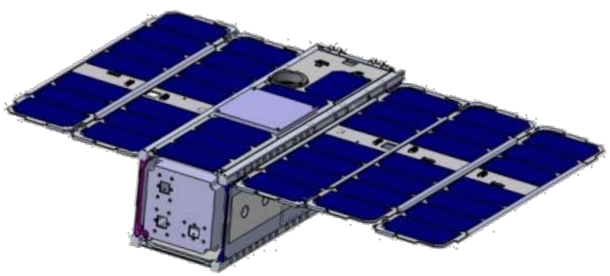
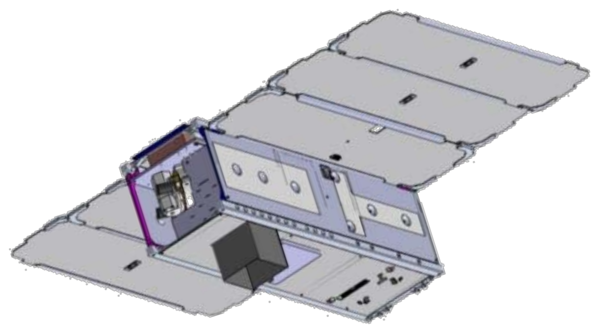
Space Environmental NanoSat Experiment (SENSE)

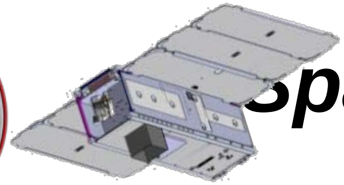




Capt Paul La Tour
SENSE PM

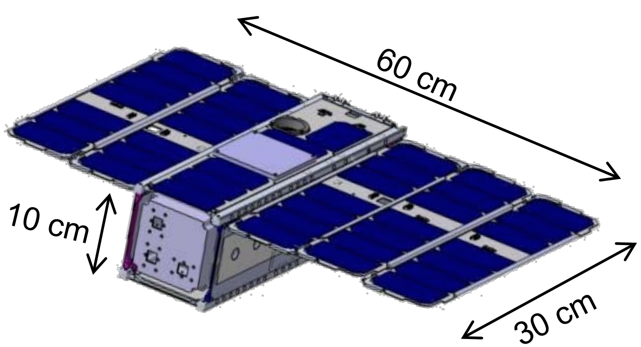
Overview

- 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



Space Environmental NanoSat Experiment (SENSE)

- 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.

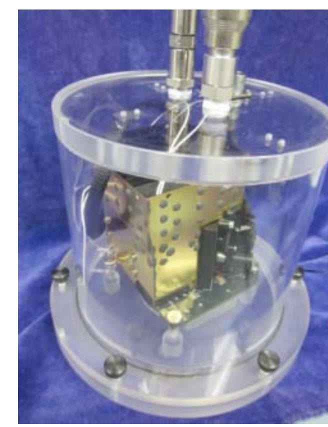


SV #2
Wind Ion Neutral Composition Suite (WINCS) Configuration

Photos of actual Flight Hardware

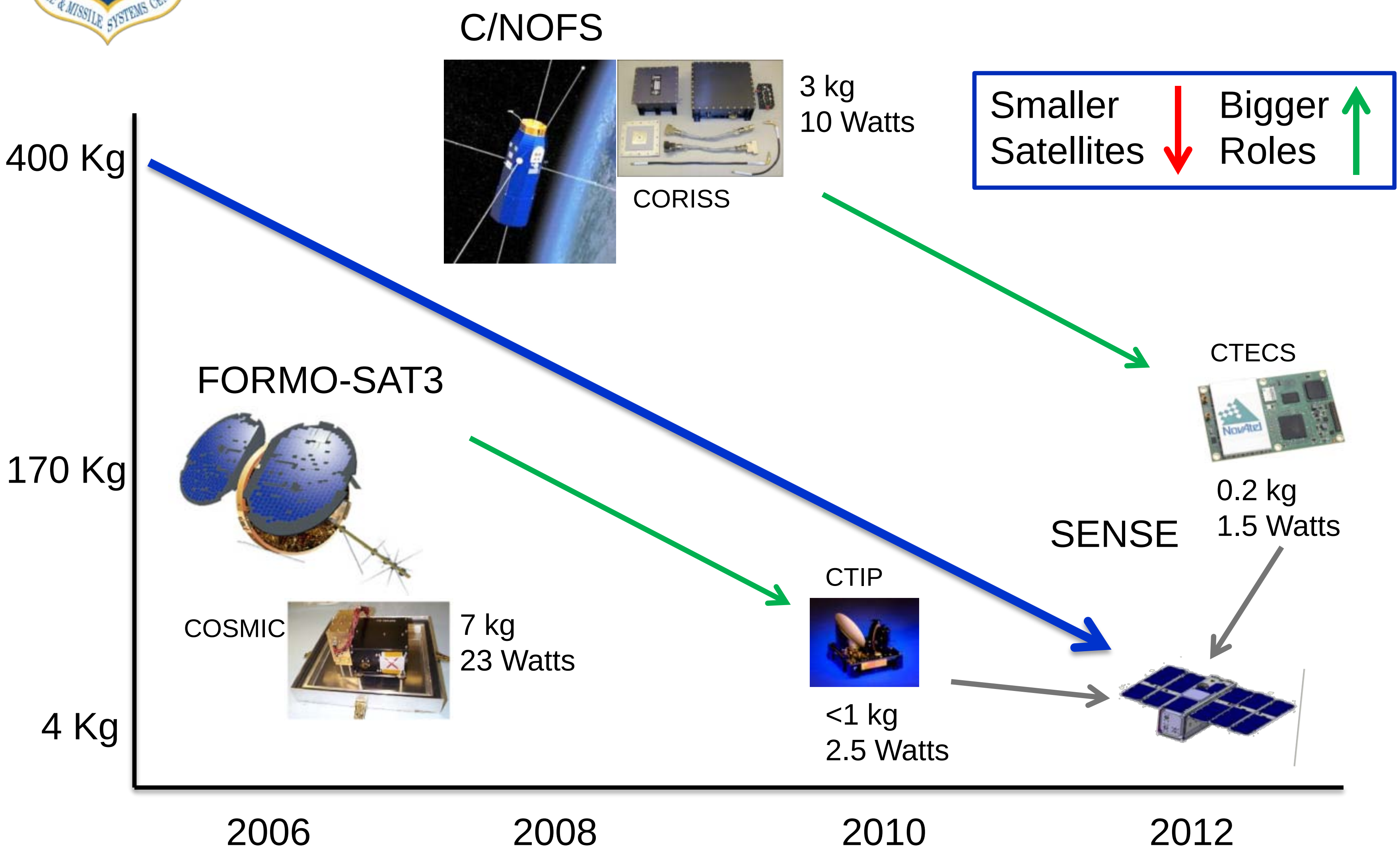
Compact Total Electron Density Sensor (CTECS)

