

US Army
Space and Missile Defense Command
Operational Nanosatellite Effect (SMDC-ONE)
Program Status
CubeSat Workshop 2009



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System Configuration

SMDC-ONE
Spacecraft Segment

Bus
Element

Comm
Element

Structures &
Mechanical

Guidance Nav
& Control

Thermal
Control

Electrical
Power

Command &
Data Handling

DEPLOYABLE
ANTENNA TURN
STILE

RECEIVER PHASE
SPLITTER

HYSTERESIS
RODS

RF FILTER

PERMANENT
MAGNET
(ATTITUDE
CONTROL)

THERMAL
RADIATOR

END CAP SOLAR
PANEL

POWER

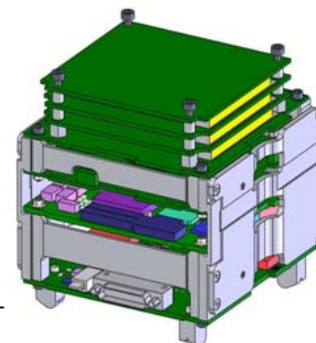
FLIGHT
COMPUTER

UMBILICAL
BOARD

PAYLOAD

SOLAR CELLS

TRANSMITTER
PHASE SPLITTER



PCB
SUBASSEMBLY

Mission Objectives

Mission Objectives

Minimum Success Criteria

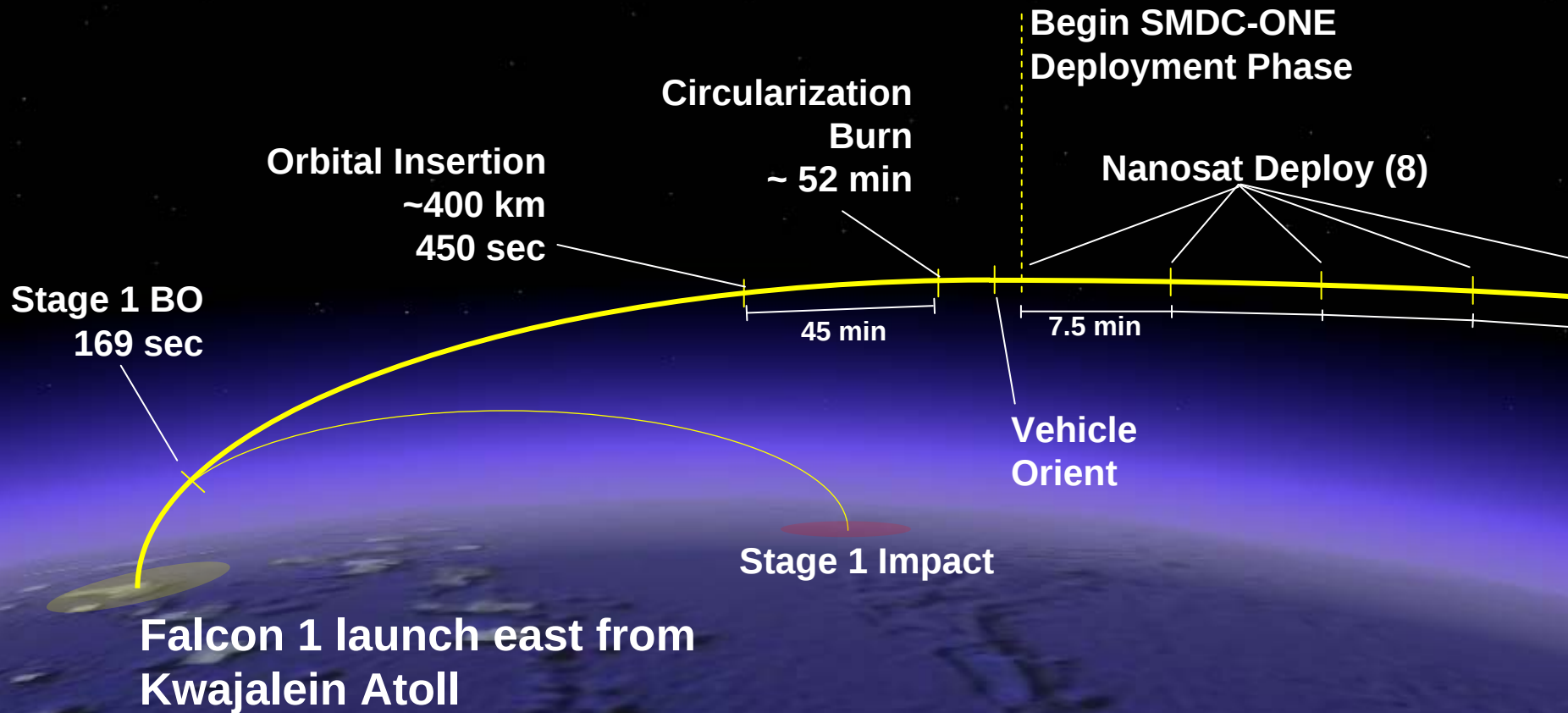
1. Demonstrate the ability to rapidly design and develop militarily relevant low cost spacecraft.
2. Primary Operational Objective
 - a. Scenario OV-1. Receive packetized data from multiple Unattended Ground Sensors (UGS). Transmit that data to ground stations within the SMDC-ONE ground track.
3. Secondary Operational Objective
 - a. Scenario OV-2. Provide real time voice and text message data relay to and from field deployed tactical radio systems.
4. Demonstrate SMDC-ONE operational life time of 12 months or longer.

