step
- Structured design methods for each step
- Structured Artifacts to capture, archive, and disseminate the steps of the design process

Structured Design Method(s)



Structured Design Method(s)



- Clarification of Objectives
  - Objective Tree
  - GOTChA chart
- Establish Function
  - Function Diagrams
  - System Architecture
- Set Requirements
  - Specifications

(Structured) Design Artifacts

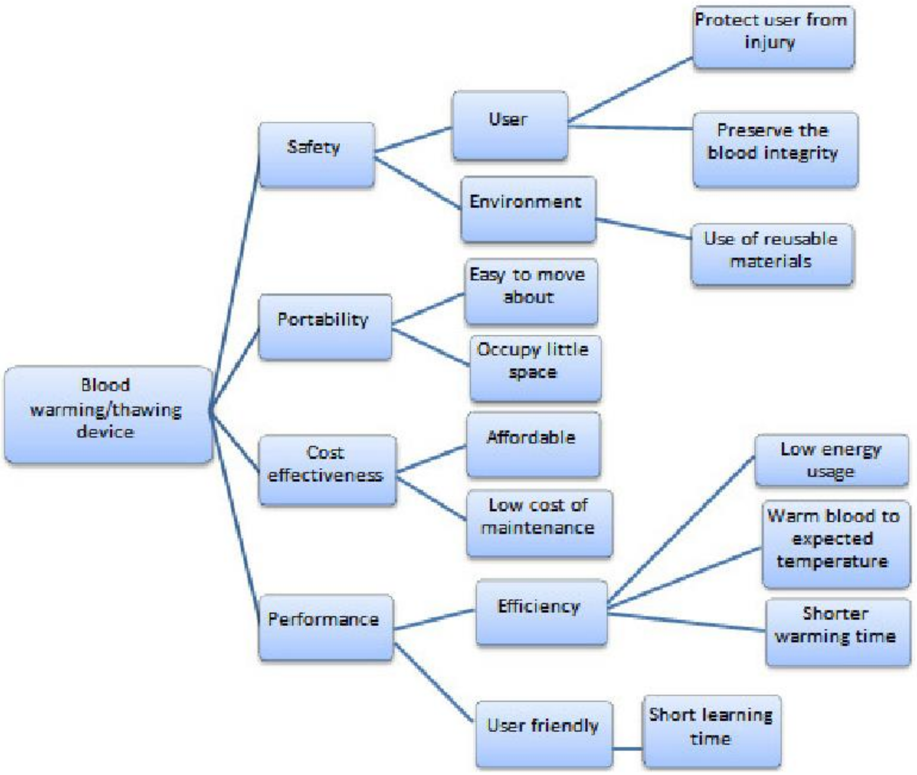
Main Idea:

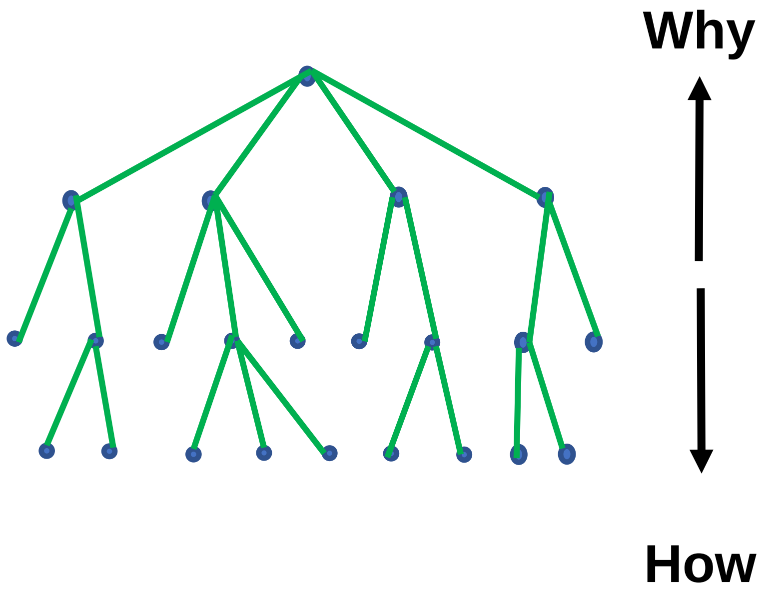
- Capture key steps of the design process
- Communicate intent.
- Provide directions to designers, developers, testers
- Different artifacts needed for different users and process stages