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

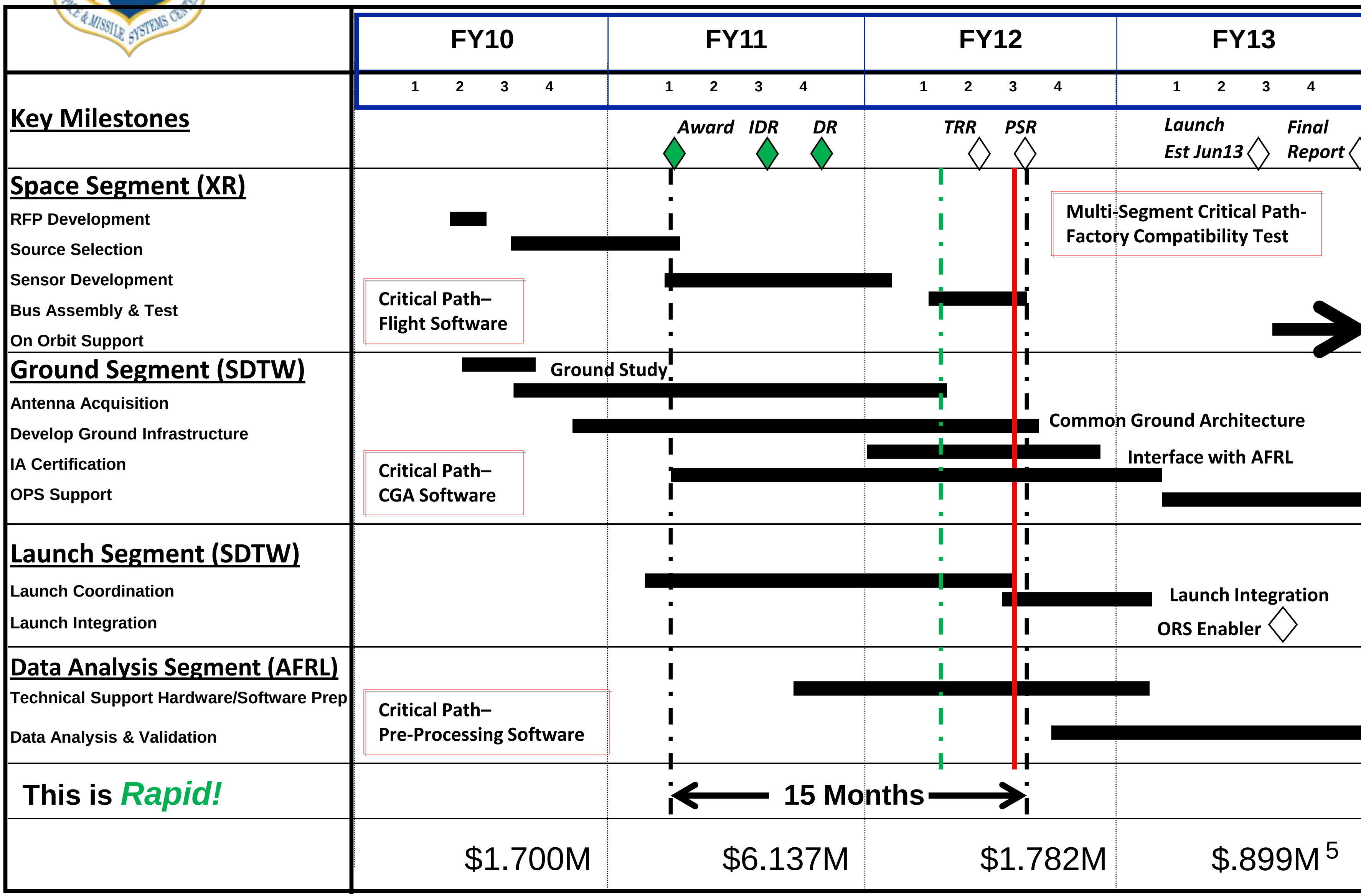


Cubesat Tiny Ionospheric Photometer (CTIP)

SENSE Sensor History (Evolution)



Schedule


FY10
FY11
FY12
FY13
1 2 3 4
Key Milestones
Award
IDR
DR
TRR
PSR
Launch Est Jun13
Final Report
Space Segment (XR)
RFP Development
Source Selection
Sensor Development
Bus Assembly & Test
On Orbit Support
Multi-Segment Critical Path- Factory Compatibility Test
Critical Path– Flight Software
Ground Segment (SDTW)
Antenna Acquisition
Develop Ground Infrastructure
IA Certification
OPS Support
Ground Study
Common Ground Architecture
Interface with AFRL
Critical Path– CGA Software
Launch Segment (SDTW)
Launch Coordination
Launch Integration
Launch Integration
ORS Enabler
Data Analysis Segment (AFRL)
Technical Support Hardware/Software Prep
Data Analysis & Validation
Critical Path– Pre-Processing Software
This is Rapid!
15 Months
$1.700M
$6.137M
$1.782M
$.899M

