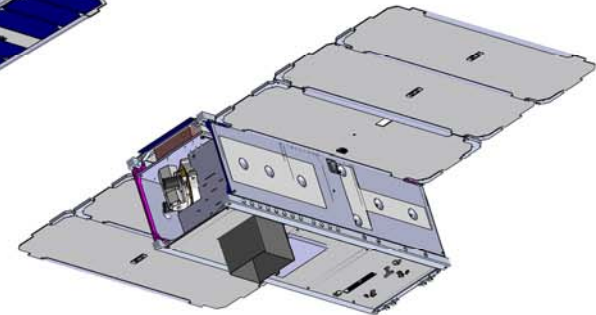
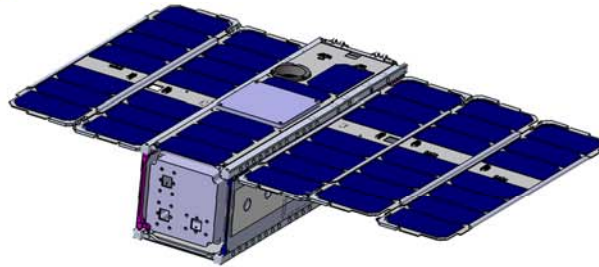


Space Environmental NanoSat Experiment (SENSE)



Capt George Sondecker
SENSE Program Manager



Overview

- **SENSE Mission Overview**
- **Space Vehicle Bus and Payloads**
- **Data Products and Users**
- **Rapid Development Timeline**
- **Lessons Learned through SV Operations On Orbit**
- **Back-Up Photos**

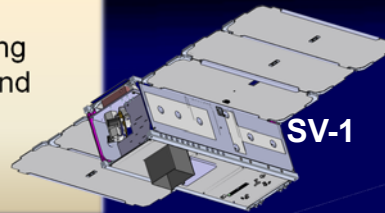


Space Environmental NanoSat Experiment (SENSE)

OBJECTIVE: SENSE is a space weather demonstration for evaluating the cost-effectiveness and resiliency of CubeSat architectures for augmenting or performing future operational missions. Additionally, SENSE is a risk reduction pathfinder for the Common Ground Architecture (CGA) and the Global Space Telemetry Resource (GSTR) antenna suite.

SENSE Overview:

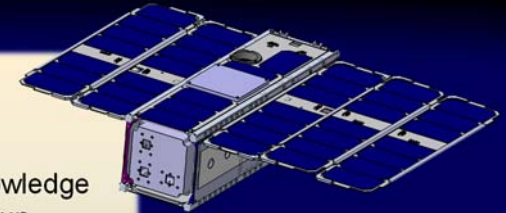
- Mission: Space Environmental Monitoring
- Architecture: Two 3U CubeSats & Ground
- Mission Life: 1yr
- Launch: Nov 2013, ORS Enabler 3
- Orbit: 500km Alt, 40.5° Inclination



SV-1

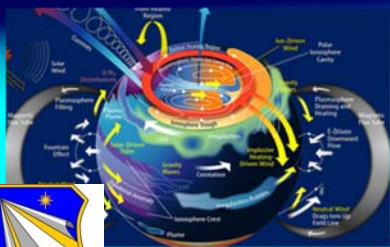
Bus Performance:

- Mass: 4kg
- Power: 10W Avg, 37W Peak
- ADCS: <0.5° pointing, <0.3° knowledge
- Data Rate: 1Mbps down, 4kbps up
- Encryption: AES256 Type II



SV-2

GAIM Ionospheric Model



Sensors and Measurements:

1. CTECS: Electron Density (TEC), Scintillation
2. CTIP: Ionospheric Structure
3. WINCS: Temps & Composition of Ions & Neutrals
4. Dosimeter: Cumulative Radiation



