Space Environmental NanoSat Experiment (SENSE)

Capt Paul La Tour
SENSE PM
Overview

- Objectives, Organizations, and CONOPS
- Spacecraft Bus
- CTECS (Compact Total Electron Content Sensor)
- WINCS (Wind Ion Neutrals Composition Suite)
- CTIP (Compact Tiny Ionospheric Photometer)
- Interesting Mission Features
SENSE is SMC’s premier rapid development effort which will demonstrate the capability of NanoSats to perform space missions in an affordable and resilient manner.

- 15 Months ATP to SV delivery (July 2012), 27 Months ATP to launch (July 2013)

- The first AF NanoSat mission, designed to prove the OSS&E of the NanoSat class space vehicle for the war fighter
  - Pathfinder to determine if NanoSats are suitable as potential SSAEM follow-on
  - Delivers three first generation miniature sensors; WINCS, CTIP, GPS-RO.

- A “lights-out” ground architecture with leave-behind capability to fly the next minimally-manned satellite mission.

Photos of actual Flight Hardware

SV #2
Wind Ion Neutral Composition Suite (WINCS) Configuration

Compact Total Electron Density Sensor (CTECS)

1 Mb/s S-Band Radio, Diplexer and Encryption Module

Cubesat Tiny Ionospheric Photometer (CTIP)
SENSE Sensor History (Evolution)

- **C/NOFS**
  - Weight: 3 kg
  - Power: 10 Watts

- **SENSE**
  - Weight: 0.2 kg
  - Power: 1.5 Watts

- **FORMO-SAT3**
  - Weight: 7 kg
  - Power: 23 Watts

- **CORISS**
  - Weight: <1 kg
  - Power: 2.5 Watts

- **CTIP**
  - Weight: 2.5 kg
  - Power: 23 Watts

- Smaller Satellites → Bigger Roles
### Schedule

<table>
<thead>
<tr>
<th></th>
<th>FY10</th>
<th>FY11</th>
<th>FY12</th>
<th>FY13</th>
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<td>Sensor Development</td>
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<td>Bus Assembly &amp; Test</td>
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<td>On Orbit Support</td>
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<td><strong>Ground Segment (SDTW)</strong></td>
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<td>Antenna Acquisition</td>
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<td>Develop Ground Infrastructure</td>
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<td>Launch Integration</td>
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<td>Data Analysis &amp; Validation</td>
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<td></td>
<td>$1.700M</td>
<td>$6.137M</td>
<td>$1.782M</td>
<td>$.899M</td>
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</table>

**Multi-Segment Critical Path**
- Factory Compatibility Test
- Interface with AFRL
- Common Ground Architecture
- ORS Enabler

- Critical Path–Flight Software
- Critical Path–CGA Software
- Critical Path–Pre-Processing Software

- Launch Est Jun13
- Final Report

This is **Rapid!**

15 Months
SENSE Organizations

Demo Stakeholder
SENSE Demo Lead
Demo Stakeholder

SMC

Space Segment (XRFF)
Launch Segment (SDTD)
Ground Segment (SDTO)
Data Analysis & Mission Validation (RVBX)

DWSD
**Ground Segment**

**BACKGROUND:**
- Current satellite C2 systems utilize 24/7 ground monitoring; SENSE striving for “lights out” capability
- Kirtland RSC Operations Center developing capability to connect to distributed sites from single terminal
- FY 2013-14 SENSE demonstration period with option to extend ops 1-year

**Contribution to Greater Capability:**
- Demonstrate a distributed architecture to support small satellite missions including “lights-out” (unmanned) operations
  - Established conductivity between Air Force mission operation center, Navy communications, and joint service command network
  - Define architecture for pre-processing of data and automatic distribution
  - Develop ground architecture with “leave behind” capability for future CubeSat programs
    - Operations Center improvements enabling flexible, distributed architectures
    - Platform for operator training