SENSE Organizations

Demo Stakeholder

SMC

SENSE Demo Lead

Demo Stakeholder

DWSD

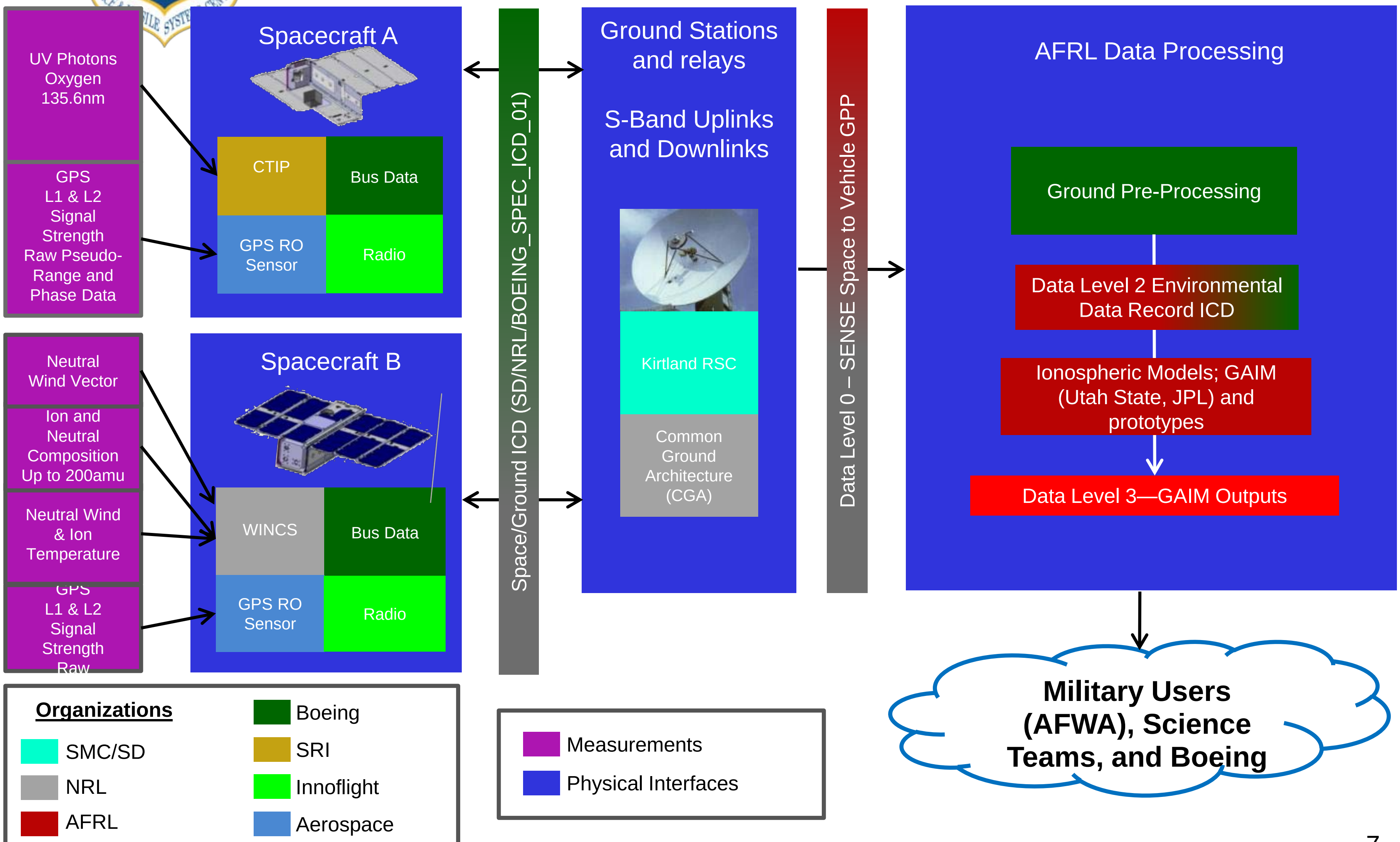
Space Segment (XRFF)

Launch Segment (SDTD)

Ground Segment (SDTO)

Data Analysis & Mission Validation (RVBX)

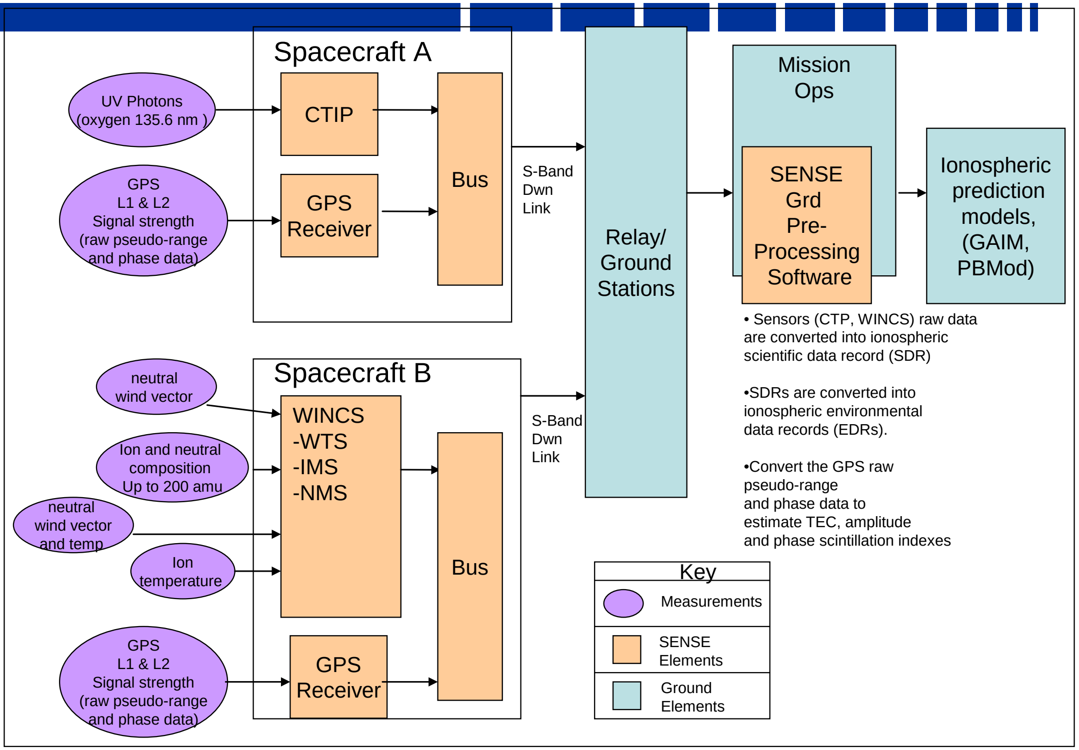
SENSE Data Flow and Partner Organizations



