INCA
Ionospheric Neutron Content Analyzer
New Mexico State University
University NanoSat-8
CubeSat Workshop Presentation
August 2, 2014; Logan, UT
Presentation Outline

- Mission Overview
- Mission Relevance
- ConOps
- INCA Payload
- Subsystem Design
- Thanks & Questions
INCA – A Collaboration

• AFRL Space Weather Center of Excellence
  – Contacts: S. White, R. S. Selesnick
  – Space Weather Forecasters are the Prime Customer

• NASA Goddard Space Flight Center
  – Contacts: Eric Christian, Georgia de Nolfo
  – Payload Instrument Support & Testing

• University of New Hampshire
  – Contacts: James Ryan, Peter Bloser
  – Payload Instrument Primary Provider
Mission Overview

• Project Objectives
  – Design and fabricate a small satellite that fulfills the design constraints of the University NanoSat Program and supports the requirements of the UNH Neutron instrument.
  – Provide professional engineering quality design while maintaining educational responsibilities.

• Mission Objectives
  – PRIMARY: To demonstrate the functionality of Scintillator/SiPM-based neutron spectrometer in Low Earth Orbit.
  – SECONDARY: To gather neutron flux data and corresponding latitude metadata from at least three latitudinal zones.
  – TERTIARY: To detect a primary solar neutron event.
Atmospheric Neutrons

• Neutron Sources
  – Air Shower Neutrons
  – Albedo Neutrons
  – Solar Neutrons

• Payload Detector
  – Scintillators & SiPMs
  – Solid Angle
  – Time Stamping
  – GPS Stamping
Mission Relevance

AFRL’s Space Weather Center of Excellence

• Mitigate effects of space environment on systems
• Robustness depends on validation of physical observations.

NASA Science Directorate

• Atmospheric Composition Modeling and Analysis Program (ACMAP)

INCA will enhance the robustness of Space Weather models by adding measurements of the neutron spectrum observed in LEO.
<table>
<thead>
<tr>
<th>Measurement Requirement</th>
<th>Range/Value</th>
<th>Source of Req.</th>
</tr>
</thead>
<tbody>
<tr>
<td>The UNH Instrument shall measure the flux of neutrons in a certain energy range.</td>
<td>1MeV – 20MeV</td>
<td>Customer Proposal</td>
</tr>
<tr>
<td>The UNH Instrument shall measure a minimum number of neutron events.</td>
<td>20</td>
<td>MO 1/Uncertainty Calculation</td>
</tr>
<tr>
<td>The UNH Instrument shall be pointed at the Sun with a certain accuracy.</td>
<td>+/- 10 degrees</td>
<td>Customer Q&amp;A</td>
</tr>
<tr>
<td>The orientation Metadata (from ADC) shall have a certain accuracy.</td>
<td>+/- 2 degrees</td>
<td>Customer Q&amp;A</td>
</tr>
<tr>
<td>The UNH Instrument shall be monitored with sensors to generate housekeeping data.</td>
<td>20 voltage monitors, 20 current monitors, 3 temperature sensors</td>
<td>MO 1/Customer Q&amp;A</td>
</tr>
<tr>
<td>The longitudinal Metadata (from ADC) shall be gathered by GPS accurate within a certain degree of latitude.</td>
<td>1 Degree</td>
<td>MO 2/MO 3/Customer Q&amp;A</td>
</tr>
</tbody>
</table>
• **Launch Sequence.**
  – Launch Vehicle Ascends.
  – Eject from Launch Vehicle.
  – Deploy Antennas.

• **45-Minute Sleep Period.**

• **Activation Sequence.**
  – System Check.
  – First Transmission.
  – Detumble & Point.
  – Charge Batteries.

• **Science Mission Sequence.**
  – Record Data, Metadata.
  – Transmit Data, Metadata.
  – Repeat.

