Mission Abstract (2)

There is overwhelming evidence that the concentrations of volatile organic compounds (VOCs), sub-stratospheric ozone, and high particulate counts are important pollutants that can cause or contribute to negative health effects. Further, the levels of these substances can lend insight into the ambient pollution of an area. Relative to their importance, however, there is little data regarding the concentrations of these compounds, especially in Colorado and especially as they relate to altitude and proximity to industries. This information is of particular interest to, among many others, those involved in environmental science education at Front Range Community College. Satisfying this interest is the aim of the Romulus DemoSat, part of the Colorado Space Grant Consortium (COSGC)’s DemoSat Program. To this end, the Romulus DemoSat will utilize the following sensors: a CCS811 VOC sensor, an MQ131 low-concentration ozone sensor, an SPS30 particulate sensor, as well as an MS5803-14BA pressure sensor. We intend to then apply the DemoSat position monitoring offered by the COSGC with wind speed data to compile a comprehensive portrait of these pollutants and their geographical relationships to industries such as fracking and agriculture.
Scientific Overview (3)

- According to a number of case studies compiled by Joe Huffman of Carleton College, fracking releases large amounts of methane, along with other pollutants such as ground level ozone, nitrogen oxides, a variety of volatile organic compounds, and particulates.


- The EPA has released information regarding the production of ozone as a result of nitrogen oxides and VOCs. Therefore, the data we collect on both VOCs and ozone can lead us to conclusions regarding the overall pollution levels of the area.

Mission Overview (4)

Our goal was to build a payload which could observe and record the following datapoints:

- Ozone (trioxygen, an unstable allotrope of oxygen which is a pollutant at ground level)
- Volatile Organic Compounds (VOCs, a large group of organic compounds with high vapor pressure which can cause severe health effects alone and combine with oxides of nitrogen to create smog)
- Particulates (atmospheric particulate concentrations are a disastrous contributor to urban pollution which can lead to respiratory disease)
Mission Overview Cont. (5)

We then will compare this to historic data to assess how various industries including oil and natural gas exploration have impacted our atmosphere locally. Environmental science faculty on our campus have expressed interest in this data.
Systems (6)

- Life Support: power supply (batteries), heating, etc.
- Sensors: ozone, VOC, particulates, pressure
- Structural: frame, mylar shielding, insulation
- Data Recording: SD card, writer
- Time Recording: timestamping of data
Microcontroller and Sensor Selection (7)

Our experience with the DemoSat program and Arduinos lead us to select the Teensy 3.5. It has a built in SD card system that was very easy to implement. It also has built in real time clock, lots of interfacing opportunities, and a faster operating frequency.

Sensors were selected partially based on prior experience. These include the TMP36, TMP102, and SPS30. There were very few ozone sensors on the market, so we selected what we could in the MQ131. CCS811 and MS5803 were selected due to their sensing ranges and ruggedness.
Parts List (8)

- **Control**: Teensy 3.5 Microcontroller with SD
- **Sensors**: 
  - MQ131 Ozone Sensor
  - 110-406 Ozone Sensor
  - SPS30 Particulate Sensor
  - CCS811 VOC Sensor
  - MS5803-14BA Air Pressure Sensor
- **Life Support**: Heating pads, mylar shielding, temperature sensors, batteries, etc.
## Sensor Requirements (9)