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**

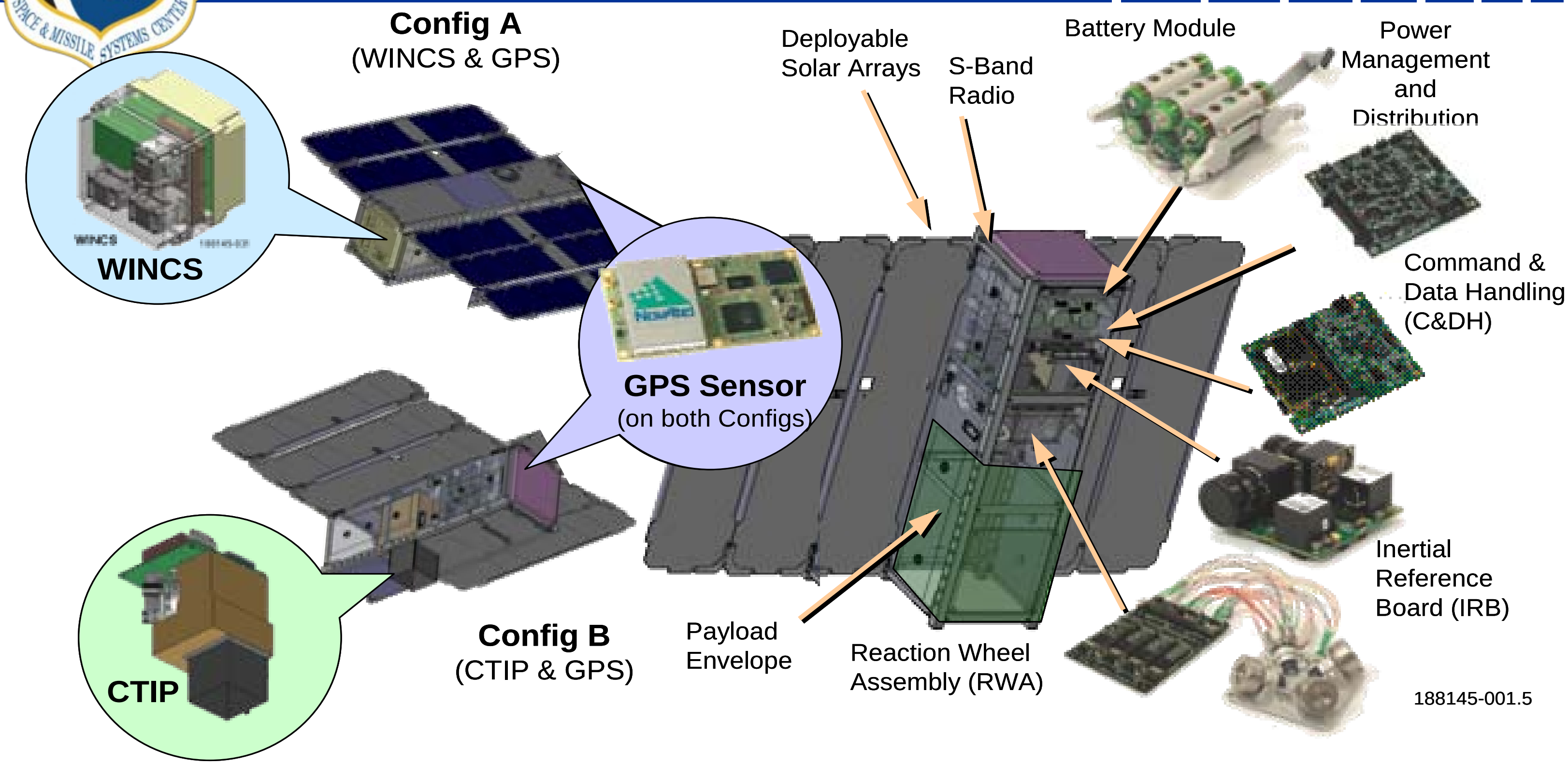
SEM Matrix

Space Environment Measurement Matrix					
Measurement	DMSP Polar Orbit Fixed LT	C/NOFS Equatorial Orbit All LT	SENSE Instruments All LT	SENSE + Ground Processing	DMSP, C/NOFS, SENSE
Auroral Particles	G	N / A	N / A	N / A	G
Auroral Energy Deposition	G	N / A	N / A	N / A	G
Auroral Imagery	G	N / A	N / A	N / A	G
Auroral Boundary	G	N / A	N / A	N / A	G
Energetic Ions	Y - L	N / A	N / A	N / A	Y
Medium Energy Particles	G	N / A	N / A	N / A	G
High-Lat Ionospheric Scintillation	Y - A	N / A	N / A	N / A	G
Low-Lat Ionospheric Scintillation	Y - OA	G	Y - O	G	G
High-Lat *In Situ* Electric Field	G	N / A	N / A	N / A	G
Low-Lat *In Situ* Electric Field	Y - O	G	Y - OT	G	G
High-Lat Electron Density Profile	Y - A	N / A	N / A	N / A	Y
Mid-Lat Electron Density Profile	Y - OA	N / A	G	G	G
Low-Lat Electron Density Profile	Y - OA	G	Y - O	G	G
Neutral Density Profile	R	Y - AT	Y - AT	G	G
In Situ Neutral Winds	R	Y - AT	Y - AT	Y	Y
High-Lat Geomagnetic Field	G	N / A	N / A	N / A	G
Low-Lat Geomagnetic Field	Y - O	G	R	R	G
In Situ Plasma Temperature	G	G	Y - T	Y	G
In Situ Plasma Fluctuations	G	G	R	R	G

