Ionospheric Neutron Content Analyzer (INCA)

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On behalf of the INCA Team
Mission Overview

Primary
INCA will be a demonstration flight for a novel neutron detector for measurements supporting Space Weather Prediction. The detector is capable of measuring both the energy and direction of neutrons (2-15 MeV energy range) using a double scatter technique.

Tertiary
INCA will explore the dependence of the neutron flux as a function of solar activity.

Secondary
INCA will measure the neutron flux to look for both a latitude dependence and temporal variations. These measurements will help to improve current Space Weather models and mitigate threats to space and airborne assets.

Quaternary
INCA will search for primary solar neutrons.
Mission Overview (cont.)

- 3U CubeSat - 10cmx10cmx30cm
- Deployable solar panels
- Side solar panels
- Deployable antennas
- Avionics located in the rear 1U
- Neutron Detector located in the front 2U

- Circular orbit
- 500 km altitude
- 90 degree inclination
- Orbital period of 94.62 minutes
Launch

- Takes off from Spaceport located in Mojave, California
- Air launches over the Pacific
- Launch is scheduled for early 2018

Images courtesy of Virgin Galactic
ConOps

Pre-Flight Operations
- Pre-Flight Checkout
- Charge Batteries
- Launch Vehicle Integration

Launch

Startup Sequence

Deployment Safe
- Fault before antenna deployment
- No Fault
- Operator Command

Deployment Sequence
- < 45 min after initial power on
- > 45 min after initial power on

Bootup
- Fault after antenna deployment
- Safe Mode (Entered if serious fault detected)
- Systems Checkout
- Safe Mode (Exited if fault cleared)
- Operator Command

Normal Operations

Low Power Modes
- Batt > 10%
- Batt < 5%
- Batt > 90%
- Batt < 10%

Charge Battery
- Batt > 20%
- Batt < 20%

Science
- Out of Range
- Batt > 20%

Comm Pass
- End of Life
- De-Orbit within 25 years

All numbers are approximate values and should be considered TBD.
Detector Modeling
- Using GEANT/MEGALib
- Using solar and ionospheric histogram data to model the radiation sources and incorporating constraints of the detector

Radiation Environment Modeling
- Using SPENVIS/System Toolkit’s SEET addon
- Produced radiation data tables for various orbital parameters
- Researched same hardware implemented on other CubeSat missions

Electromagnetic Interference Mitigation
- Designed workflow of round robin type testing
- Developed methodology for flatsat testing and assembled modes testing

GEANT model of detector using solar histogram data
Radiation testing in NMSU physics lab
NX model of detector
Attitude and Determination Control

Simulation/Controller Design
- Custom attitude simulation using MATLAB
- Implementing a Bdot bangbang controller and PID controller for during and after detumble state
- Using a Kalman filter for situational awareness

Custom Sun Sensor Design
- Must be accurate to 2 degrees
- Includes 3D printed wedges and Wheatstone bridge to increase photodiode sensitivity
- Integrated temperature sensor for thermal monitoring

ADC Hardware
- Manufactured custom 3D printed air core magnetorquer
- Using integrated rate gyros
- Using integrated magnetometers
**Electrical Power System**

### LED Solar Simulator
- 16 High Luminous Efficacy Cool White LEDs
- Designed for 29.1 V and 8.4 A where current is adjusted for proper solar simulation testing
- Heat sink designed and manufactured at NMSU

![Led solar simulator](image1.png)

### Battery Testing
- Two cell 37 Wh Polymer Lithium-ion battery pack
- Using Arduino Uno to obtain voltage and current data
- Planning for a stand alone test to determine various parameters

![Single battery replica](image2.png)

### Deployable Solar Panel Design
- Consists of 15 cells, 3 strings of 5 cells connected in parallel
- Designed for 2.75 V and 1.23 A
- Includes temperature sensor and nichrome wire configuration

![Deployable solar panel test setup](image3.png)
Communication & Command and Data Handling

**Uplink and Downlink Communication**
- UHF Radio for command and telemetry
- UHF Radio running in the amateur bands
- Using Global Star beacon for basic status of satellite

**Main Control of Satellite**
- Using Atmel ARM9 processor
- Embedded Linux allows large flexibility
- Low power - Operates at 300mW

**Tvyak System**
- Fully integrated with ARM processor
- Integrated sensors for avionics bus
- Control over all systems from main processor

Tyvak UHF radio

Atmel ARM9 processor

Full Tyvak system
Structures

Mitigation of Failure

- Implemented a modified BostonU research design for a spring solar panel hinge design
- Adjusted model component spacing and mitigated heat issues
- Will add rubber damping to compensate for failures shown after running software and physical vibrations testing

Physical Design Requirements

- Designed rails for detector and “clips” for side solar panels for secure attachment
- Implementation of a deployable solar panel system that fits in case for launch

Manufacturing

- 3D printed prototype components for design and fit checks
- Detector case / other small solid metal components manufactured at NMSU
- Epoxy, metal plating, general materials, and electronics are ordered as parts and assembled by hand

NX model of structure excluding solar panels

NX model of complete structure

3D printed hinge model design test
Thermal Protection

- Will use Mylar in order to reflect radiation
- Will be adding a nichrome solar shield for shielding of the sun’s radiation

Thermal Model

- In depth mathematical model produced using MATLAB
  
- Thermal modeling consists of modeling the body, deployable solar panels and payload at an ideal orbit

- Have an approximate that the body will reach 50°C, deployable solar panels 40°C and payload 30°C

Thermal Testing

- Plan to place satellite in a vacuum chamber where it will cycle through to maximum and minimum temperatures
- Plan to record the functionality of the satellite at the maximum and minimum temperatures and after overall testing
- Planning to test through Air Force Research Lab

Sample of Mylar material

Nichrome solar shield concept
Questions?