1. Design, develop, and deliver eight SMDC-ONE satellite systems within 12 months of ATP (April 2008) for a hardware cost not to exceed \$350k per satellite.
2. Receive UGS signal on two or more SMDC-ONE satellites and successfully relay that signal to a deployed ground station.*
3. Not required for mission success.
4. Demonstrate an on-orbit operational life of 6 months or longer.**

•Dependent upon launch of 8 satellites

•** Dependent upon assigned orbit

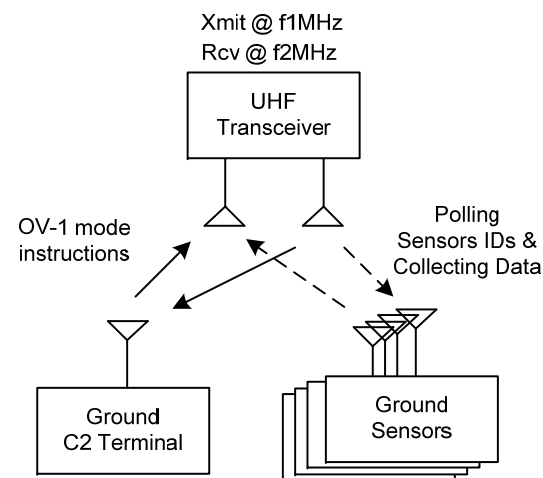
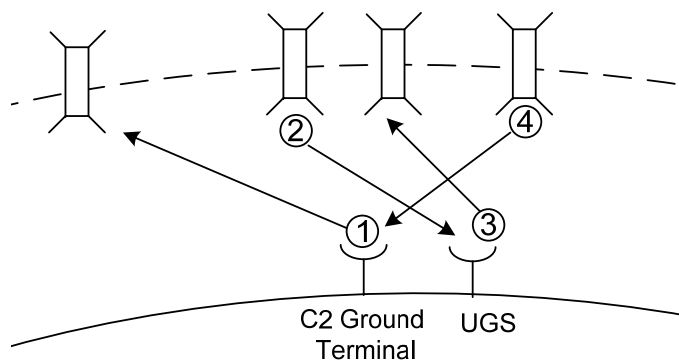
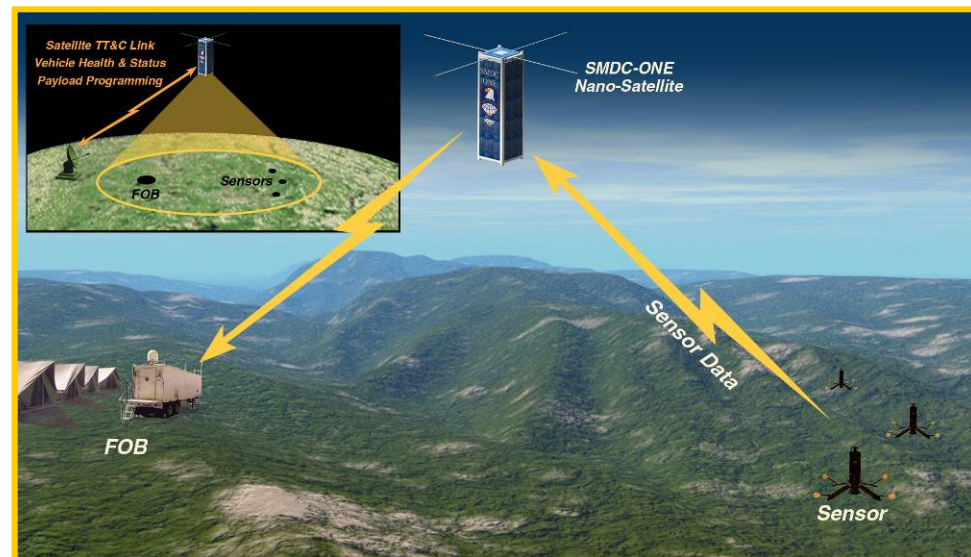
Design Reference Mission