• **End of Life Sequence.**
INCA Spacecraft Overview

• The Basics
  – 6U (30cm x 20cm x 10cm) Structure
  – Planetary Systems Corp. Standard
  – Mainly COTS Parts in Preliminary Design
  – KISS

• The Payload
  – Being adapted from Solar PRobe Ion Neutron & Gamma-ray Spectrometer (SPRINGS) design
  – Bus and Payload design happening side-by-side
  – Pointed in same direction as Solar Array
ADC Subsystem Design

Attitude Determination

ISIS CubeSense

Accuracy:

- Nadir: 0.18° (where Earth is completely visible in field-of-view)
- <0.5° over ± 35° FOV
- <2° over ± 45° FOV
- Sun:
- <0.3° over ± 40° FOV
- <1° over ± 60° FOV
- <1.85° over ± 90° FOV

Product Properties

- Power: 360mW max, <100mW avg
- Size: 96mm, 91mm, 10mm (excluding cameras)
- Mass: 110g (including cameras)
- I2C and UART interface available
ADC Subsystem Design

Attitude Control

ISIS Magnetorquer Board

Performance

- Actuation level
  - Max: 0.24 Am² (@ 20°C, 5V)
- Power consumption (@ 20°C)
  - Torque rods: ~1 Watt/Am²
  - Air core: ~2 Watt/Am²

Properties

- Two torque rods and one air core torquer
- Mass: ~195 grams
- Operational temperature range: -40 to +70°C
- Dimensions: 95.9 x 90.1 x 15 mm³
- Supply voltage
  - Actuation: 5V
EPS Requirements

• **Major Driving Requirements**
  – Shall harvest solar energy using a solar panel
  – Shall convert harvested solar energy to electrical power
  – Shall charge onboard batteries during sun exposure
  – Shall use battery power during orbital eclipses
  – Shall distribute current at the required voltage to each respective system
  – Shall regulate distributed current at the required voltage appropriate to each system

• **Verification Methods**
  – Testing and simulation for
    • Solar Panels
    • Battery
EPS Subsystem Design

Solar Panels

EPS Board

Batteries
COM Requirements

• **Major Driving Requirements**
  – Transmit PAY Data/Metadata to ground station
  – Receive commands from ground station
  – Observe required radio silence window
  – Maintain a +6dB link margin for both uplink & downlink
  – Maintain system compatibility with ground station

• **Verification Methods**
  – Link and Data Budgets
  – Simulations (STK)
  – FlatSat Mock-Up
  – Individual Subsystem Testing
CDH Subsystem Design

- **Hardware**
  - GOMSpace NanoMind A712C
  - 32-bit ARM7 RISC CPU
  - 40 MHz Clock
  - 2 GB MicroSD Slot
  - Numerous I/O: I2C, UART
  - Temperature Sensors
  - Flight Heritage

- **Software**
  - Embedded Linux
  - Included Device Drivers
  - Programmed in Linux & C
NMSU Ground Station

• Major Driving Requirements
  – Track INCA Spacecraft
  – Send commands to INCA Spacecraft
  – Receive acknowledgments, PAY Science Data & Metadata, and housekeeping data from INCA Spacecraft

• Verification Methods
  – Practical Tests with COM Subsystem
  – Practical Tests with FlatSat Mock-Up

• Ground Station
  – NMSU EE Dept. Senior Capstone Project
  – Taylor Burgett KF5UIP
  – Status
Ground Station Design

- Support directional Yagi antennas.
- Full sky, computer controlled azimuth/elevation antenna rotator.
- Weather proof connections (Tape/Tar)
- Antennas rated to 100 mph winds.
Cleanroom & Lab
Thanks & Acknowledgments

• Monetary Support
  – New Mexico Space Grants Consortium
  – Harris Corporation

• NMSU Organizations
  – Physical Sciences Lab
  – Industrial Engineering Dept.

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  – Dr. Jim Ryan
  – Dr. Peter Bloser
  – Dr. Georgia de Nolfo
  – Ms. Patricia Sullivan
  – Dr. William Godwin
  – Mr. Brian T. Sanders