INTRODUCTION

**what is the competition?**

• What is the Hyperloop?
  • Proposed transit between Los Angeles and San Francisco
  • Low pressure tube
• What are the requirements of the competition?
  • Levitating
  • Traveling a 1-mile tube
  • Braking safely at the end
  • Communicating telemetry wirelessly
  • Controlling the pod
INTRODUCTION

pod concept
DEVELOPMENT TEAM

areas of expertise

• Celeste Bean: microcontroller, photoelectric sensors, control systems
• Connor Buckland: ranging sensors, accelerometer
• Cameron McCarthy: LCD screen, consolidated sensor
• Ben Hartl: barometer/thermometer, gyroscope
• Connor Mulcahey: WiFi, web application
INITIAL SPECIFICATIONS

competition requirements

• Wirelessly communicate at 1 Hz
  • Pressure
  • Temperature
  • Acceleration
  • Velocity
  • Position
  • Attitude
• Check the readiness of all systems and begin testing
• Manage stability/levitation/braking control systems
• Ensure emergency braking can activate
uCONTROLLER

LPC NXP4088

• Planning to use (2) 4088 microcontrollers
  • (1) includes all of our current requirements
  • (2) is allocated for unanticipated needs
• Has more than enough horsepower for our usages and integrates well with LPCOpen
• Plan on running both at 120 MHz
• Synced using a real time clock
**SENSOR BOARD**

*10-DOF IMU Breakout*

- Main source for telemetry
- Combines four sensors:
  - Temperature sensor
  - Pressure sensor
  - Accelerometer
  - Gyroscope
- Communicates via I2C
  - Memory-mapped addressing to specify component
  - Allows for selectivity in reading sensors
SENSORS

**consolidated board**

- **Accelerometer**: *LSM303DLHC*
  - Telemetry, navigation, and emergency braking
  - I2C access at data rates <5.376 KHz
  - Sensitivity: 1 mg/LSB at +/- 2G measurement range

- **Gyroscope**: *L3GD20*
  - Telemetry and stability control
  - I2C access at <400 kHz
  - Degrees per second (DPS): 250, 500, or 2000 DPS

- **Barometer/thermometer**: *BMP180*
  - Telemetry
  - I2C access at <3.4 MHz
  - Pressure range: 300 – 100 hPa
    - Accuracy: -4 hPa to + 2 hPa
  - Temperature range: 0°C to 65°C
    - Accuracy: ±1°C
LONG DISTANCE RANGING

**GP2Y0A02YK**

- Long distance ranging sensor for the pod’s top and sides
  - Re-correlates estimated attitude with actual attitude
  - Gives position relative to sides of the tube
- Accurate from 20 cm – 150 cm
- Analog output requires use of A/D converter for digital reading
SHORT DISTANCE RANGING

*GP2Y0A51SK0F*

- Short distance ranging sensor for the pod’s bottom
  - Re-correlates estimated attitude with actual attitude
  - Gives position relative to sides of the tube
  - For stability/levitation feedback
- Accurate from 2 cm – 20 cm
- Analog output requires use of A/D converter for digital reading
PHOTOELECTRIC SENSOR

E3FB-DP13 2M

• Diffuse-reflective photoelectric sensor
  • Detects when reflected light is above a configurable threshold
  • Used to recognize the positional strips on the top half of the tube
  • Will recalibrate INS system
• Accurate up to 1 m
• 0.5 ms response time
• Analog output requires use of A/D converter for digital reading
LCD SCREEN

*NHD-0416BZ-NSW-BBW*

- Display sensor readings and initial start up checks during testing
- New character can be displayed every 600 nS
  - Writes by specifying cursor location and the character to be written there
- Decided more expensive option on the Development Kit was overkill
ETHERNET MODULE

$WIZ820io$

- Will communicate with SpaceX’s Network Access Panel
  - SpaceX is providing a solution to communications problems
  - Requires a DB9 connector
  - Requires an Ethernet interface
Introduction
Components
Control Systems
Power
High-Level Plan
Conclusion
PRINTED CIRCUIT BOARD

physical layout
CONTROL SYSTEMS

• **stability**

• Closed feedback loop:
  • 6 inputs
    • 2 gyroscopes at front and back of pod
    • 4 ranging sensors at bottom corners of pod
  • 4 actuators
    • Control each motor’s levitation to maintain stability and correct disturbances
CONTROL SYSTEMS

navigation

- Tube will have reflective strips on upper half
  - 100 ft intervals
  - More condensed strips indicate 1000 ft and 500 ft left
- Dead reckoning
  - Double integrate accelerometer
  - Determines position between strips
  - Recalibrate with diffuse-reflective photoelectric sensor
  - Determines absolute position
  - Recognize the reflective strips on the top of the tube
  - Compensates for accelerometer integral drift
CONTROL SYSTEMS

- **braking**

  - Dynamic braking command
    - navigation system determines position in pod

  - Hard-wired braking command
    - velocity profile determines exact time at which brakes should be applied

[Diagram showing position profile over time]
## POWER DISTRIBUTION

- Electrical Engineering team supplying 8V to our PCB
  - 5V analog, 5V digital, 3.3V analog, 3.3V digital, and an isolated 3.3V digital line
- Photoelectric sensor will be handled separately

<table>
<thead>
<tr>
<th>Components</th>
<th>Supply Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photoelectric sensors (2)</td>
<td>12 V</td>
</tr>
<tr>
<td>Gyro/Accel/Temp/Press (2)</td>
<td>5 V</td>
</tr>
<tr>
<td>Long ranging sensors (6)</td>
<td>5 V</td>
</tr>
<tr>
<td>Short ranging sensors (4)</td>
<td>5 V</td>
</tr>
<tr>
<td>LCD Screen (1)</td>
<td>5 V</td>
</tr>
<tr>
<td>uController (2)</td>
<td>3.3V</td>
</tr>
<tr>
<td>Ethernet module (1)</td>
<td>3.3 V</td>
</tr>
</tbody>
</table>

**Onboard electronics**

(telemetry, controls, and wireless communication)
CRITICAL ELEMENTS  
potential points of failure

• Short distance ranging sensor  
  • Pod needs to know how far it is from the bottom of the tube  
  • Could stray too far and derail  
  • Could drop too low and scrape the bottom of the tube  
• Photoelectric sensor  
  • Pod needs to know its position relative to the end of the tube  
  • Will feed data back to slow down  
• Accelerometer  
  • Pod needs to know how fast it is moving to anticipate braking requirements
TECHNOLOGY/IP REUSE

existing efforts

• Developing on the NXP LPC4088 Developer’s Kit
• Using LPCOpen
  • Open source libraries and code
• Consolidated sensor board has associated template code
• LCD Screen has associated code
BILL OF MATERIALS

*tentative budget*

- Please see attached documentation.
CONCLUSION

• Moving forward
  • Winter quarter
    • Prototyping our sensors using the 4088 Developer’s Kit
    • Developing website
    • Attending the SpaceX Design Weekend in January
  • Spring quarter
    • Integrating our testing into our PCB
    • Developing controls systems

• Thank you to Dr. Johnson and Will Miller for their patience and guidance.

• Questions?