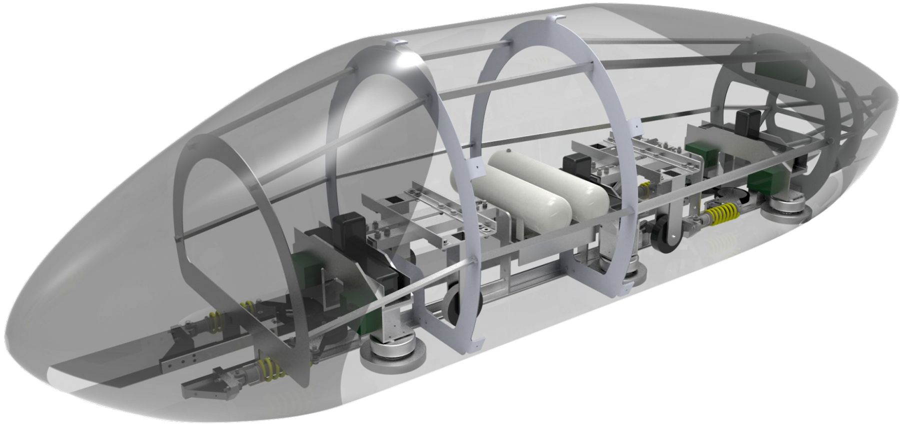
Sensors & Controls

Initial Design Review

Introduction

- The Hyperloop Competition
  - Pod design competition hosted by SpaceX
  - ~1 mile long low pressure tube test track
  - Pods judged on max speed and successful deceleration
- The Sensors and Controls Team
  - Create a control system to interface with sensors and mechanical parts



Development Team

Yang Ren: Microcontroller, PCB SPI interface, data storage

Asitha Kaduwela: Mag Lev motor sensors and control

Tristan Seroff: Braking sensors and control, slave board SPI interface

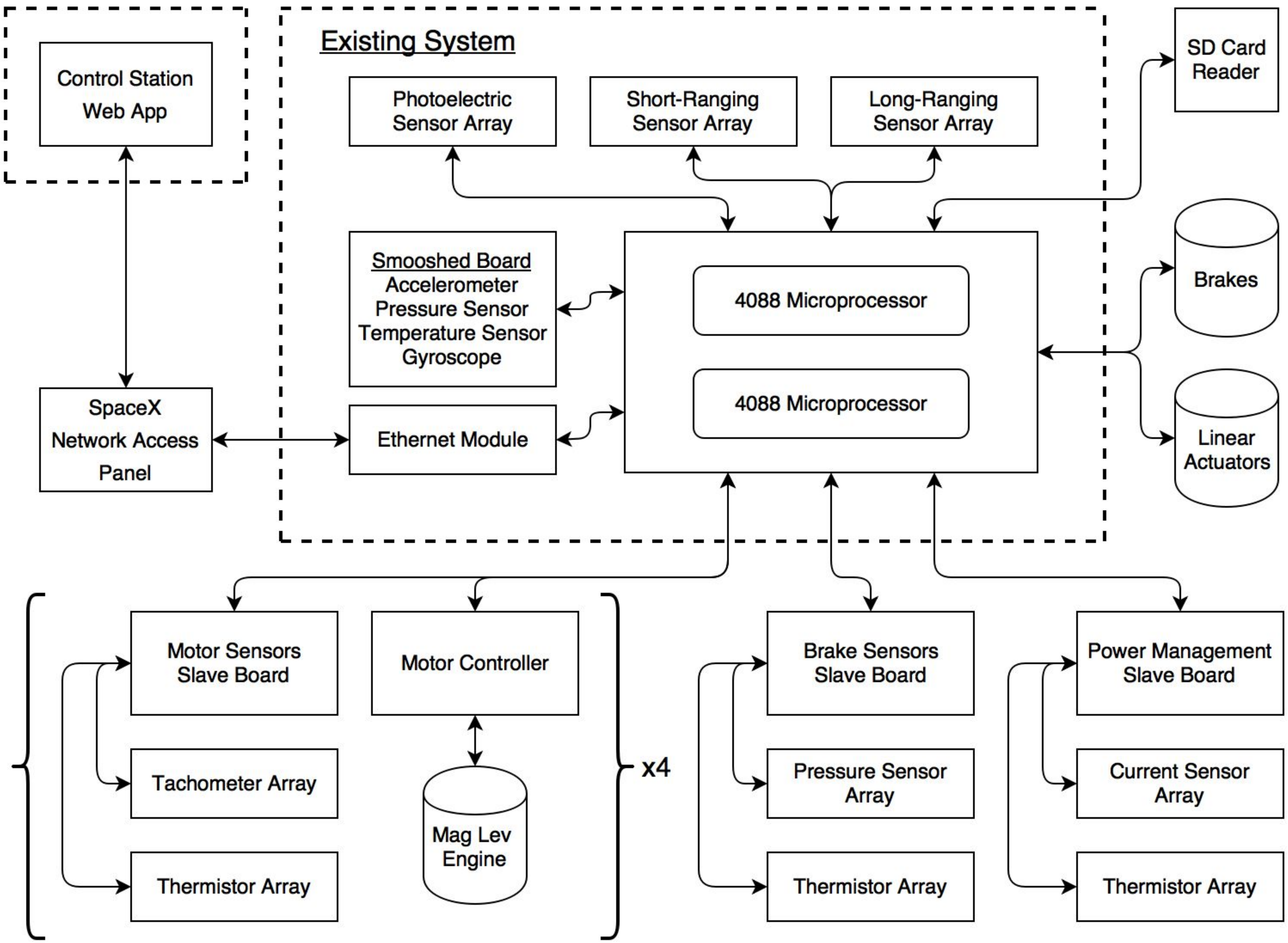
Jesus Diera: Web application, Ethernet interface