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

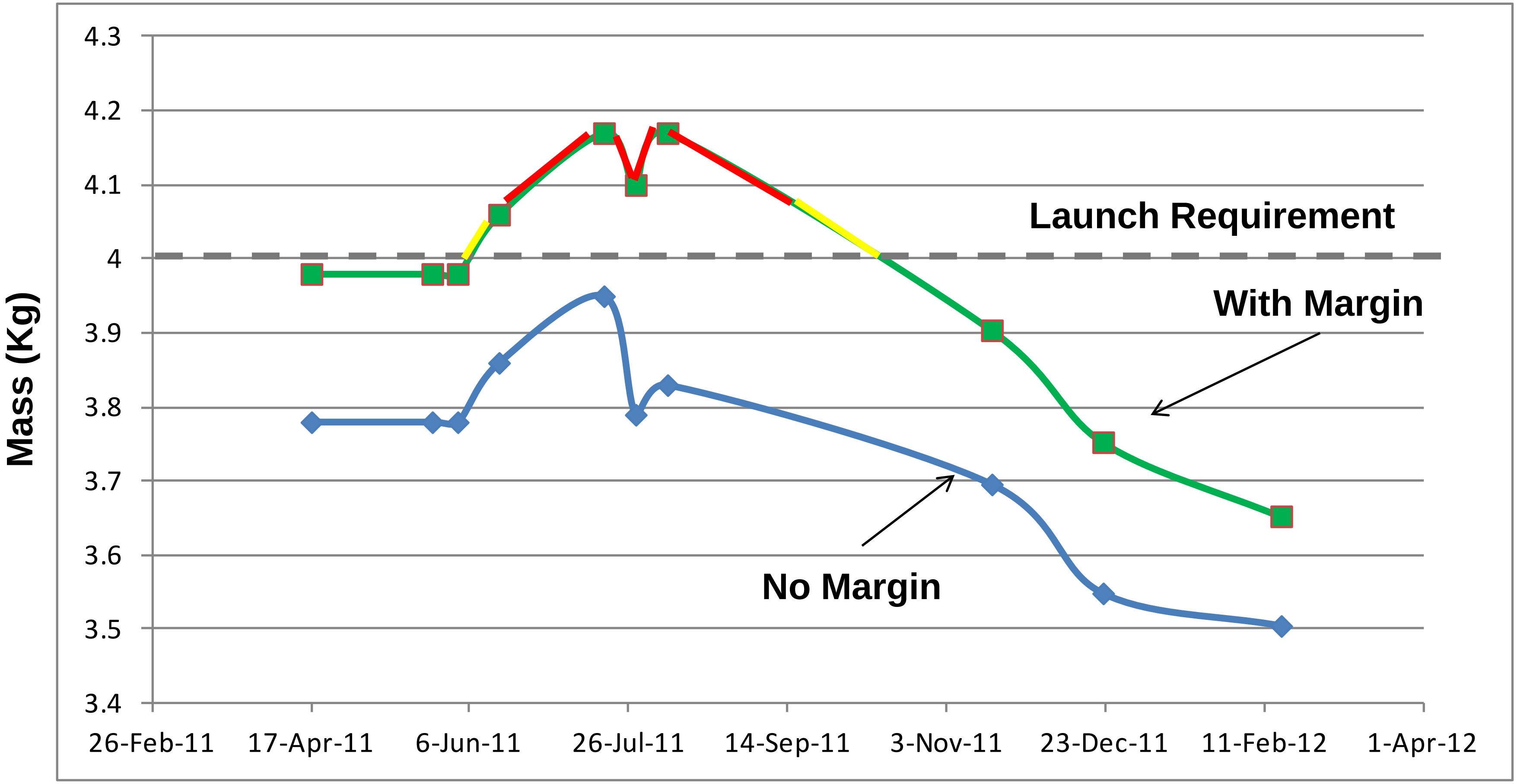
O	Sub-optimal orbital inclination
A	Orbit altitude
T	Technology – instrument has limited or unproven capability for this parameter
L	Instrument covers a limited range of the parameter

SENSE Bus

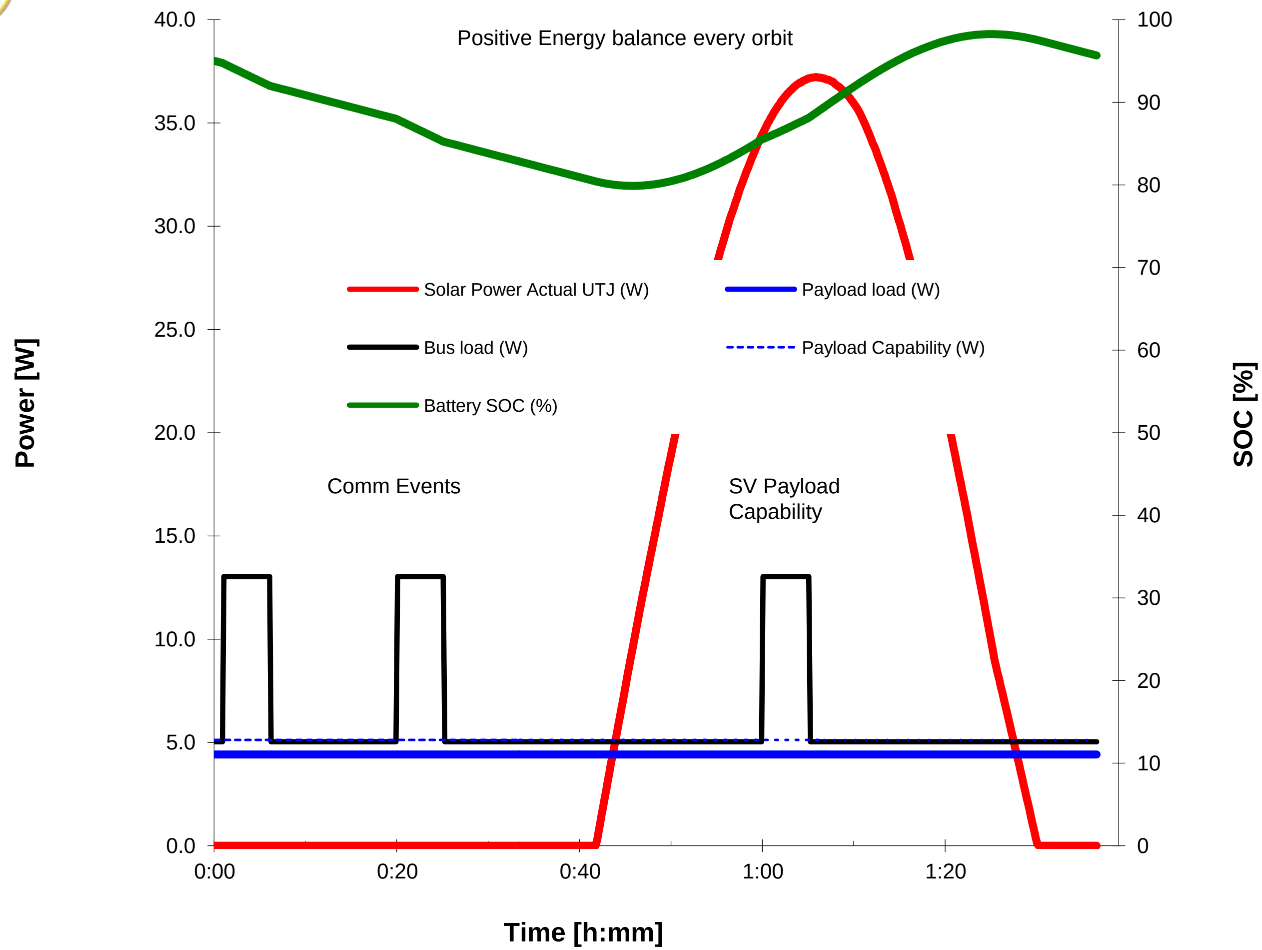


- **Very capable and low cost bus, considered infeasible only 4 years ago**
  - **Three axis stabilized; four reaction wheels**
  - **Two star cameras and GPS**
  - **Dosimeter included into Bus design**
- **1 Mb/s Downlink & 4 kb/s Uplink S-Band Encrypted transceiver**
- **35 watts generated orthogonal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

