Visual Approximation of Nanosat Trajectories to Augment Ground-based Estimation

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Customer: Prof. Penina Axelrad (CCAR), John Gaebler (CCAR)

Advisor: Prof. Marcus Holzinger
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<th>Section</th>
<th>Presenter</th>
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<td>Overview</td>
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<td>Schedule</td>
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<td>Manufacturing</td>
<td>Zach Talpas, Aaron Aboaf, Jerry Wang, Dylan Bossie</td>
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<td>Budget</td>
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Project Purpose

Objectives:

The long term vision of this project is to augment existing, ground-based CubeSat Space Situational Awareness (SSA) by observing CubeSat deployments from the perspective of the NanoRacks (NR) ISS-based deployer.

This year’s VANTAGE team will produce a proof of concept for this mission by developing a ground based prototype which will be tested using a simulated CubeSat deployment in a laboratory environment.

Project Stakeholders:

- **Customer:** Prof. Axelrad and John Gaebler
- **Associated Company:** NanoRacks
## Specific Objectives

<table>
<thead>
<tr>
<th>Structures - STR (level 2)</th>
<th>All key system components <em>fit</em> in the structure, but they only need to <em>function</em> as a “flat sat”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tracking - TRK (level 2)</td>
<td>VANTAGE software will <em>track the states</em> of 1-6 mock CubeSats out to 100m and <em>report off-nominal velocities</em> of these CubeSats</td>
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<tr>
<td>Power - EPS (level 3)</td>
<td>VANTAGE’s EPS will distribute power corresponding to the available power from the NR deployer</td>
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<tr>
<td>Testing - TST (level 2)</td>
<td>Test rigs can <em>simulate physical deployment</em> of up to six (6) mock CubeSats <em>out to 100m</em> and record position <em>truth data</em></td>
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</tbody>
</table>
CONOPS

Boot > Manifest > Pre-Process > Ready! > Go! > Sensing > Post-Process > Output

Launch File

Deployment Tube, Number of Sats, Type of Sats, Etc.

Ready For Launch!

Calculating Position and Velocity

Output File

Calculate Position and Velocity

Manufacturing Status Review
Baseline Design Overview
Baseline Design Overview

Interface With NanoRacks Ground-based Hardware

Avionics and Software

Next Unit of Computing (NUC)

MATLAB SW

Acquire Data

Time of Flight (TOF) Camera

Monochrome Camera

External Mounting

Interface With NanoRacks Ground-based Hardware

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External Mounting
Modular Test Overview

Shelf holds VANTAGE structure

Cart holds up to 6 1U mock cubesats

Motor pulls Cart

10m

*Full Track Not Shown*
100m Test Overview

Legend
- CubeSat Kabob
- 10ft Test Boom
- GPS unit

Up to 6U of CubeSats

VANTAGE (stationary)

Metal boom to extend mock cubesats from vehicle

Roof rack mounts to vehicle

Cubesat Kabob for mock cubesat configurations

**CubeSat Kabob**

**10ft Test Boom**

**GPS unit**
Design Updates Since CDR

- Swapped Arduino with Raspberry Pi for low-power mode
- Testing an additional GPS system for our 100m test
- Adding stabilizing harness to our 100m test boom mount
<table>
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<th>CPE Summary</th>
<th>Specific Objective</th>
<th>Manufacturing Task</th>
</tr>
</thead>
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<tr>
<td>Error in Position and Velocity Measurements</td>
<td>Tracking Lvl. 2</td>
<td>Integrate Position and Velocity Measurements into Command and Data Handling Suite</td>
</tr>
<tr>
<td>Calculate Individual CubeSat Position and Velocity</td>
<td>Tracking Lvl. 2</td>
<td>Integrate Fall Prototype Algorithms into Software Architecture</td>
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</table>
All Tasks have built in 10% approximate margin

**LEGEND**

- Critical Path
- Electronics
- Software
- Sensors
- Structures
- Testing

**Software Integration Schedule**

- Transfer CDR Prototype Code to Architected Classes
- Integration Testing of Software with Simulation
- Integration Testing of Software on NUC
- Debugging Results of Modular Test
- Debugging Results of 100m Test
Manufacturing
Modular Test Manufacturing Status