Users

- *Stakeholders:* the people affected by the system design & deployment
- Management
- Design, Development, and Test Teams

Objective Tree





GOTChA Charts

(for developers and managers)

GOTChA :

- **G**oals
- **O**bjectives
- **T**echnical **Ch**allenges
- **A**pproach

- Use a *Quad Chart* structure

Goals: high level description of main goal(s) and desired results of the project/effort	**Technical Challenges:** list expected difficulties • ***Challenge 1*** • ***Challenge 2*** • ***Challenge 3***
Objectives: list of objectives required to meet goal • **Obj. 1:** <*obj* > < *date* > • ***Obj. 2:*** <*obj*> < *date* >	**Approach:** list of proposed methods to realize goals/objectives • ***Act. 1*:** < build a model > • ***Act. 2*:** < simulate the model > • ***Act. 3*:** < design experiment

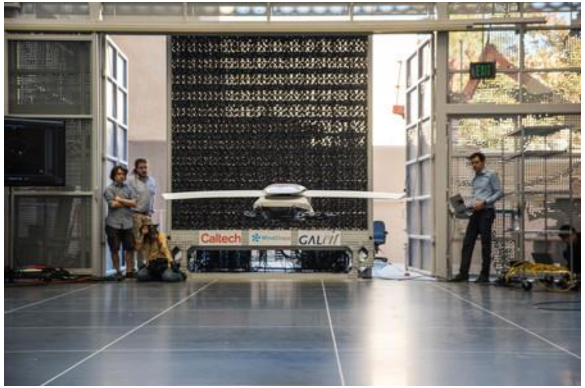
Learning to Fly

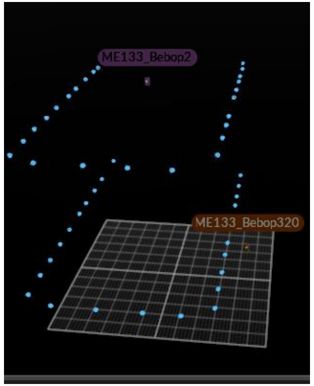
Anima Anandkumar (animakumar@gmail.com), Joel Burdick (jburdick@caltech.edu, 626-395-4139), Soon-Jo Chung (sjchung@caltech.edu), Yisong Yue (yyue@caltech.edu),

Need/Justification:

- Vehicle performance can be strongly affected by nonstationary and variable effects in its surrounding fluid flow
- Current practice relies upon exhaustive and expensive wind-tunnel testing to refine control system design and performance.
- Rigorous nonlinear, optimal, stochastic control techniques that incorporate learning could improve performance, and lower wind-tunnel and flight testing costs.

Objectives: Based on theoretical, simulation, and experimental investigations, this effort will demonstrate in the CAST center at Caltech the ability for autonomous fixed wing aircraft and rotorcraft to ***safely*** and ***stably*** incorporate real-time learning of changes in environmental and system dynamics. We will build and demonstrate this capability through 5 demonstrations, and quantify the efficiency, robustness, and effectiveness of the techniques.

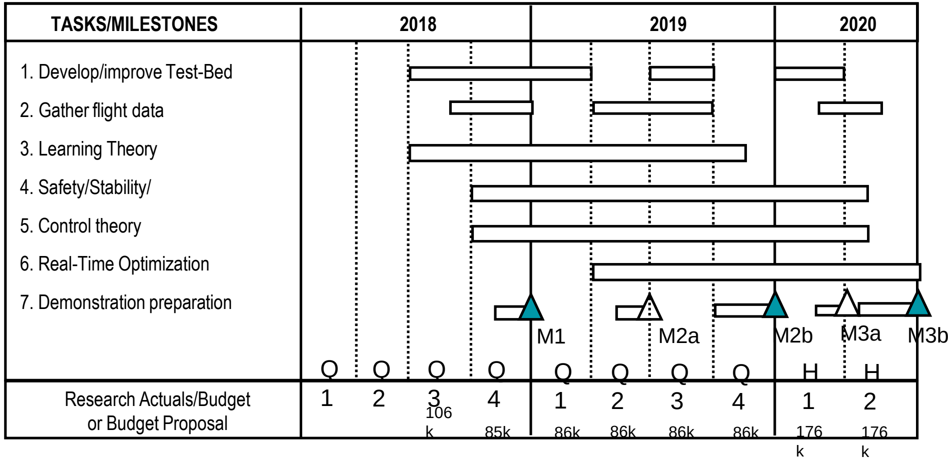




Approach: The proposed program will incorporate the following activities.

