Mission
Design and build a 1.5U CubeSat which will facilitate the on-orbit test and demonstration of an NSA encryption/decryption module and a NASA power distribution payload.

Payloads
1. NASA Payload
NASA wants to replace bulky batteries with thin power storage boards that also serve as the CubeSat’s exoskeleton.
They can also distribute power back and forth with neighboring boards.

2. NSA Payload
Amateur satellite command and control (C&C) is typically not encrypted.
NSA seeks to provide an encrypted C&C capability for CubeSats.

Design
1. NASA Payload
   - Ouroboro Power Dist. Module
2. NSA Payload
   - GoSecure Chip
3. NSAT CPU
4. UHF and VHF Antennas and Radios
5. Mechanical Antenna Deployment
6. Solar Panels and Li-ion Batteries

Software
3. CPU
   - Houses dsPic processor
   - Stores/processes data
   - Receives/sends commands
   - Uses I2C & serial protocol

Antennas/Radios
4. UHF and VHF Antennas
   - Pair of orthogonal UHF nitinol antennas
     - 450 MHz uplink
     - 300 MHz downlink
     - 4 antenna configuration
     - 2 Astrodev Helium radios

Mechanical Structures
5. Antenna Deployment
Four nitinol antennas coiled into holding bays, held shut by swinging doors.
The doors are retained with a plastic wire. The antennas are released when a burn resistor breaks the wire.

Conclusion
NSAT is fully designed and ready to be assembled. It is predicted to be complete by Fall 2017.
NSAT is scheduled to launch in February 2018.

Acknowledgements
MidN 1/C Cho, Evans, Giornelli, Gray, Misch, Scheiner, Scigliano, Walker, Williams
CDR Bruninga, CDR King, Professor Kang

EPS
6. Solar Panels & Li-ion Batteries

Software
3. CPU
   - Motherboard
     - Houses dsPic processor
     - Stores/processes data
     - Receives/sends commands
     - Uses I2C & serial protocol
   - Interface board
     - Compiles/packages sensor data
     - Uses an SPI protocol

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USNA Small Satellite Program
April 26, 2017
MIDN 1/C Cho, Evans, Giornelli, Gray, Misch, Scheiner, Scigliano, Walker, and Williams
Overview

- Motivation
- Team Organization
- Mission
- Payloads
- Satellite Design
- Success Criteria
Motivation

Support payloads
- Demonstration of NSA CubeSat encrypted communications
- Proof of concept for NASA Ouroboro system

Educate USNA astro-track midshipmen on satellite development process with hands-on experience
# Team Organization

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/C Evans</td>
<td>Team Lead</td>
</tr>
<tr>
<td>1/C Scigliano</td>
<td>Operations</td>
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<tr>
<td>1/C Walker</td>
<td>Software &amp; Safety</td>
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<tr>
<td>1/C Scheiner</td>
<td>Comms</td>
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<tr>
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<td>1/C Giornelli</td>
<td>ADCS</td>
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<td>1/C Gray</td>
<td>Build</td>
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<td>1/C Misch</td>
<td>Structures/Mechanical</td>
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<tr>
<td>1/C Williams</td>
<td>Telemetry</td>
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</table>
Mission

Design and build a 1.5U CubeSat which will facilitate the on-orbit test and demonstration of an NSA encryption/decryption module and a NASA power distribution payload.
Communications Setup & NSA Payload

- CubeSat command and control (C&C) is typically not encrypted
- NSA seeks to provide an encrypted C&C capability for CubeSats
NSA Payload
Concept of Operations

- Encrypted communications (black data) process
NSA Payload Data Structure

- Break up the telemetry requests into 16 byte packets (plus 1 config byte) because the NSA encoder pieces it together in that size

- COSMOS open source ground station software program used for coding/decoding NSAT packets

- **Configuration Byte**
  - Reserved for ECU
  - Determines if data should go through ECU or continue directly to the flight CPU
  - *Stripped off after being read

- **Command Byte**
  - Indicates type of packet being received

- **Data**
  - 15 bytes
Clear Communications
Concept of Operations

• Unencrypted (red data) process uses secondary He-100 radio without ECUs

• For experimental comparison & back-up system
NASA Payload

Ouroboro

NASA wants to replace bulky batteries with thin power storage boards that also serve as the CubeSat’s exoskeleton. They can also distribute power back and forth with neighboring boards.