(EEs: Kevin Kha, Brian Canty, Ricardo Castro)

Initial Specifications

- Read pod sensors
  - Position, velocity, acceleration
  - Temperature, motor rotation, battery current, brake actuation
- Perform telemetry
  - Send pod status data to web app
- Control pod states
  - Startup, shutdown, emergency braking
- Control navigation and stabilization systems

Block Diagram



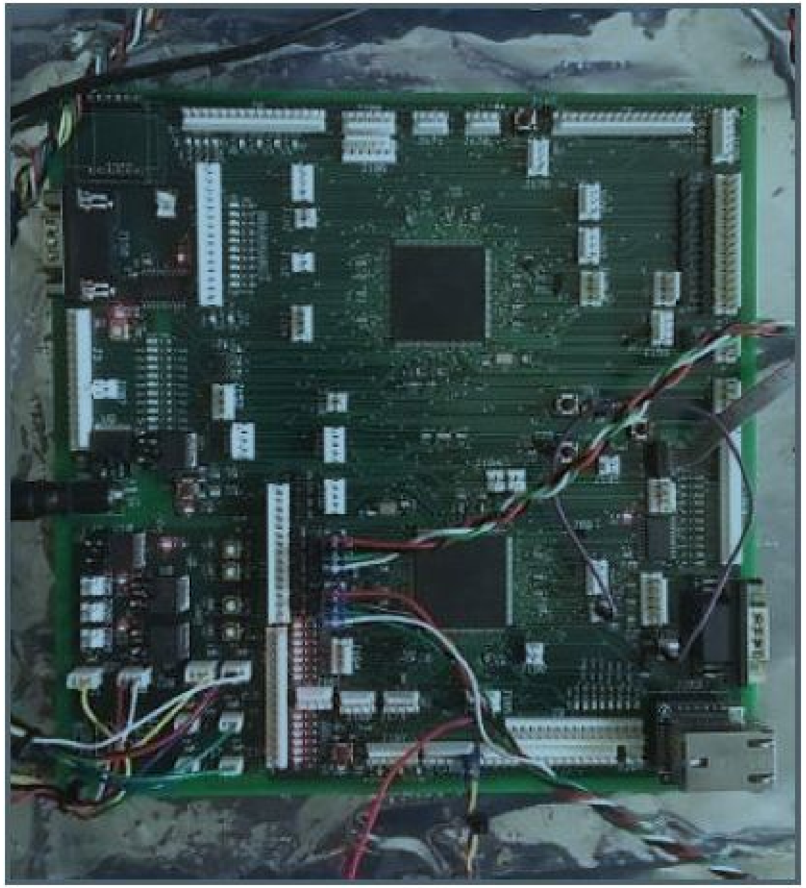
Development Plan Overview- Fall ‘16

- Develop all sensor slave boards (November 8th, 2016)
- Calibrate all sensors (November 15th, 2016)
- Display all sensor data on web app (November 15th, 2016)
- Control all individual mechanical parts (Dependent on MEs)
- Create pod state machine (Dependent on MEs)

A detailed Gantt chart can be found here (requires Gantter for Google Drive).