1. **Theory & Algorithms:** We will explore and compare multiple approaches to dynamic model learning based on Gaussian Processes, Koopman Spectral Techniques, and Reinforcement learning. For safety and stability we will investigate and compare new techniques in Control Barrier Functions, safe optimization, and nonlinear stochastic optimal control and stabilization. New techniques that blend the novel learning and nonlinear control methods will be developed and compared.
2. **Simulations:** We will develop strip-based aerodynamic models of the CAST flying ambulance to vehicle to serve as a starting model for the learning processes.
3. **Experiments:** We will instrument and gather data from a fixed wing and multi-rotor craft operating in unsteady flow conditions in the CAST center at Caltech.
4. **Demonstrations:** Demonstrations are planned every 6 months as an integrating focus and as a procedure to evaluate progress, and evaluation methodology.
5. **Knowledge transfer:** technical papers, copies of the prototype code and algorithms used in CAST demonstrations, data resulting from simulations and tests, seminars at Raytheon Missile, exchange of student interns and researchers with Raytheon Missile.

MILESTONES & SCHEDULE: **Proposed 2018/2019 Budget: $535k**



Adaptive Self-Correcting T/R Module

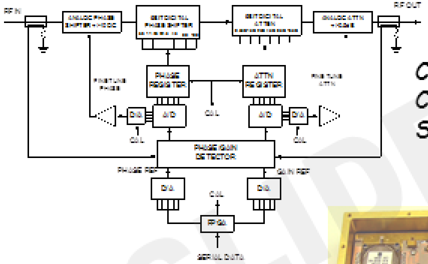
PI: Wendy Edelstein, JPL

Objective

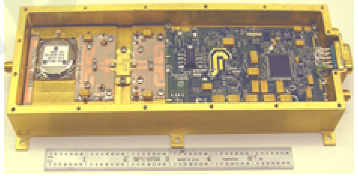
Develop a practical and low cost adaptive L-band T/R module with integrated calibrator for use in phase-stable array antennas for interferometric synthetic aperture radar (InSAR) applications.

Performance goals are <1 deg absolute phase stability and <0.1 dB absolute amplitude stability over temperature.

Technologies include high efficiency L-band T/R module; integrated phase/amplitude detector; closed-loop detection and correction circuitry.



Closed-Loop Calibration Scheme



High-Efficiency L-band T/R module to be modified with integrated calibrator

Approach:

Modify an existing high-efficiency L-band T/R module with built-in calibrator by:

1. Developing a stable closed-loop amplitude and phase detector circuit.
2. Integrating the calibrator circuit into the L-band T/R module.
3. Characterizing performance over temperature to demonstrate ability to self-correct for variations in insertion phase or amplitude.