Primary Mission OV-1 CONOP

Satellite-Autonomous Data Collection from Unmanned Ground Sensor (UGS) Segments

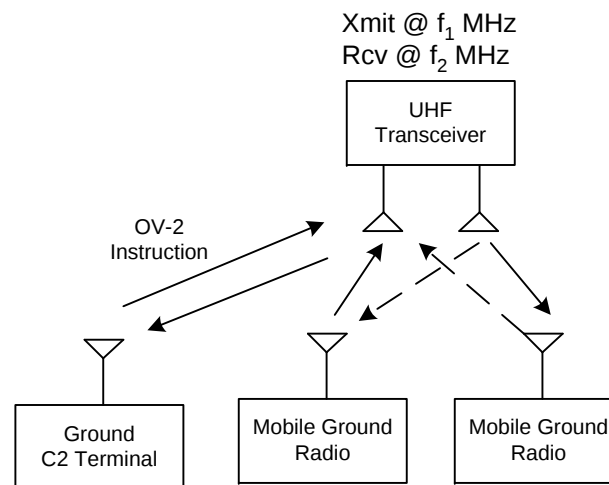
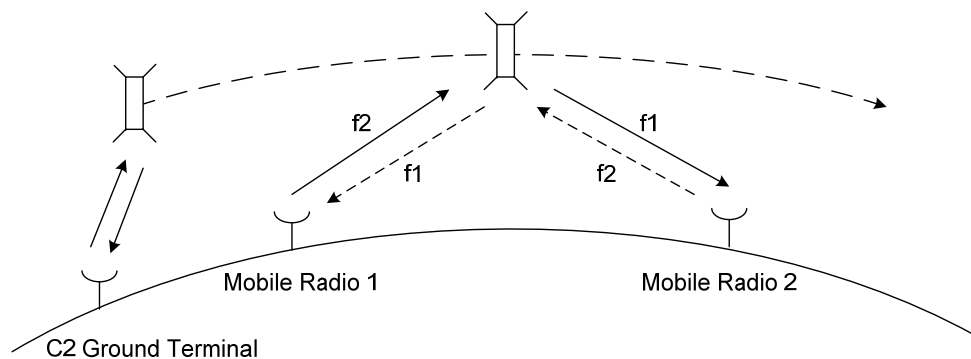
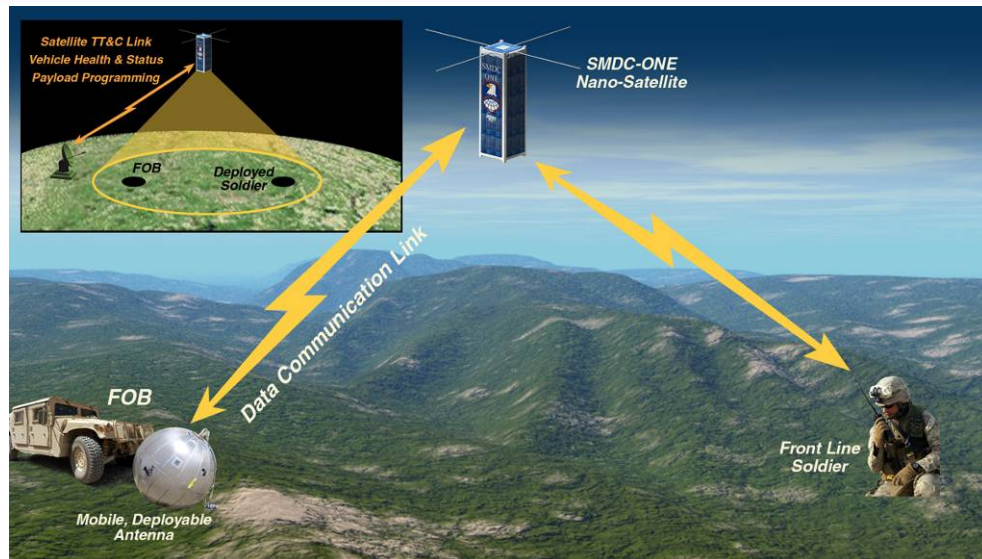
- Mission Executed From Stored Scheduler or C2 Uplink Instructions “1” Based on Time Schedule
- Satellite Polls Pre-Loaded UGS ID # “2” on Ground and Retrieves Data
- Satellite Data Collection from Unmanned Ground Sensors (UGS) “3”
- Collected UGS Data Transferred to Ground “4”