Technology/IP Reuse: PCB

- 8.1” x 8.1” printed circuit board
  - 2 ARM Cortex-M4 microcontrollers
  - 430 components
- Sensor Data
  - Receive and send data to SD card and Web App
  - Sensors connect through external slave boards
- Ethernet module
  - Communicate data to Web App at least once per second
- Expandable
  - Can integrate newly added sensors

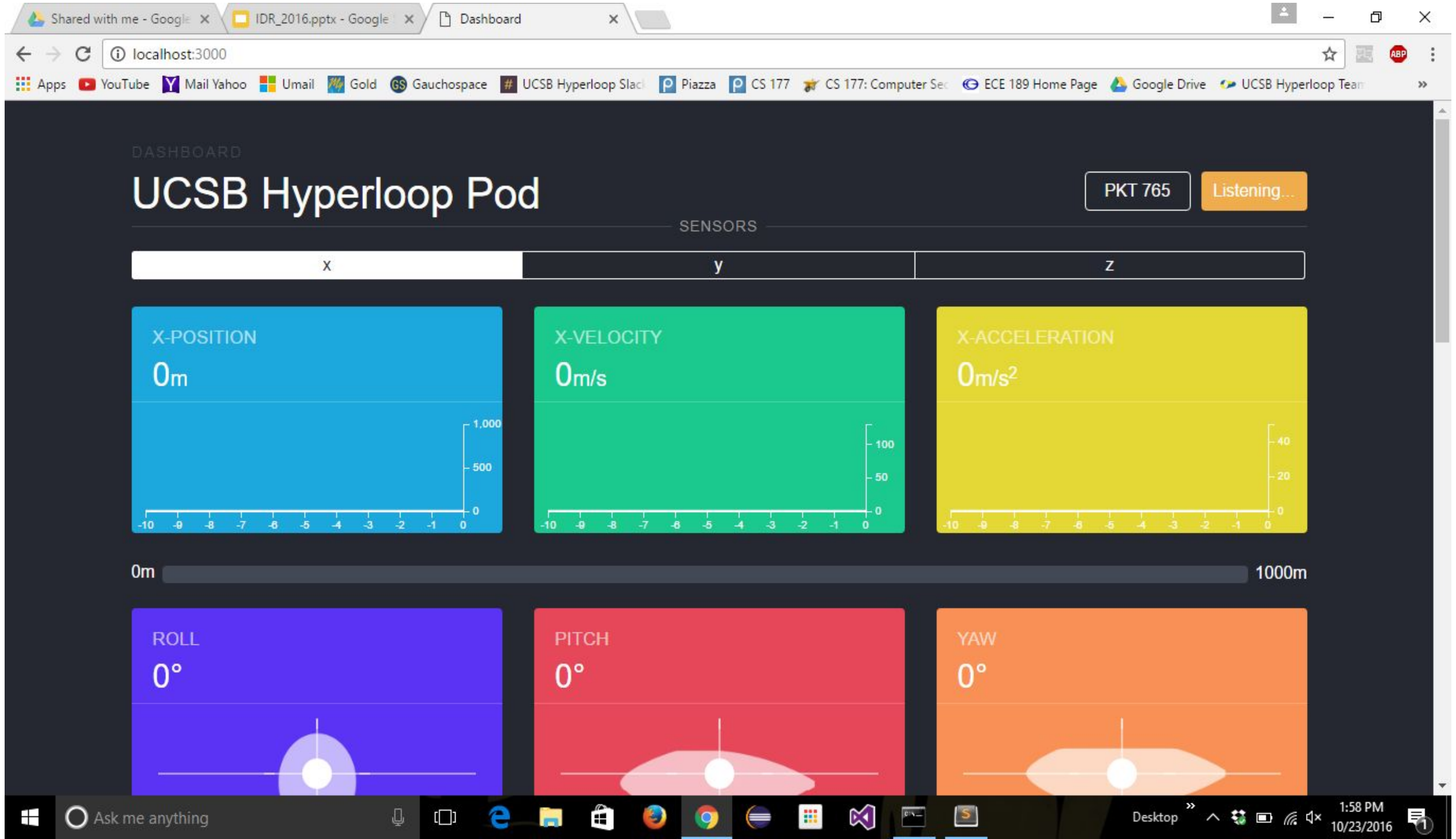


Technology/IP Reuse: Sensors

- Long Distance Ranging
  - Long distance ranging sensor for the pod’s sides
  - Gives position relative to sides of the tube
- Short Distance Ranging
  - Short distance ranging sensor positioned on bottom four corners of the pod
  - Roll/pitch/yaw derived for stability/levitation feedback
- Photoelectric sensor
  - Recognize reflective strips mounted on the tube to determine pod travel distance in the test track

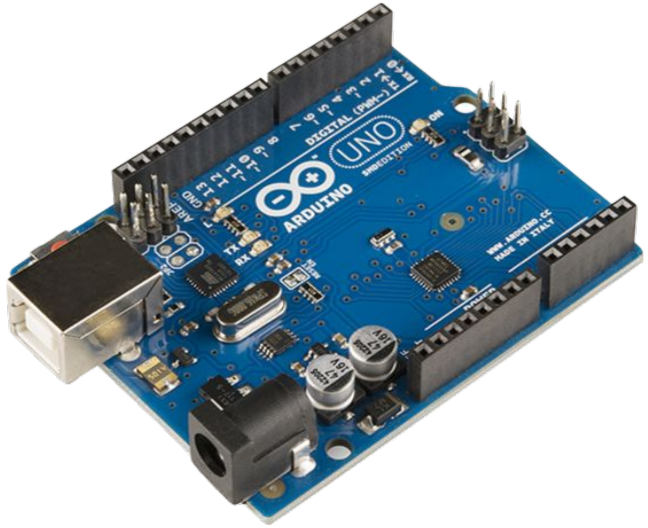
Technology/IP Reuse: Web Application

- Monitor real time sensor data at least once per second