Space Vehicle Mass (Worst Case SV #2)



Positive Energy Balance



•SV has the ability to transmit 15 min/orbit
•Enables latency requirements satisfaction for SEM mission

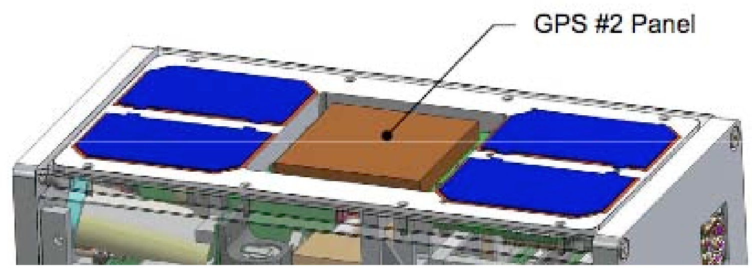
CTECS- Radio Occultation Sensor

- **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

NovAtel OEMV-2 receiver



AutoCad drawing of CTECS custom dual patch antenna embedded in the MTV satellite panel.

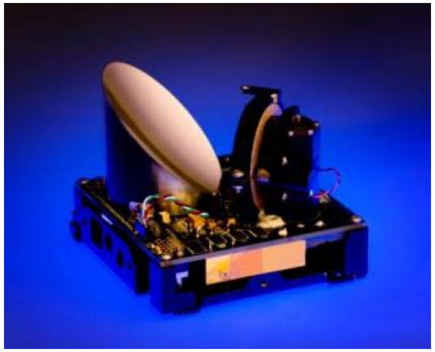
Compact Tiny Ionospheric Photometer (CTIP)

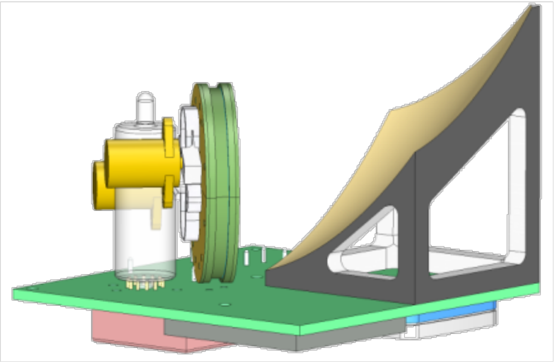
Objective: Gather data to characterize the ionosphere through the natural decay rate as seen in recombination of O^+ ions and electrons

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

Measures:

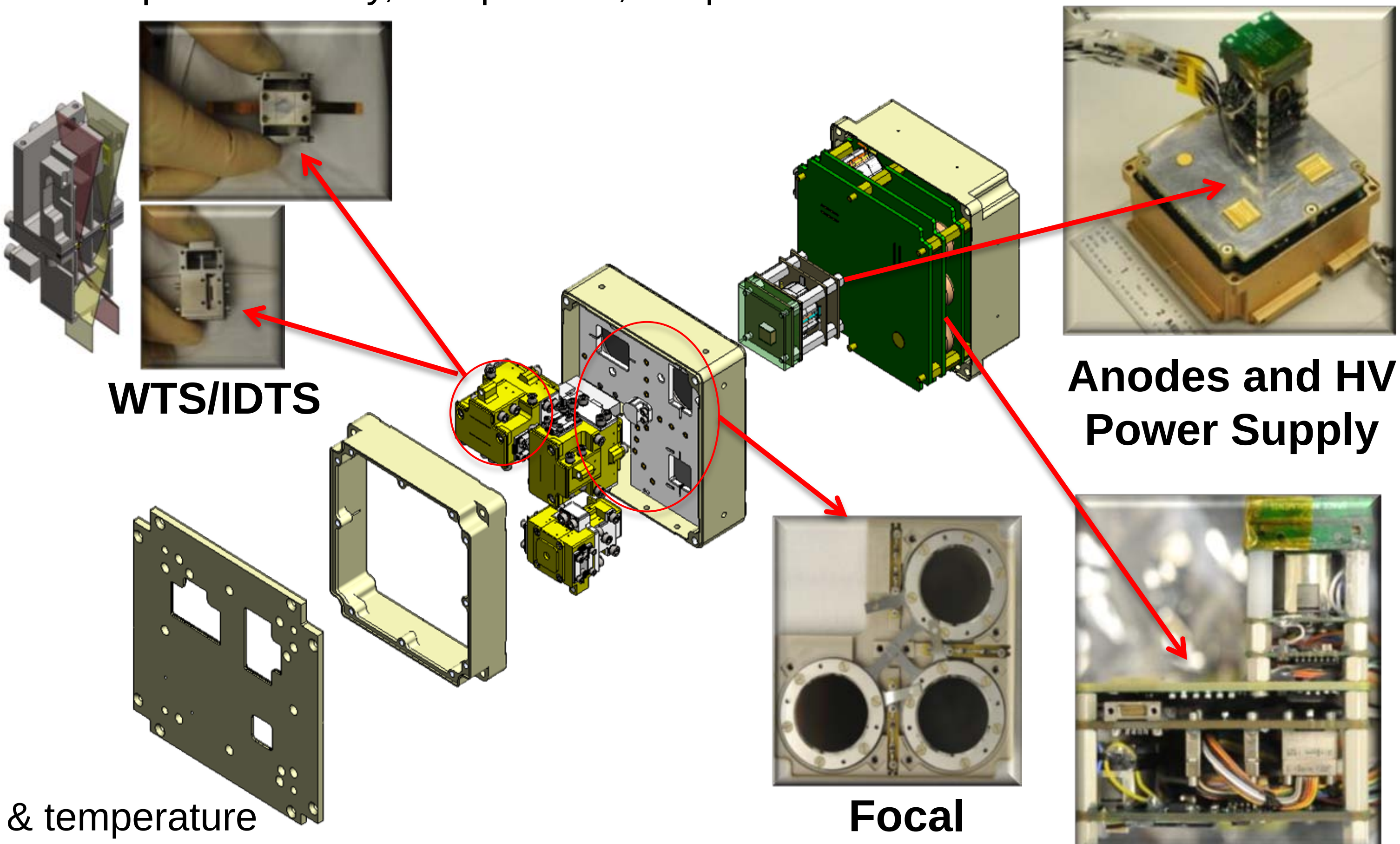
1. Ultraviolet Airglow at 135.6 nm





Wind Ion Neutral Composite Suite (WINCS)