→ NSAT will carry 2 Ouroboro boards to provide NASA proof of concept for its design.

<table>
<thead>
<tr>
<th>Solar panel</th>
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</thead>
<tbody>
<tr>
<td>Ouroboro 1</td>
</tr>
<tr>
<td>Battery pack</td>
</tr>
<tr>
<td>Ouroboro 2</td>
</tr>
</tbody>
</table>

Produces:
- 70-140 bytes every 10 seconds
- 0.375 Watts/orbit
Mission Objectives & Success Criteria

Supporting CubeSat Systems

• Antennas/Radios
• CPU
• EPS
• Antenna deployment
• Ground communications
Antennas/Radios

UHF Antennas
Pair of orthogonal UHF nitinol antennas

- 450 MHz uplink
- UHF downlink (frequency TBD)
- 4 antenna configuration
- 2 Astrodev Helium radios
NSAT CPU

- CPU will comprise of two boards: Motherboard & Interface Board
- Motherboard will be responsible for storing and chopping data, deciphering commands, toggling switches, processing and interpreting data, and sending commands
- Motherboard will communicate with the EPS Board and Interface Board using an I²C Protocol. Communication with the Helium Radios will use a Serial Protocol
- In order to interpret the sensor data, the Interface Board will collect all information from the spacecraft to package and send to the Motherboard
- The Interface Board will communicate with the ADIS Board using an SPI Protocol. Additionally, the board will communicate with the other sensors using a Serial Protocol
NSAT Motherboard

- Motherboard will largely be the same design as the Motherboard on USNA BRICSAT.
- The Processor on board will be a dsPIC33 and will run Pumpkin Salvos RTOS software.
- The housekeeping and science code for the processor was already written for USNA CubeSat Bus (UCSB). This code and PCB Board will be the same used for NSAT.
- New code was needed is to add a separate relay channel to communicate with the second Helium radio on board the spacecraft.
- Additionally, the code will need to be updated to represent a different radio code than UCSB radio.
- All hardware for the Motherboard will be purchased commercial off the shelf.
The Interface Board for the NSAT will act as a packaging center for the CPU.

The board will gather data from all the sensors on board and package the information.

Data from the Interface Board will then be interpreted by the Motherboard for further commands.

The Interface Board will house the ADIS hardware and the Arduino Mini as the board’s processor.

Arduino software will run two distinct protocols when communicating with the sensors: Serial and SPI.

Will receive gyro, acceleration, and temperature information from the ADIS on SPI Protocol.

Sun sensor, OUROBORO, solar panel (current and voltage), and external thermistor data will be sent to the interface through a Serial Protocol.
Reset Command Structure

- **Ground Station**
  - Reset Command from Ground

- **Helium Radios**
  - Heartbeats

- **CPU**
  - 5 Day Watchdog Timer
  - Request Telemetry
  - Send Telemetry

- **EPS (4 min Reset Timer)**
  - Reset Command

- **Telemetry**
  - Send Telemetry
Electrical Power System

- SUN
- Solar Panels
- Daylight
- Satellite Bus
- Eclipse
- Charging
- Clyde Space 10Whr Battery Board

Time (min)
Eclipse: 35
Daylight: 65
Power Budget

Orbit Modes:
1. Initial
2. Normal
3. Detumble
4. Safe
5. Mission
6. Ground Control

Loads:
1. 2x Helium radio Rx
2. 2x Helium radio Tx
3. NASA payload
   *Self sustaining
4. NSA payload
5. Interface (Arduino)
6. Sensors
7. Magnetotorquers
8. CPU
## Power Budget (Safe & Mission)