Kirtland AFB, NM

Blossom Point, MD

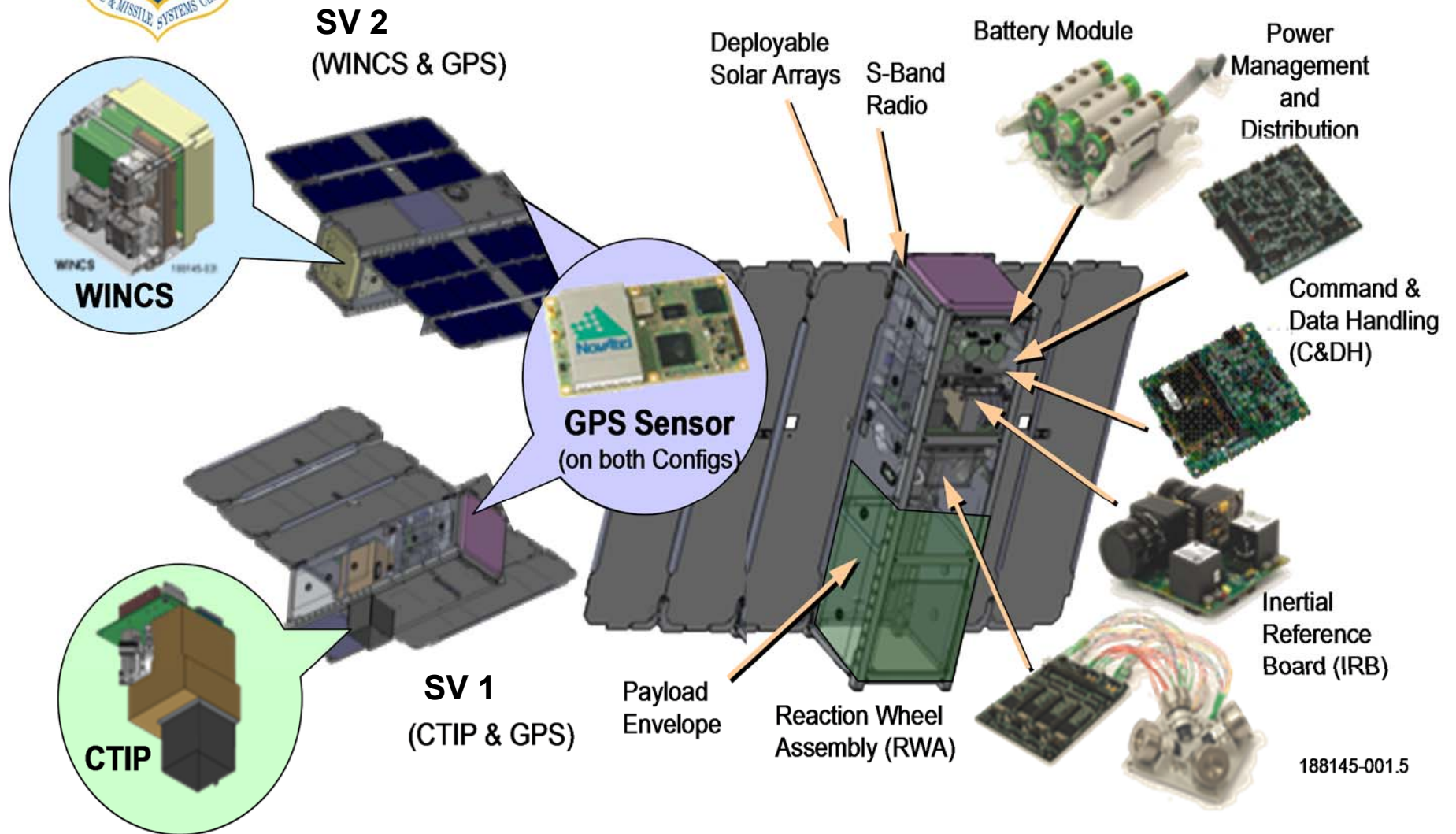
AFSCN

Ground System:

- Sites: Manzano NM, Blossom Point MD, AFSCN
- Common Ground Architecture (CGA) multi-mission, lights-out operation
- Leave-behind asset for future missions (SMC/IS WFOV)