**Future Improvements:**
- Automated satellite command and control
  - CubeSats offer potential for inexpensive distributed data collection through greater automation
  - Increase contact frequency of CubeSats on operational networks proves operational theories
  - Drive development of side-by-side operations with larger satellites on same contact network
  - Peacetime means of maintaining operator proficiency
# SEM Matrix

## Space Environment Measurement Matrix

<table>
<thead>
<tr>
<th>Measurement</th>
<th>DMSP Polar Orbit, Fixed LT</th>
<th>C/NOFS Equatorial Orbit, All LT</th>
<th>SENSE Instruments, All LT</th>
<th>SENSE + Ground Processing</th>
<th>DMSP, C/NOFS, SENSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auroral Particles</td>
<td>G</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>G</td>
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<td>N/A</td>
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<td>Medium Energy Particles</td>
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<td>High-Lat Ionospheric Scintillation</td>
<td>Y - A</td>
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<td>N/A</td>
<td>N/A</td>
<td>G</td>
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<tr>
<td>Low-Lat Ionospheric Scintillation</td>
<td>Y - OA</td>
<td>G</td>
<td>Y - O</td>
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<td>N/A</td>
<td>N/A</td>
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<td>Low-Lat <em>In Situ</em> Electric Field</td>
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<td>Y - OT</td>
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<td>Mid-Lat Electron Density Profile</td>
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<td>Low-Lat Electron Density Profile</td>
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<td>Y - O</td>
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<td>Neutral Density Profile</td>
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<td>Low-Lat Geomagnetic Field</td>
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<td>G</td>
<td>R</td>
<td>R</td>
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</table>

**Legend:**
- **G**: Good measure of parameter
- **Y**: Measurement made, but with limitation(s)
- **R**: No measurements made to address this parameter
- **N/A**: Does not apply in specified orbit
- **O**: Sub-optimal orbital inclination
- **A**: Orbit altitude
- **T**: Technology – instrument has limited or unproven capability for this parameter
- **L**: Instrument covers a limited range of the parameter
SENSE Bus

- Very capable and low cost bus, considered infeasible only 4 years ago
  - Three axis stabilized; four reaction wheels
  - Two star cameras and GPS
  - Dosimeter included into Bus design
- 1 Mb/s Downlink & 4 kb/s Uplink S-Band Encrypted transceiver
- 35 watts generated orthogonal to sun
  - 9.5-10.5 watts average on orbit power (orbit dependent)
Space Vehicle Mass (Worst Case SV #2)
Positive Energy Balance

Positive Energy balance every orbit

- Solar Power Actual UTJ (W)
- Payload load (W)
- Bus load (W)
- Battery SOC (%)
- Payload Capability (W)

• SV has the ability to transmit 15 min/orbit
• Enables latency requirements satisfaction for SEM mission
CTECS- Radio Occultation Sensor

- **CTECS is a GPS occultation sensor**
  Primary data product: line-of-sight TEC to all GPS satellites in view for ingest into ionospheric models
  Secondary data product: L-band scintillation observations
- **Antenna is dual patch**
  - 1557 MHz and 1227 MHz
  - A Low-Noise-Amplifier (LNA) is placed between antenna and receiver
- **L1, L2, L2c signal tracking capability**

Measures:
1. Delay of signal between SENSE and the GPS transmitter to extract Total Electron Count in the atmosphere
2. Atmospheric Scintillation
Compact Tiny Ionospheric Photometer (CTIP)

**Objective:** Gather data to characterize the ionosphere through the natural decay rate as seen in recombination of $O^+$ ions and electrons

- Atomic Oxygen ions constitute the primary ionospheric species in the F-region
- In the night-time F-region ionosphere
  - $135.6$ nm photons are emitted spontaneously
  - from the recombination of atomic oxygen ions
  - $O^+ + e^- \rightarrow O \ (5P) + h\nu_{135.6}$

- $O^+ \text{ and } e^-$ are in equal number and $135.6$ nm emission is proportional to the path integral of $[O^+]$ squared

**Measures:**

1. Ultraviolet Airglow at $135.6$ nm
Wind Ion Neutral Composite Suite (WINCS)

Objective: Acquire simultaneous co-located, in-situ measurements of atmospheric density, composition, temperature and winds.