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Temp</th>
<th>Humidity</th>
<th>Avg Current</th>
<th>Voltage</th>
<th>Bus</th>
<th>Other</th>
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</thead>
<tbody>
<tr>
<td>MQ131 (Ozone)</td>
<td>20 C Self Heating</td>
<td>65% RH Calibrated</td>
<td>139 mA</td>
<td>5V</td>
<td>I2C</td>
<td>48 hour Preheat</td>
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<td>TMP36</td>
<td>-40 to 125 C</td>
<td>NA</td>
<td>50 uA</td>
<td>2.7 to 5V</td>
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<td>TMP102</td>
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<tr>
<td>SPS30 (Particulates)</td>
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<td>0 to 95% RH</td>
<td>60 mA</td>
<td>5V</td>
<td>UART, I2C</td>
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<tr>
<td>CCS811 (VOC)</td>
<td>-40 to 85 C</td>
<td>10 to 95% RH</td>
<td>30 mA</td>
<td>3.3V</td>
<td>I2C</td>
<td></td>
</tr>
<tr>
<td>MS5803 14BA (Press)</td>
<td>-40 to 85 C</td>
<td>Unknown</td>
<td>1.4 mA</td>
<td>3.3V</td>
<td>I2C or SPI</td>
<td>0 Bar, RH not in datasheet</td>
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<tr>
<td>Requirement</td>
<td>-10C min</td>
<td>10% with Calibration</td>
<td>229 mA avg L Supp. TBD</td>
<td>5V and 3.3V</td>
<td>I2C and 1 UART</td>
<td>About 1 Watt</td>
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</tbody>
</table>
Special Requirements Summary (10)

- Heating (both for sensors and our power supply)
- Ozone Sensor (more on next slide)
- 5V line (not provided by Teensy)
- I2C and UART interfaces
- Data Storage
- Accurate Time Stamping
- Air Pressure Sensing
- Temperature Sensing
Code Overview (11)

- Code has been separated into classes that cover the functionality for the sensors, data recording, time keeping, and thermal control.
- The sensor class contains a pure virtual function, FillData().
- The code also features a number of guard-rails within loops. These are meant to break functionality of loops that we might get stuck in.
- The base SD library for the arduino also contains a one-line code patch identified in the forums which allows us to hot-insert the SD card. This is to safeguard against the SD card disconnecting and reconnecting during flight.
Code was stored on Github so that each member could work on coding in their own time. As it coding is such a core part of the DemoSat program, we wanted to make sure each member could have an opportunity to do some hardware programming. An **abstract** sensor class was developed to fulfill this, as there were enough sensors to split evenly amongst the team. The abstract class had a number of functions that would be called from the main loop, and each member had to implement a function to fill an array of sensor values. This allowed the main loop to be coded pretty quickly, and helped in isolating bugs.

Since some members of the team had more coding experience than others, it became a great way to generate team engagement, and active learning.
Solutions (13)

- States: Pre-Heat, Ready, Running
- Loop: Get Data -> Record Data -> Life Support -> Jump to start
- Memory: 32gb SD to give us a large allowance
- Samples: While we’ll attempt to sample as often as possible, this will probably be less than 1 per second
- Data Transfer: ‘Native’ SD
- Clock: ‘Native’ Real Time Clock

Notes: Most of our loops have counters to break them out if a serial interface becomes unresponsive.
Protoboard Mounting Bracket
Test Plans (17)

- Standard tests that are explained in the Demosat User Manual will be performed (whip, drop, bench, etc…)
- Sensor Tests: will be completed after each sensor is calibrated
- At least one full pre-heat and cold bench test will be performed for system validation.
- General calibration can be done via colocation. This will involve going to an already calibrated sensor, and adjusting the code to account for the difference for each sensor.
- Failures can occur if sensors are calibrated improperly, or code gets hung up in a loop.
## Budget (18)

~$500 limit

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<th>Item</th>
<th>Quantity</th>
<th>Cost per Item</th>
<th>Cost</th>
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<td>20.95</td>
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<tr>
<td>SPS30</td>
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<tr>
<td>TL431BQLP VREF</td>
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<td>MS5803-14BA</td>
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<td><strong>Total</strong></td>
<td><strong>174.02</strong></td>
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</tr>
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</table>
Management (19)

Team Leader: James Craft, Electrical Engineering

Team Members:

- DJ Richardson, Computer Science
- Vivia Van De Mark, Biomedical Engineering
- Tyler Dow, Computer Science

Mass Budget: Must be less than 800g (COSGC Limit)

Financial Budget: ~$500