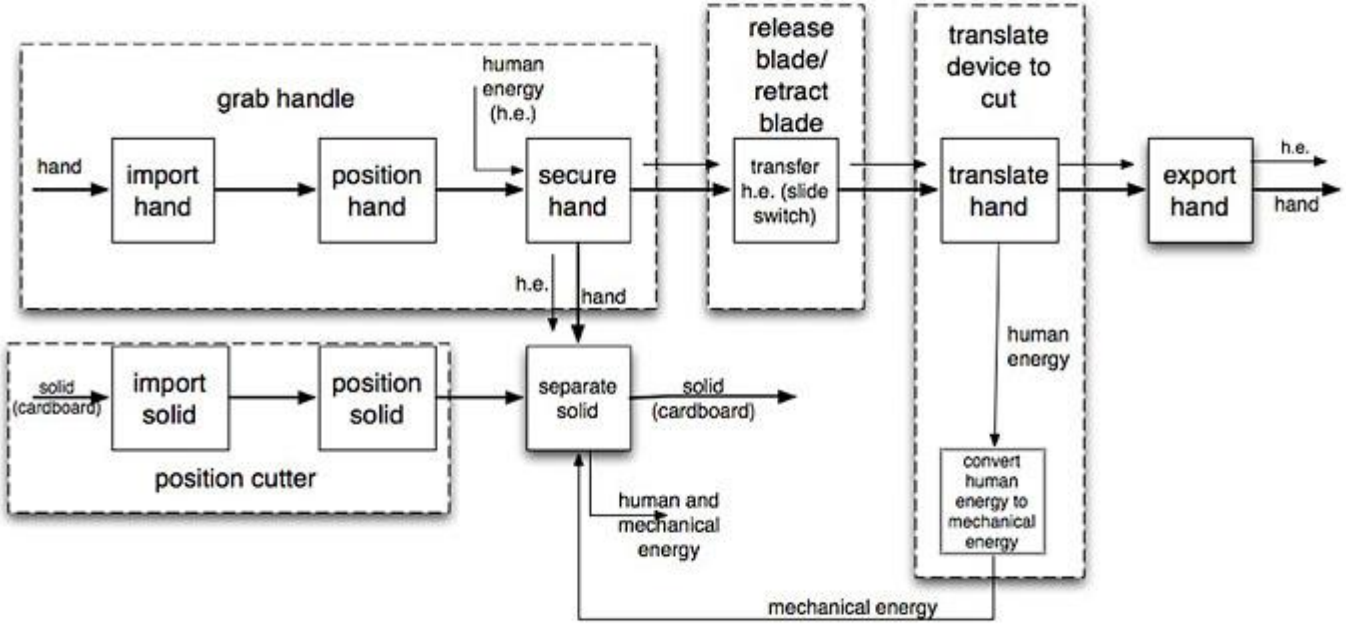
CoIs: Constantine Andricos, Gregory Sadowy, JPL

Key Milestones

• Requirements, architecture, design	7/06
• Breadboard demo (TRL 5)	1/07
• Build T/R with integrated calibrator	7/07
• Prototype validation (TRL 6)	1/08

TRL_{in} = 4

Function Diagram



System Architecture

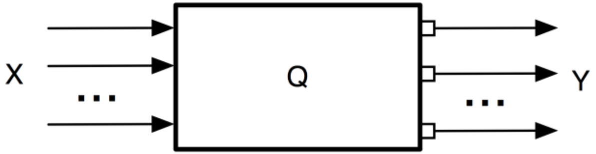
What is an Architecture:

- A model/structure of the system
- Properties of the various elements involved in the system
- Relationships between the various elements
- Behaviors and Dynamics of the various elements
- Multiple Views of the system (from energy usage, information usage

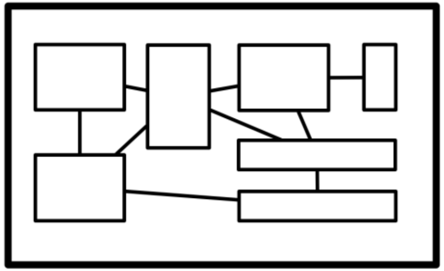
System Architecture

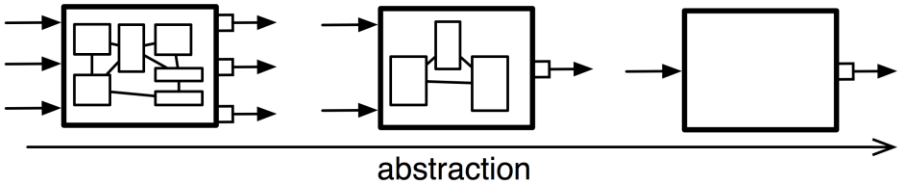
Requirements for an Architecture:

- The objects/elements of the system can be modeled (possibly as their own systems)