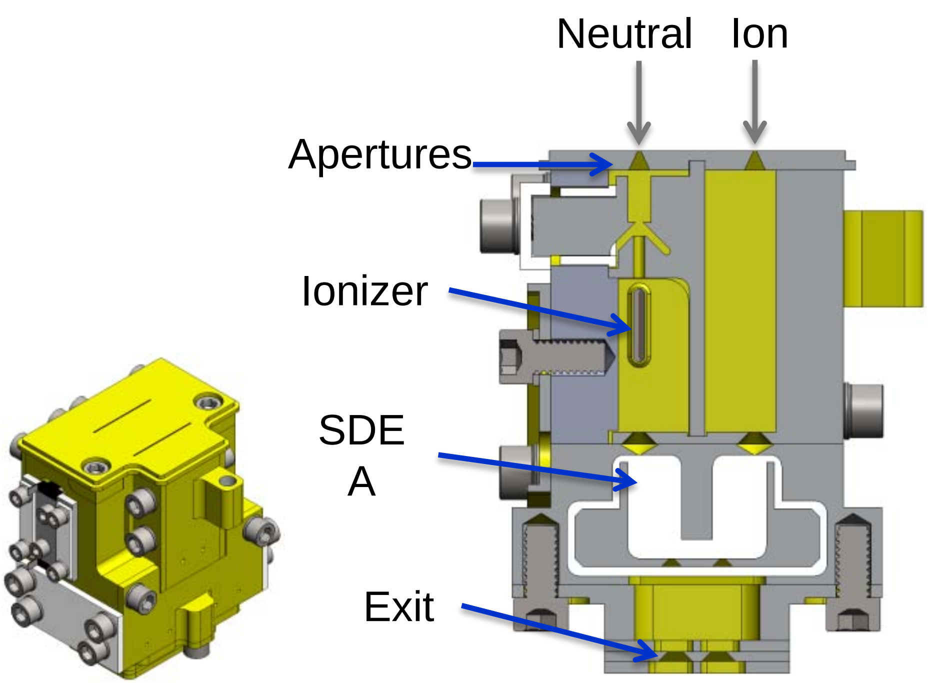
Objective: Acquire simultaneous co-located, in-situ measurements of atmospheric density, composition, temperature and winds.



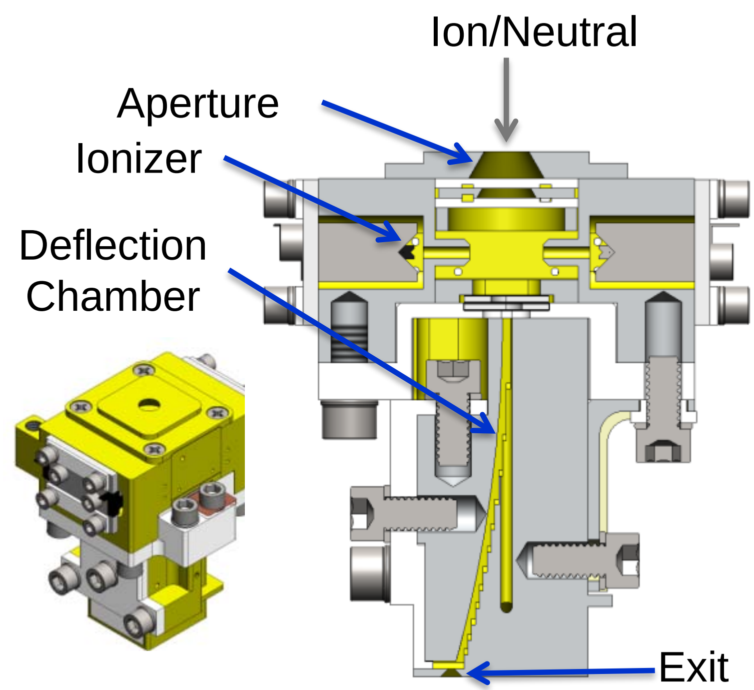
Measures:
1. Neutral winds & temperature
2. Ion-drift & temperature
3. Ion & Neutral composition
4. Plasma Composition

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**



WTS/IDTS

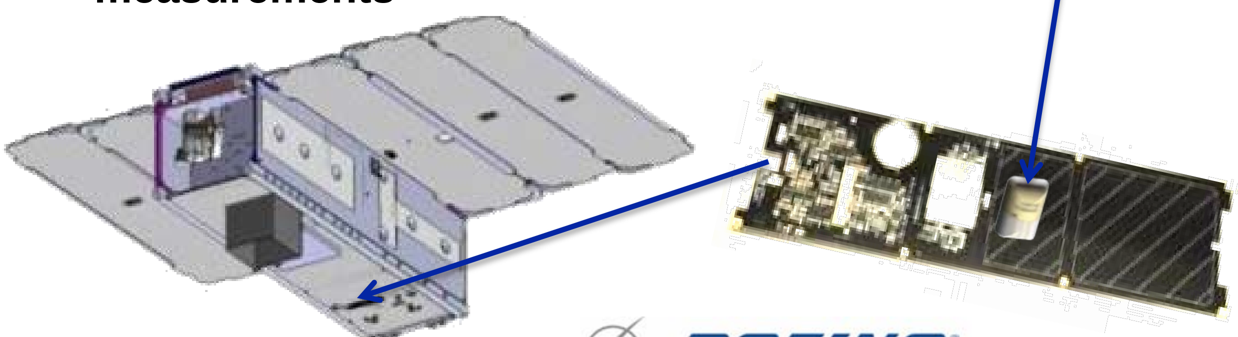


GEMS: IMS/NMS

Teledyne Micro-Dosimeter

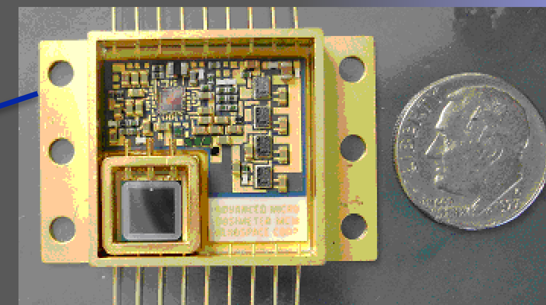
Objective: Provide radiation dosage for measurement and to correlate system performance with exposure