- Send control signals for things like Emergency Braking, Powering Up
- Communicate through SpaceX NAP connected to PCB's ethernet module



New System: Slave Boards

- Arduino “slave boards” collect subsystem sensor data
  - Utilize the ADC peripherals of Atmel microcontrollers
  - Communicate data back to main PCB with SPI connections
  - Cost: $25/unit
- Specific configuration and calibrations for each subsystem:
  - Mag Lev motors
    - Monitor temperature and rotational speed of motors
  - Power distribution
    - Monitor temperature and current of battery cells which supply motors and electronics
  - Braking
    - Monitor temperature and actuation status (pressure / position) of braking systems

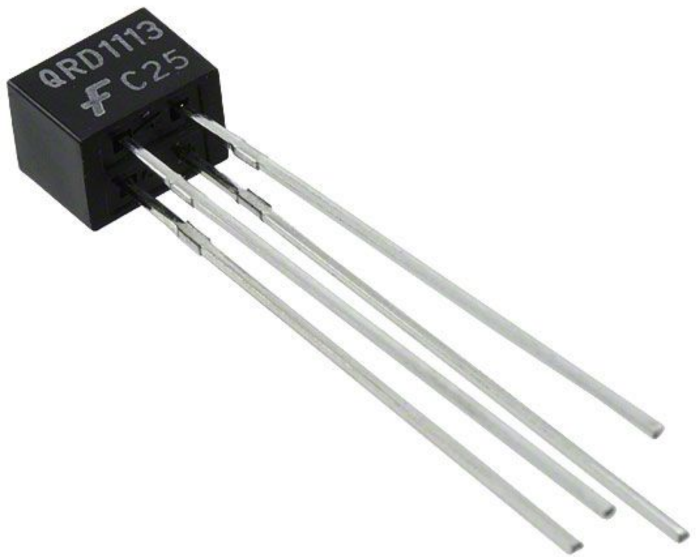


New System: Thermistors

- Temperature Monitoring
  - Motors, batteries, brakes
- NTC Thermistor 10k Bead
  - Range: 55°C to 125°C
  - Resistance: 10kΩ @25°C, 0.5-50kΩ range
  - Cost: $1.50/unit