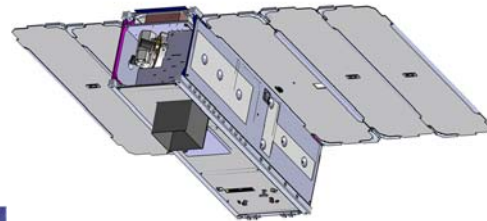
SENSE Bus



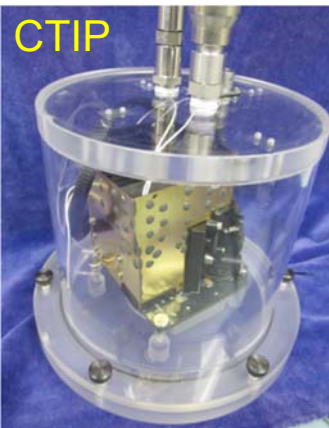
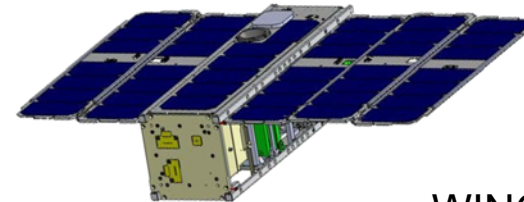


Space Weather Sensors

SV-1: CTIP + CTECS



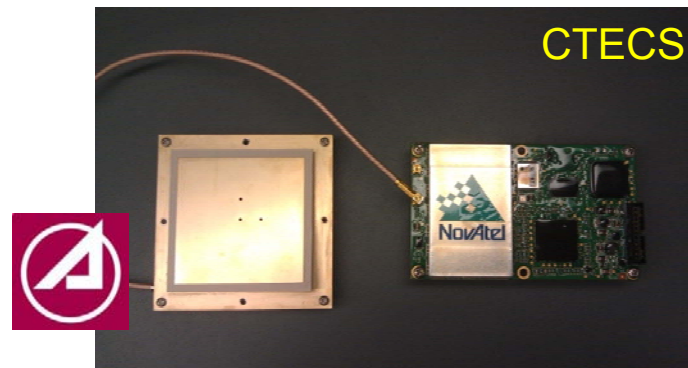
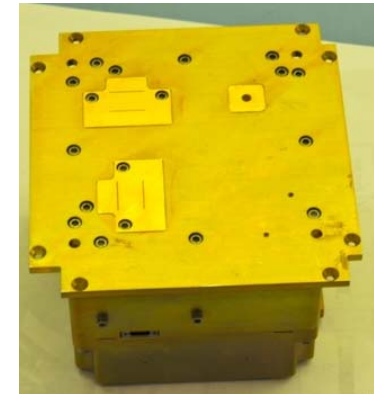
SV-2: WINCS + CTECS



CTIP



WINCS



CTECS

Compact Tiny Ionospheric Photometer (CTIP)

Measures 135.6 nm UV nightglow giving ionospheric density variation and structure

CubeSat Total Electron Content Sensor (CTECS) (x2)

