Ground Station Project

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Scheme of Maneuver

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Purpose and Design
Background

The United States Naval Academy currently has small satellites operating in Low-Earth Orbit (LEO) and lacks an operational ground station capable of establishing two-way communication due to the ongoing construction of Rickover Hall. The necessity of a mobile ground station platform has been addressed by previous Aero Capstone groups, particularly the N*STAR ground station project in 2018. Given the circumstances of the Naval Academy’s primary means of communication, a mobile ground station is critical for current and future small satellite operations.
Purpose

To establish a practical ground station configuration and assemble a practical, small satellite using a standardized bus in order to allow for simple understanding and replication by all engineers.
Mission Statement

To develop a mobile ground station capable of establishing a communication link with a PSAT in order to allow the command, control, and downlink of telemetry and payload data.
Overview

The PSAT-1U consists of 4 components:

- **EPS Board**
  - Six NiCd cells

- **ADCS Board**
  - Arduino microprocessor

- **Communications Board**
  - Operates at 144.390 MHz

- **Payload**
  - Tentative, depending on mission
  - Height capacity of ~40 mm
# Key Operating Characteristics

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Frequency</td>
<td>144.390 MHz</td>
</tr>
<tr>
<td>Data Rate</td>
<td>1200 Baud</td>
</tr>
<tr>
<td>Volume</td>
<td>1000 cm³</td>
</tr>
<tr>
<td>Mass</td>
<td>1.3 kg</td>
</tr>
<tr>
<td>Bus Voltage</td>
<td>4 V</td>
</tr>
<tr>
<td>Nominal Orbit Average Power</td>
<td>3.5 W generated</td>
</tr>
</tbody>
</table>
Hardware
Board Assembly

ADCS Board

Communications Board

19.05 mm aluminum alloy spacers

EPS Board
EPS Board

- Main source of power for the satellite
- Six 1.2V, 700mAh NiCd cells arranged in three parallel pairs in series
- Total voltage provided is 3.6-4.2 Volts
- Capacity of 1.837 A-hr
ADCS Board

- Determines position of satellite and adjusts
- Driven by sensor inputs from magnetometers and sun sensors located on the solar cell side panels
- Primary communication through arduino chip
Communications Board

- Used for uplink/downlink of data
- Packet-radio uplinks are capable of commands up to eight output bits or serial text to the other boards
- Downlink can contain a periodic Telemetry packet containing five analog channel inputs
External Frame

- 1U cubesat structure
- 10 cm threaded rods through in all four corners
- 19.05 mm spacers between each board
- Made of aluminum alloy
Software
## Command Format

<table>
<thead>
<tr>
<th>Command Input</th>
<th>Byte #</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar Panel Deploy</td>
<td>1</td>
<td>Not used</td>
<td>Not used</td>
<td>Not used</td>
<td>Not used</td>
<td></td>
</tr>
<tr>
<td>Spacecraft Rotation</td>
<td>2</td>
<td></td>
<td>x, y, or z</td>
<td>+ or -</td>
<td></td>
<td>Two digit number of degrees to rotate</td>
</tr>
<tr>
<td>Transmit Telemetry Log</td>
<td>3</td>
<td>Not used</td>
<td>Not used</td>
<td>Not used</td>
<td>Not used</td>
<td></td>
</tr>
<tr>
<td>Transmit Current Telemetry</td>
<td>4</td>
<td>Not used</td>
<td>Not used</td>
<td>Not used</td>
<td>Not used</td>
<td></td>
</tr>
<tr>
<td>Payload Operation</td>
<td>5</td>
<td>User defined</td>
<td>User defined</td>
<td>User defined</td>
<td>User defined</td>
<td></td>
</tr>
<tr>
<td>Reset Memory</td>
<td>6</td>
<td>Not used</td>
<td>Not used</td>
<td>Not used</td>
<td>Not used</td>
<td></td>
</tr>
<tr>
<td>Additional User Defined Command</td>
<td>7</td>
<td>User defined</td>
<td>User defined</td>
<td>User defined</td>
<td>User defined</td>
<td></td>
</tr>
<tr>
<td>Additional User Defined Command</td>
<td>8</td>
<td>User defined</td>
<td>User defined</td>
<td>User defined</td>
<td>User defined</td>
<td></td>
</tr>
<tr>
<td>Additional User Defined Command</td>
<td>9</td>
<td>User defined</td>
<td>User defined</td>
<td>User defined</td>
<td>User defined</td>
<td></td>
</tr>
</tbody>
</table>

Example Command: “2x+45” would command the spacecraft to turn 45 degrees about positive x axis
Parsing Commands in Arduino

- Data is received serially by comms board and forwarded to the onboard Arduino.
- Every transmission starts with “CQ:” to separate distinct commands and prevent noise from being read as a command.
- The bytes following “CQ:” is the command that the user transmitted and is stored as a string in the arduino.

E.g.: If the user types “2x+45” the ground station will send “USNA1>CQ:2x+45” where “USNA1” is the user callsign
Ground Station
Ground Station

- Ground station consists of a personal computer with the SSH program PuTTY installed and a HAM radio with USB connectivity.
- PuTTY displays serial traffic to and from the PSAT in print-line format.
Automatic Packet Reporting System Protocol

- Amateur radio based digital communication protocol utilized
- Covers a large number of stations
- Operates at 144.390 MHz
- APRS packet always begins with a call sign followed by the protocol used in the format “KC3OTU>APRS” followed by the data sent in that packet in the format seen below
Results

- The PSAT-1U project has integrated simple component architecture in an attempt to provide an easily assembled product in conjunction with a ground station of commonly accessible items.
- The ADCS and CD&H board drives the satellite and processes the data in two-way radio traffic of the communications board operating at 144.390 MHz. This data is parsed, identified, and executed by the direct evaluation developed by the command logic programming.
- System data and telemetry are then collected and downlinked to the mobile ground station the users are operating.
Conclusion

- The establishment of a ground station that is simple, practical and mobile and could be easily replicated by all engineers is a significant development in communication.
- In addition to cost effectiveness mobile ground stations are more accessible with only the need for a personal computer with a USB compatible HAM radio, making it easier for amateurs to learn on a simple program and making communication more accessible in remote locations without an excess of equipment.
Resources

- PSAT-1U Design Document
- PSAT EPS Board Build Integration Manual rev-1d
- PSAT Comms Board Build Integration Manual rev-1f
- ADCS Build Manual rev-f
- Kilic, Cagri. “Figure 1.4: 1U CubeSat Skeleton CAD Model.” ResearchGate, January 14, 2020. https://www.researchgate.net/figure/1U-CubeSat-skeleton-CAD-model_fig2_260095777.
- www.aprs.org
Questions?