New System: Reflective Object Sensors

- Sensors used to validate RPM of Mag Lev motors
  - Reflective strips on motor disk trigger sensor
- QRD1113
  - Response time: 10µs
  - Sensing Distance: 1.27 mm
  - Cost: ~$1.50/unit

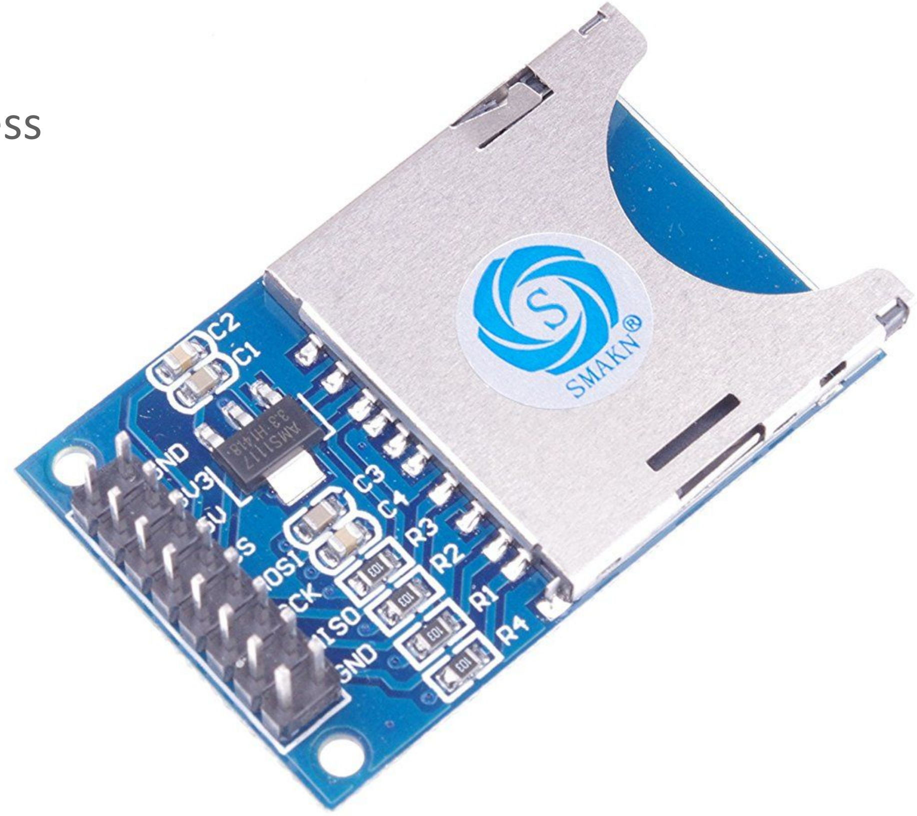


New System: Current Sensor

- Current monitoring
  - Batteries for PCB, brakes, motors
- ACS759
  - Hall effect based current sensor
  - Analog voltage output signal
  - Sensing range: 150A
  - Cost: $31.25

New System: SD Card Reader

- Sensor Data Storage & Event Logging
  - Store sensor data as individual files on SD card for easy access
  - Log pod events for testing and debugging
- SMAKN® SD Card Reader Module Chip
  - SPI Interface
  - Cost: $5.66



Bill of Materials

Existing System	**New System**
PCB components: $382.25	Current Sensors: $250
Photoelectric Sensors: $60	Thermistors: $45
Long Ranging Sensors: $8.74	Arduinos: $200
Short Ranging Sensors: $7.48	Reflective Object Sensors: $6
Ethernet Module: $28.00	SD Card Reader: $5.66
	Total: $983.13

Critical Elements: Potential Points of Failure

- Sensor data will need low latency in order to provide effective control of critical pod systems such as stability
- Sensor calibration accuracy
- Development of feedback control will be “open-loop” for time being due to physical pod construction taking time
  - Algorithms will need refinement in the future once testing is possible

Conclusion

- Any questions?