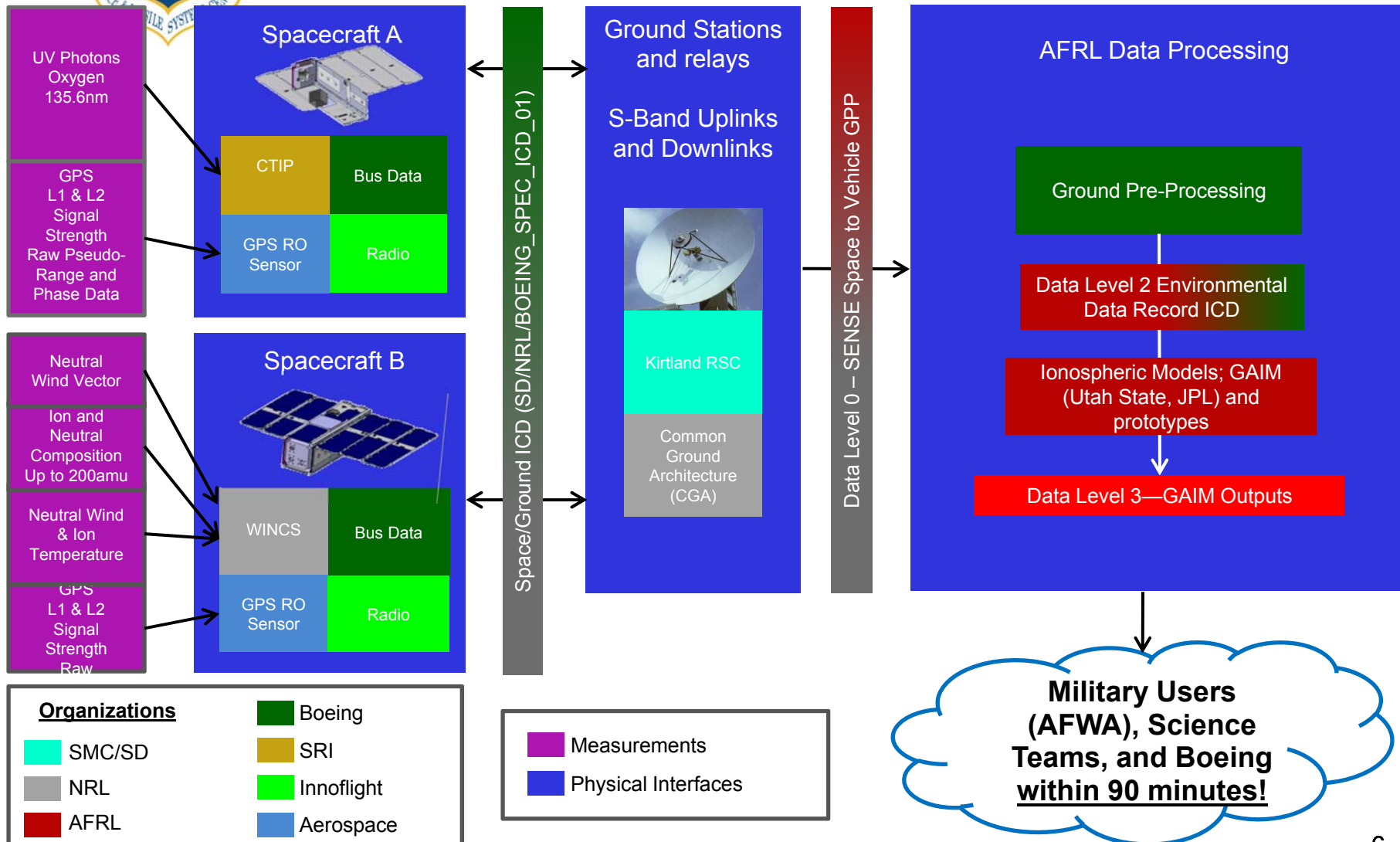
Measures amplitude and phase variations of occulting GPS signals giving ionospheric density and scintillation

Winds Ions Neutrals Composition Suite (WINCS)

Measures ram fluxes of ions and neutral particles giving local electric field, densities, neutral winds, and temperatures

