Program Executive Office
Space Systems (PEO SS)

Integrated Communications Extension Capability (ICE-Cap) Overview

04 August 2015
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Statement A: Approved for public release, distribution is unlimited (5 AUGUST 2015)
SPAWAR security and policy review tracking number SR-2015-295.
What is ICE-Cap?

- U.S Navy’s 3U CubeSat Technical Demonstration for Communication
- Integrated Communication Extension – Capability (ICE-Cap)

Objectives

- Demonstrate a cross-link from Low Earth Orbit to MUOS WCDMA in Geosynchronous Orbit
- Polar UHF SATCOM relay using CubeSats
- Mature and miniaturize radio, antenna and other technologies for potential responsive UHF SATCOM missions
ICE-Cap Configuration

Stowed Configuration

Deployed Configuration
ICE-Cap OV-1 (WCDMA)

Orange lines show MUOS WCDMA cross-link.
Yellow lines show Legacy cross-link and communications with legacy users.
Stakeholders

- **Navy PEO Space Systems**: overall management and funding of four SBIR technologies
- **SPAWAR Systems Center (SSC) Pacific**: Systems engineering and support
- **Army Space and Missile Defense Command (SMDC)**: Provided the satellite bus (SMDC-ONE)
- **Air Force Research Lab (AFRL)**: Managing the crypto contract
Work Breakdown Structure

- **Project Management:** PEO Space Systems / SSC PAC
- **Space Segment:** 3U CubeSat
  - UHF software defined radio – **Vulcan Wireless**
  - High Assurance IP Encryptor – **InnoFlight**
  - High gain antenna – **Physical Optics Corporation**
  - Omni antenna/Bus Integration/Flight Computer – **Space Micro**
  - Flight Software – **SSC PAC**
- **TT&C**
  - Primary: WCDMA Point to Net to computer on network
  - Secondary: Line of sight Legacy 25 kHz
- **Ground Segment**
  - SSC Pac with support from NPS
- **User terminals:** Legacy 25 kHz UHF SATCOM
ICE-Cap Interface Architecture

Legend

- **Power**
- **I2C**
- **RS422**
- **RF**
- **Analog**

- **Space Resistor Experiment**
- **ADCS**
- **Flight Computer**
- **Interface Board**
- **Electrical Power System**
- **Battery Stack**
- **Solar Panels**
- **High Gain Antenna**
- **Low Gain Antenna**
- **GPS Antenna**
- **Radio**
- **ECU**
- **Torque Rod Control**
- **RS-422**

Connections:

- Power (red)
- I2C (yellow)
- RS422 (blue)
- RF (black)
- Analog (green)

Deployment Lines:

- LGA
- HGA
- Deployment Line

Experiment Type:

- Space Resistor Experiment
- ADCS
- Flight Computer
- Interface Board
- Electrical Power System
- Battery Stack
- Solar Panels
- Torque Rod Control
- RS-422
- Power
- I2C

Antennas:

- High Gain Antenna
- Low Gain Antenna
- GPS Antenna
Mode Transfer State Diagram

- **Initialization Mode** – Occurs when power is enabled or watchdog resets flight computer
- **Safe Mode** – Only essential system safety commands are executed
- **Normal Mode** – Executes mission autonomously based on mission schedules from Ground Station
- **Sleep Mode** – Conserves power by running low-power mode or off
Antenna Deployment Sequence

- After ICE-Cap is deployed from the CubeSat Dispenser, the flight software will trigger the antenna deployment sequence
- Monitors for a successful deployment
- Attempts to minimize additional spin caused by deployment
- Failure of antenna deployment may cause serious degradation in communication
Ground Station SW Architecture

- Ground Station (GS) is located in San Diego, CA
- GS will provide command & control, retrieve & analyze telemetry & mission data
- GS Software
  - **Command Database** – Stores list of commands that SV is able to execute and accept
  - **Command Message Generator** – Used to create Real Time and Store Command Sequence Messages
  - **Command Scheduler** – Maintains a queue of messages that must be transmitted to SV
  - **Telemeter Database** – Used to store downloaded SV health and status & Mission data
Message Acknowledgement Protocol

- Flight Computer must acknowledge (ACK) all received messages immediately
  - Flight Computer will send ACK message whenever receives command from Ground Station
  - Payload indicator will indicate ACK by providing 0x01 value
  - Last 4 bytes in message Payload is reserved for return argument from real-time command
- Ground Station do not need to ACK received messages

**Message Structure Format**

<table>
<thead>
<tr>
<th>Category</th>
<th>Header</th>
<th>Message Payload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mnemonic</td>
<td>Start</td>
<td>Message Number</td>
</tr>
<tr>
<td>Size [Bytes]</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Position</td>
<td>0:1</td>
<td>2:3</td>
</tr>
<tr>
<td>Example</td>
<td>0x1CEF</td>
<td>0x0003</td>
</tr>
</tbody>
</table>
**Mission execution will be carried out by sending stored command sequence**

**Stored Command Sequence is a sequence of real-time commands with start time of each command**

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**Stored Command Sequence Structure**

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Start</th>
<th>Message number</th>
<th>Payload Length</th>
<th>Message Payload</th>
<th>Checksum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (bytes)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>0-8191</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Payload Indicator</th>
<th>SCS Header</th>
<th>SCS Command 1</th>
<th>SCS Command 2</th>
<th>...</th>
<th>SCS Command N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (bytes)</td>
<td>1</td>
<td>10</td>
<td>6</td>
<td>6</td>
<td>...</td>
<td>6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Priority</th>
<th>Number of times SCS repeats</th>
<th>Interval between repeats in seconds</th>
<th>Start time based on RTC</th>
<th>Number of commands in the SCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (bytes)</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Command-N ID</th>
<th>Command-N argument</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (bytes)</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>
System Test Plan

• Hardware Environmental Testing
  ➢ Vibration Testing
  ➢ Thermal Operations
  ➢ RF Antenna Characterization

• Software Testing
  ➢ Static testing
  ➢ Unit Testing
  ➢ Integration Testing
  ➢ Functional Testing
  ➢ System Testing
Testing
Schedule

• ICE-Cap Kickoff: July 2012
• Hardware Delivery: May/June 2014
• Final delivery of hardware: December 2014
• Spacecraft Integration complete: Sep 2015
• Ready for Launch Integration: Oct 2015
• Launch: Dec 2015 – Feb 2016
We influence, develop, integrate, and maintain space-enabled capabilities for Naval, Joint and Allied operations.