**Work Completed:**
- Cart, Motor Assembly, and Shelf manufacturing and assembly
- Assembly & Test Procedure
- Motor Qualification Test

**Pending:**
- Mock CubeSats printing
- VICON training - scheduled for Feb. 6 (Tomorrow)

*Full Track Not Shown*
Motor Qualification Test

● **Problem:**
  ○ Current max speed is 1.3 m/s
  ○ Requirement: [0, 2] m/s

● **Source:**
  ○ Controller angular velocity is limited

● **Mitigation Strategy:**
  ○ Design spool with larger radius
  ○ Increases cart speed

● **Next Steps:**
  ○ VICON Integration
  ○ Sensor Interface Testing
Pending

Fit Check Planned

- Verbal permission obtained
- VANTAGE team has reached out several times to get written permission
- Airport contact has been slow to respond with written permission

Trimble GPS System
Rigid Mount and Power

- Trimble system has battery powered receiver box which does calculations and data storage
- Cables will connect to antenna and pass through the sunroof of the car

Optical Camera in same configuration as VANTAGE

Written Approval to use Airport Location

1 of 4 Cable Tension Assemblies

VANTAGE Sensor Mounting Tripod Assembly Fit Check Planned

- Trime Real Car
- Boom Assembly Mounted to Car

1U Mock CubeSat on Kabob
Manufacturing Status Review

Assembly Procedure

NRCA/Hardware Integration

Written

CNC'd parts

Procedures

Written

Assemble Procedure

Machining Strategy In-Place

Ready to Machine

CAM Program Written &
Avionics Power System
Actual EPS System

- All testing before final integration will be done with provided wall adapters
- Converters demonstrated to produce desired voltage with static load

120-24 DC/DC
24-19/9 VDC

Simulated NanoRack Power
120VDC 520W.
Avionics Power System Power Budget

● CDR Predicted Power Usage
  ○ Based on Data Sheets
  ○ ToF Sensor - 10.0 W
  ○ Total (41.6% Margin) - 81.8 W

DC-DC Power Limit is 120W:

● After Hardware Inspection
  ○ Label has discrepancy from data sheet
  ○ ToF Sensor - 62.4 W
  ○ Total (11.6% Over) - 133.4 W

Pending

1. Load Test ToF Sensor
2. Load Test Avionics Power System

Potential Solutions

1. Underclock NUC
2. DC-DC OC mode.
3. Purchase a new power supply.
Hardware Communications

Tasks:
- Raspberry Pi boots NUC over LAN
- Data transfer from student laptop to NUC

Done:
- Raspberry Pi demonstrated to boot laptop over LAN
- See video

In Progress:
- Boot NUC over LAN with Raspberry Pi
- Set up data transfer from student laptop to NUC
Sensor Automation

Tasks:
- Manual sensor data capture on student laptop
- Automated sensor data capture on NUC

Done:
- Manual sensor data capture on student laptop
- Automated sensor data capture on student laptop

In Progress:
- Automated sensor data capture on NUC

Challenges:
- Integrating sensor controls with MATLAB
- Measuring accurate sensor parameters

02/05/2019
Tasks:
- TOF data processing and centroiding
- Optical camera data processing and centroiding
- Sensor Fusion

Done:
- TOF data processing
- Optical camera data processing
- Sensor Fusion

In Progress:
- TOF centroiding
- Optical camera data centroiding
- Further, Exhaustive Testing

Challenges:
- Solving image processing edge cases
### Incomplete Procurements

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Expected Cost</th>
<th>Status</th>
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<tbody>
<tr>
<td>INTEL® NUC KIT NUC8I7BEH</td>
<td>$671.28</td>
<td>Pending Changes</td>
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<tr>
<td>PHYS Machine Shop Use</td>
<td>$170.00</td>
<td>Scheduled</td>
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</table>

### Budget

#### Subsystem: Structures, Sensors, Software, Electronics, Testing, Total

<table>
<thead>
<tr>
<th></th>
<th>Structures</th>
<th>Sensors</th>
<th>Software</th>
<th>Electronics</th>
<th>Testing</th>
<th>Total</th>
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<tbody>
<tr>
<td>CDR Expected Total:</td>
<td>$365.86</td>
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