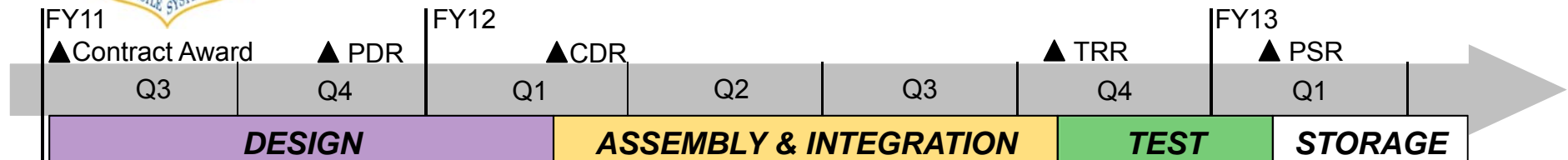


SENSE Data Flow

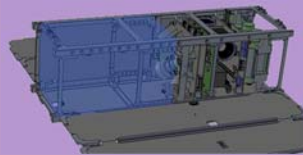




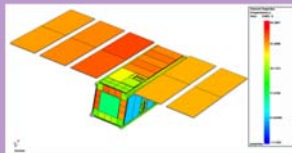
SENSE SV Development



DESIGN



Leveraged NRO's Colony II bus



Conducted extensive M&S



S-Band XCVR

Developed functional prototypes to reduce risk

ASSY & INTEGRATION



SV Assembly at Boeing Phantom Works

8/10/2012 removed RIB S/N 29 and replaced with S/N 2. S/N 29 is now designated a flight unit.
 8/24/2012 began assembly of unit
 8/28/2012 completed vehicle assembly through sequence 27, skipping steps 3, 5, 8, 17, 18, and 21. Was not able to complete step 2 due to lack of tapped holes in frames for deployment switches. Called Boeing for testing.
 10/10/2012 swapped GX and RX frames for ones with tapped deployment switch holes, delivered a non-flight-X panel to Boeing to facilitate testing. Hooked up battery (step 17).
 10/15/2012 removed radio for independent testing.
 10/18/2012 returned vehicle to LEDA for further assembly. Removed CTR, rRWAs and EPIC/PMAD stack for modification. Added C-177 Jameson Connection. Modified PMAD while were jumpers to eliminate Y panel RF shield interference.
 10/26/2012 reassembled vehicle through step 26, skipping 23 and 24. After battery connection, RFP pin plugged on, reattached paper to the vehicle. Immediately heard a pop and got some smoke. Jiggled off the RFP pin. Disconnected the battery. Returned vehicle to Boeing.
 11/9/2012 removed EPIC/PMAD for testing. Removed battery for testing.
 11/9/2012 radio cable has a loose connection. Removed it and replaced it with a flight radio cable. Reinstalled EPIC/PMAD. Reinstalled battery.
 11/9/2012 removed EPIC/PMAD stack to confirm test failures.
 11/13/2012 replaced vehicle to LEDA. Replaced EPIC/PMAD 528545 with 524442. Modified CTR/PMAD to route 60-200 connectors while were jumpers to avoid Y panel RF shield interference.
 11/20/2012 added jumper wire from J2-39 to J3-4 on EPIC board 524 to solve Batt A/B problem.
 12/1/2012 replaced the radio trunk cable due to a short in the original cable. Restaked and returned to RB for integration into the vehicle.

Maintained Detailed Assy Logs

TEST

1. HW/SW Compatibility Test
 - Executed 19 test scripts to verify subsystem & SV functionality

2. Environmental Test



Vibration



TVAC

3. Day-In-The-Life Test

- 24hr LEO rehearsal
- Operators at RSC commanded FMs via CGA
- Verified SV compatibility with ground system

STORAGE



SV delivery to AFRL for storage



SMC/XR accepts HW delivery

Enhanced *mission assurance* provided by thorough *process execution* and extensive *testing*



On-Orbit Lessons Learned

- Space vehicle discrimination methods must improve if NanoSatellites are to be used in future operational architectures
- Small Satellite \neq Low Complexity
- Many SENSE space vehicle subsystems performing exceptionally well:
 - Li-Ion batteries
 - S-band radio
- Common Ground Architecture:
 - Versatile and stable software platform
 - Enables resilient command and control in contingency operations



SV-1 Integration



SV-2 Integration



Summary

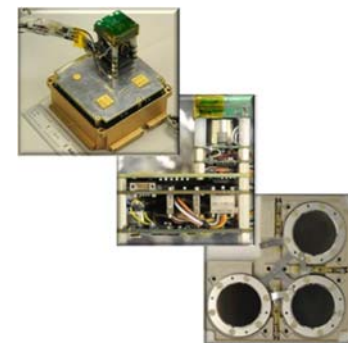
- **SENSE is SMC's premier rapid development effort which will demonstrate the capability of CubeSats to perform space missions in an affordable and resilient manner.**
 - Acquired under Air Force acquisition procedures employed for all space vehicle
 - Delivers three first generation miniature sensors; WINCS, CTIP, CTECS.
 - Addresses 2 of 12 Space Weather Gaps
- **A distributed ground architecture with leave-behind capability to fly the next minimally-manned satellite mission.**



CTIP



CTECS



WINCS



S U P P L E M E N T A R Y S L I D E S



SENSE Ground Terminal at KAFB, NM