- **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**



BOEING

Teledyne Microdosimeter



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

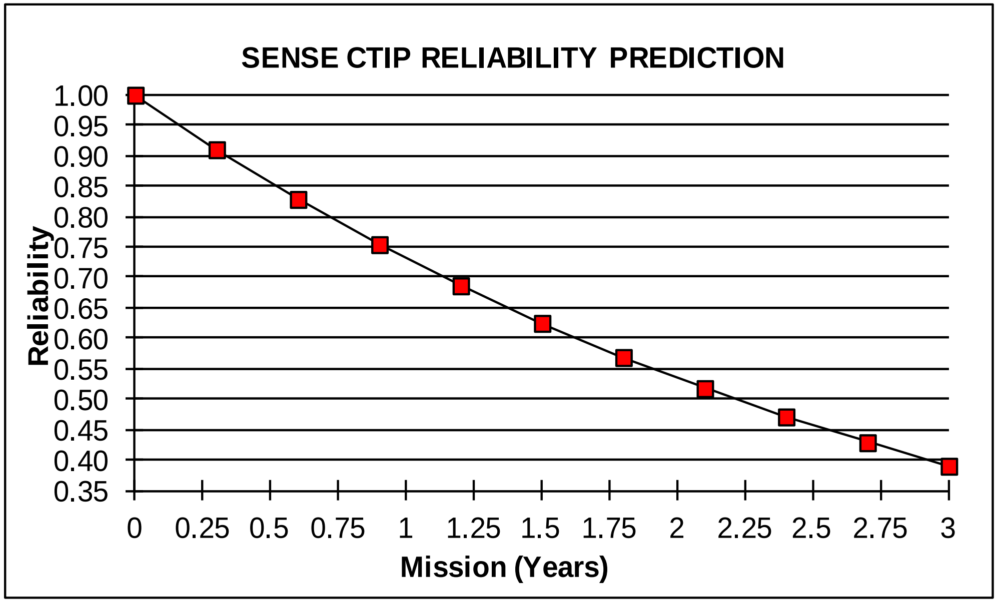
Mission Data Products (TPMs)

Environmental Data Record (EDR)	Parameter	Requirements		Current Value at DR			
		Threshold	Objective	CTECS	WINCS	CTIP	SENSE
Electron density profile	Horizontal cell size	50 km	10 km	Variable	8 km	15 km	8 km
Electron density profile	Vert Cell Size	10 km	3 km	6 km	N/A	10 km	2 km
Electron density profile	Vert coverage	90 km to Sat Alt	90 km to 1600 km	90 km to Sat Alt	N/A	90 km to Sat Alt	90 km to Sat Alt
Electron density profile	Range Ne	2.5E4 to 1E7 e/cm^3	1E4 to 1E7 e/cm^3	2E4 to 1E7 e/cm^3	1E3 – 1E7/cm^3	2E4 to 1.4E8	1E4 to 1E7 e/cm^3
Electron density profile	Range VTEC	3 to 200 TECU	1 to 200 TECU	3 to 200 TECU	N/A	3 to 19000 TECU	1 to 19000 TECU
Electron density profile	Sigma Ne	Greater of 1E5 /cm^3 or 30%	Greater of 1E4 /cm^3 or 5%	Variable[1]	10%	± 9%	< 20%
Electron density profile	Sigma TEC	Greater of 3 TECU or 30%	Greater of 1 TECU or 30%	Greater of 3 TECU or 35%	N/A	3 TECU	Greater of 1 TECU or 20%
Electron density profile	Sigma H_mF_2	20 km	5 km	20 km	N/A	N/A	10 km
Electron density profile	Sigma N_mF_2	20%	10%	30%	N/A	N/A	15%
Electron density profile	Sigma N_mE	20%	5%	100%	N/A	N/A	20%
Electron density profile	Latency	90 minutes	15 mintues	15 mintues	N/A	15 minutes	15 mintues
Scintillation	Horizontal Cell Size	100 km	25 km	500-2000 km	N/A	N/A	15 km
Scintillation	Amp. index (S4)	0.1 to 0.5	0.1 to 1.5	0.1 to 1.5	N/A	N/A	0.1 to 1.5
Scintillation	Phase Index (σ_φ)	0.1 to 20 rad	0.1 to 20 rad	0.1 to 20 rad	N/A	N/A	0.1 to 20 rad
Scintillation	Uncertainty S4	0.1	0.1	0.1	N/A	N/A	0.1
Scintillation	Uncertainty σ_φ	0.1 rad	0.1 rad	0.1 rad	N/A	N/A	0.1 rad
Scintillation	Latency	90 minutes	15 mintues	15 mintues	N/A	N/A	15 mintues
Ions	Ion species	none	O_2^+, NO^+, O^+, H^+, He^+	N/A	O_2^+, NO^+, O^+, H^+, He^+	N/A	O_2^+, NO^+, O^+, H^+, He^+
Ions	Composition discrimination	none	5% of Ne	N/A	5 % of Ne	N/A	5% of Ne
Ions	Drift velocity	none	Objective	N/A	+/- 2000 m/s	N/A	+/- 2000 m/s
Ions	Density	none	Objective	N/A	1E3 – 1E7/cm^3	N/A	1E3 – 1E7/cm^3
Ions	Density fluctuations	none	Objective	N/A	1E3 – 1E7/cm^3	N/A	1E3 – 1E7/cm^3
Ions	Energy	none	Objective	N/A	0 to 20 ev	N/A	0 to 20 ev
Ions	Temperature	none	Objective	N/A	1000 K to 4000 K	N/A	1000 K to 4000 K
Electric Field	Electric field	none	Objective	N/A	0 to 150 mV/m	N/A	0 to 150 mV/m
Neutrals	Wind speed	none	Objective	N/A	+/- 2000 m/s	N/A	+/- 2000 m/s
Neutrals	Density	none	Objective	N/A	1E3 to 1E10 /cm^3	N/A	1E3 to 1E10 /cm^3
Neutrals	Temperature	none	Objective	N/A	1000 K to 4000 K	N/A	1000 K to 4000 K

1. 100% E layer, 50% F layer bottom side, 30% F layer near peak, 15% topside

Reliability Modeling (CTIP)

- **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**