<table>
<thead>
<tr>
<th>Load</th>
<th>Voltage (V)</th>
<th>Peak Current (mA)</th>
<th>Peak Power (W)</th>
<th>Duty Cycle</th>
<th>Power (W)</th>
<th>Duty Cycle</th>
<th>Power (W)</th>
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</thead>
<tbody>
<tr>
<td>HeRadio1 - Rx</td>
<td>7.5</td>
<td>60.0</td>
<td>0.5</td>
<td>100%</td>
<td>0.5</td>
<td>100%</td>
<td>0.5</td>
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<tr>
<td>HeRadio1 - Tx</td>
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<td>333.0</td>
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<td>0.0</td>
<td>70%</td>
<td>1.7</td>
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<tr>
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<td>100%</td>
<td>0.5</td>
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<tr>
<td>HeRadio2 - Tx</td>
<td>7.5</td>
<td>333.0</td>
<td>2.5</td>
<td>0%</td>
<td>0.0</td>
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<td>Beacon - Tx</td>
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<td>100%</td>
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<td>GoSecure</td>
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<td>400.0</td>
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<td>0.0</td>
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<tr>
<td>Interface (Arduino)</td>
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<td>40.0</td>
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<td>0%</td>
<td>0.0</td>
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<tr>
<td>Sensors</td>
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<td>0.0</td>
<td>100%</td>
<td>0.3</td>
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<tr>
<td>Magnetorquers</td>
<td>3.3</td>
<td>400.0</td>
<td>1.3</td>
<td>0%</td>
<td>0.0</td>
<td>100%</td>
<td>1.3</td>
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<tr>
<td>CPU</td>
<td>3.3</td>
<td>50.00</td>
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<td>100%</td>
<td>0.2</td>
<td>100%</td>
<td>0.2</td>
</tr>
</tbody>
</table>

### Average Power

- **Generated per Orbit**: 3.4 Wh
- **Used per Orbit**: 2.6 Wh
- **Power Margin**: 0.8 Wh
Battery Capacity for Max Power Consumption

- Min Allowable Capacity: 2 Whr
- Eclipse
- Daylight
- 4.68 Whr
Solar Panels

- 5 side panels composed of UTJ Solar Cells
- 3.42W of average power generated
- Built in-house
- Ouroboro will have its own solar panel
Inhibition Scheme

• When separation switches are actuated the power supply is shorted

• When the Remove Before Flight (RBF) switch is inserted the power supply is shorted
Antenna Deployment Mechanism

Antenna Holding Bays
- 4 nitinol antennas coiled into holding bays
- Troughs cut out to keep them in place

Burn Resistor
- When ready to release antennas, current runs through resistor
- Resistor heats up and burns through the nylon string

Retaining Doors
- Swinging doors hold antennas in coiled state
- Nylon string wraps around entire mechanism to keep doors closed
- Outside walls indented to retain fishing line
Antenna Deployment Mechanism
Antenna Deployment Issues

Nitinol Antennas
Wires are relatively thick considering the height restraints of the deployment mechanism
→ Difficult to fit antennas into holding bays

Plastic Wire & Burn Resistor
Because of extreme tension on the doors, difficult to wrap/tie string around the mechanism
→ Difficult to secure string to the spring and the burn resistor

3-D Printing
Mechanism is very small (<2.54 mm)
→ 3D printing lacks resolution

Deployment Mechanism
Due to soldering and antenna location, the plastic mechanism does not sit flat on top of the antenna board
→ Antennas slip underneath and deploy prematurely

Retaining Doors
Coiled antennas put extreme tension on the doors
→ Doors bulge outward, unlikely to survive launch vibrations

Working Prototype
Ground Systems

Current Ground Station Hardware includes
- VHF Amateur Tx/Rx
- HF Amateur Tx/Rx

Ground Station software is open source COSMOS
- Capable of Lights-out telemetry receipt

Multiple Telemetry Packets defined

Commanding done through COSMOS using both real-time and pre-defined commands
Conclusion

Successful means for accomplishment of mission objectives:
✓ Designed clear and encrypted communications system
✓ Planned power budget for 6 different orbit modes
✓ Integrated motherboard and interface board CPU
✓ Designed and built antenna deployment mechanism

✓ Educate midshipmen on satellite development lifecycle

Predicted launch mid-2018
Acknowledgements
Questions?