Measures:
1. Neutral winds & temperature
2. Ion-drift & temperature
3. Ion & Neutral composition
4. Plasma Composition
WINCS Theory of Operation

• WTS/IDTS: Ionize incident air stream to measure the angular distribution at many angles simultaneously while scanning energy in time
• IMS/NMS: Time of Flight mass spectroscopy
Teledyne Micro-Dosimeter

Objective: Provide radiation dosage for measurement and to correlate system performance with exposure

- First compact microcircuit that provides a repeatable measurement of radiation dose and dose rate over a wide range of energies
- Enables routine monitoring of spacecraft radiation environment
- Custom microchip in a small footprint package for low weight and power
- Correlates environmental models and ray-tracing analyses with real in-flight measurements

Technical Specifications
- 14 uRad Dose resolution
- Survivability to 40 kRad
- Class K space qualified
- Mechanical dimensions: 3.6 cm x 2.5 cm x 0.1 cm
- 20 grams
- 10 mA, 13 Vdc to 40 Vdc
- 3 DC linear outputs
- 1 Pseudo Log
- 100 kRad total count
- Test Input bypasses silicon detector for circuitry detection
- Volatile count retention
- Updates every 30 seconds
## Mission Data Products (TPMs)

<table>
<thead>
<tr>
<th>Environmental Data Record (EDR)</th>
<th>Parameter</th>
<th>Requirements</th>
<th>Current Value at DR</th>
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<tr>
<td>Electron density profile</td>
<td>Horizontal cell size</td>
<td>50 km, 10 km</td>
<td>CTECS</td>
</tr>
<tr>
<td></td>
<td>Vert Cell Size</td>
<td>10 km, 3 km</td>
<td>WINCS</td>
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<td>Vert coverage</td>
<td>90 km to Sat Alt, 90 km to 1600 km</td>
<td>CTIP</td>
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<td></td>
<td>Range Ne</td>
<td>2.5E4 to 1E7 e/cm³, 1E4 to 1E7 e/cm³</td>
<td>SENSE</td>
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<td>Range VTEC</td>
<td>3 to 200 TECU</td>
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<td></td>
<td>Sigma Ne</td>
<td>Greater of 1E4 /cm³ or 5%</td>
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<tr>
<td></td>
<td>Sigma TEC</td>
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<td>Sigma HmF₂</td>
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<td>Sigma NmF₂</td>
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<td>Sigma NmE</td>
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<td>Scintillation</td>
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<td>Temperature</td>
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**Notes:**
- 1. 100% E layer, 50% F layer bottom side, 30% F layer near peak, 15% topside.
• CTIP vehicle reliability is estimated to be 0.7312 at 1 year.
  • 5 Bus Drivers are:
    • USB Radio (0.950)
    • IRB (0.954)
    • PMAD (0.969)
    • RWA controller (0.975)
    • +Y Body panel (0.980)
  • Payload Driver
    • CTIP (0.960)
Summary

- **SENSE** is a rapid development effort seeking to demonstrate affordable access to space for future operational CubeSat missions across SMC
  - Develop best practices for operational CubeSat/NanoSat procurement, development, test, and operations

- **The first CubeSat mission to develop a flexible, distributed ground architecture supporting small satellite missions**
  - Two one-month ops phases consisting of 24/7 operations using commercial and distributed joint service command antennae network for <90 minute data latency

- **Mature CubeSat Bus and Sensor component TRLs**
  - CubeSats drives down future costs for inexpensive distributed data collection systems through a common CubeSat Bus ($300K per bus)
  - The common Bus becomes a platform for both operational use and future sensor development efforts
    - Three first generation miniature sensors; WINCS, CTIP, GPS-RO

- **Mission data will improve current and future space weather models and demonstrate CubeSats’ utility for operational weather requirements**