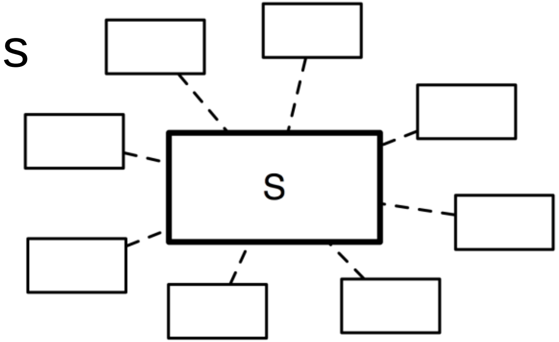
- System can be broken down into small systems (hierarchy)
  - Can be considered at various levels of abstraction



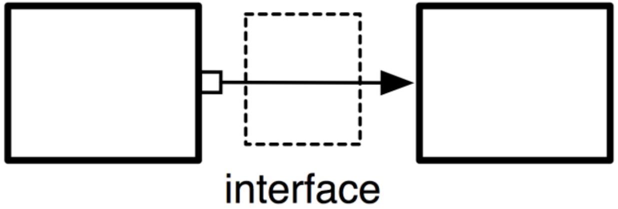


System Architecture

- Interactions with environment and other systems



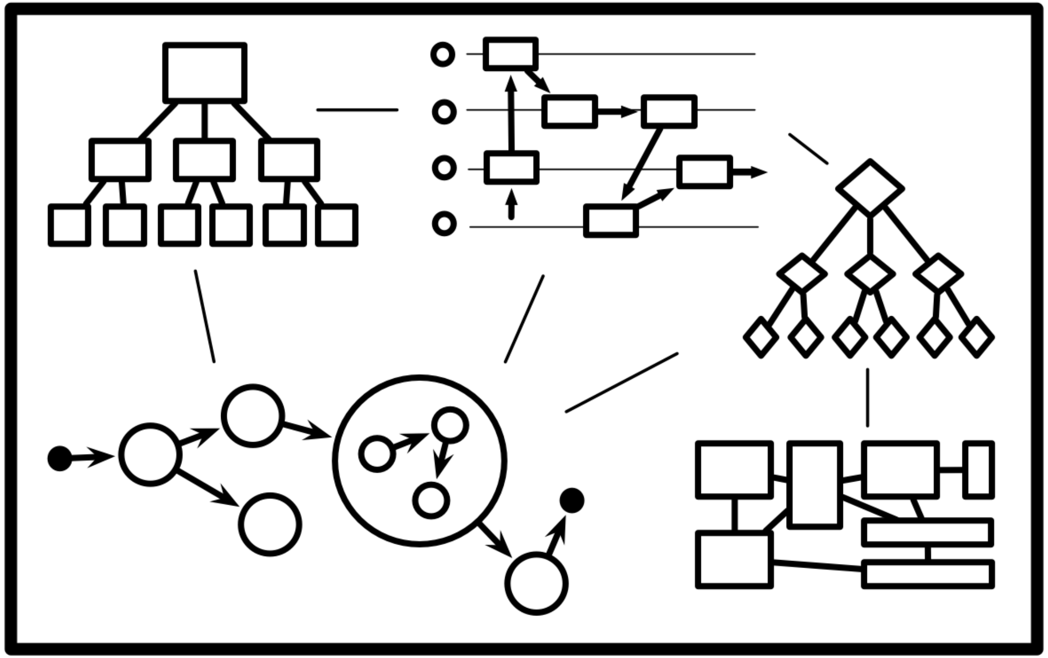
- Interfaces between components



- Socio-Technical Aspects
- Behaviors and Dynamics of the various elements
- Multiple Views of the system (from energy usage, information usage

System Architecture

- Multiple Views of the system (from energy usage, information usage



Homework

Individual Tasks:

- Get an account on GitLab: gitlab.robotics.caltech.edu. Joel will then assign permissions
- Get a slack account
  - Ask to join caltechcseeme75.slack.com

Team Tasks: (all unit levels)

- Develop a GOTChA chart for your project.
- Develop an objective tree for your project
- Create a Team project page on the course wiki
- Propose to Joel a separate 1-hour/week team meeting time

Team Tasks: (6+ unit level)

- **RC Car:** meet with Jake to get CAD models, etc. Make new GitLab project directory
- **Drive-O-Copter:** Meet with Arnon, Luis Pabon, Malcolm Tisdale to get CAD models/update
- **Extreme Localization:** Organize research sub-teams for different localization technologies