Secondary Mission OV-2 CONOP

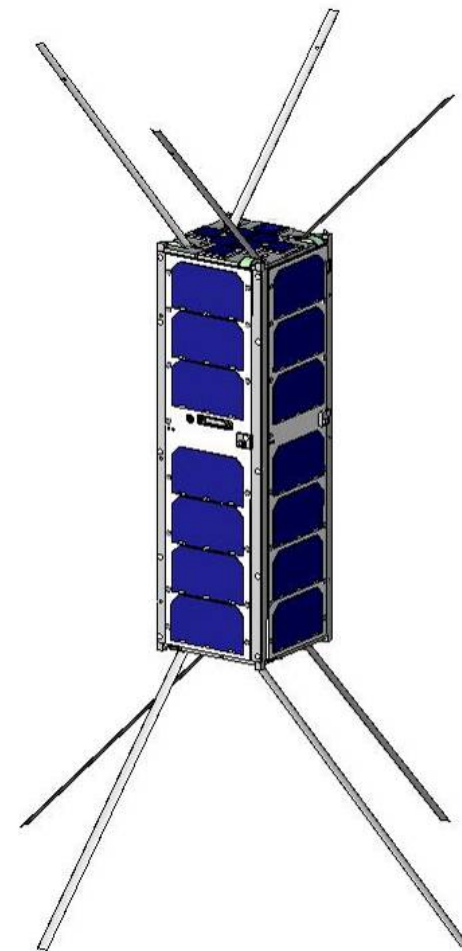
UHF Data Relay Between 2 Mobile Ground Segments (Radios)

- Mission Instructions Initiated From Stored Scheduler Events or C2 Re-Schedule
- Data Text Message Format



Status

- Spacecraft Critical Design Review Completed in December 2008
- Spacecraft Radio Frequency pattern/strength testing completed at AMRDEC Unconventional Beam Office test facility -- Redstone Arsenal, Huntsville.
- Spacecraft Integration and Functional Tests are underway.
- Environmental Test Series
 - Shock test at Marshall Space Flight Center
 - Vibration testing at Miltec Iuka, MS facility
 - Thermal Balance / Thermal Cycling at Miltec Huntsville facility
- US Army Acceptance April 28 at Miltec facility
 - 8 flight units



Verification Testing

- Shock test at MSFC on two qualification units.
- Random Vibration performed at Miltec luka facility on qual and flight units
- Thermal Balance testing performed on single qual unit as part of thermal cycling test to verify on-orbit predictions
- Thermal Cycling under vacuum on qual and flight units
- Antenna Deployment Test performed as part of thermal vacuum testing
- Antenna Pattern verification to be performed at Redstone Arsenal Army facility using specially designed RF mock-up
- Planning for end-to-end RF test at Redstone Arsenal following delivery.



Lessons Learned

The Cost of Militarily Relevant Nano & Micro Spacecraft

- Cost and Schedule are a question of Customer & Contractor Risk Tolerance (Mission Assurance)
 - Number and formality of design and readiness reviews.
 - Development products (drawings, specs, ICDs, etc.) determined by sound engineering practice and the need for a satisfactory Acceptance Data Package for government buy-off.
 - Hardware purchased and environmental tests run to gain confidence in COTS products.
 - Spacecraft verification plan requires objective evidence of compliance with requirements – documentation.
 - Twelve months is a short period to develop a first of a kind militarily relevant nanosatellite. Contracting and procurement systems have to be highly responsive to make schedule.
 - ITAR issues affect schedule and product quality
- Finality of Launch
 - Highly reliable spaceflight is hard. A great deal of effort and cost are involved.
 - Re-flights are costly or don't happen at all.
 - Government and company reputations are on the line
- Response to these forces drives customers and developers to take prudent measures to ensure mission success, or more accurately ...
 - Ensure that failure review board conclusions find appropriate actions were taken to ensure mission success.

Customer and developer views of mission success must be considered in developing successful program plans.

Lessons Learned

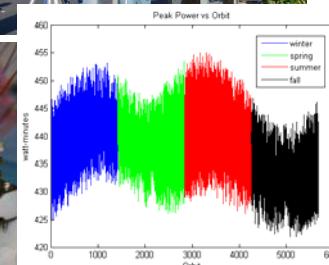
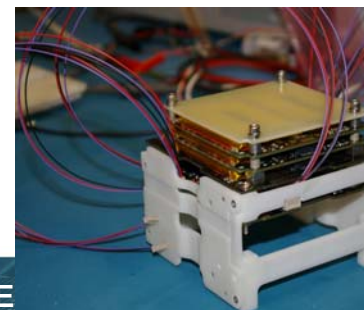
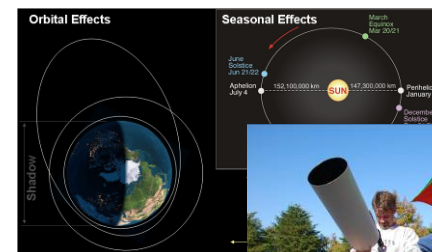
- Nanosats can be relatively inexpensive, but Mission Assurance still costs
- Flight EPS Cards and batteries \$13,000 each spacecraft
 - High efficiency ultra triple junction solar panels \$27,800 each spacecraft
 - \$800k for payload development for all spacecraft

MSFC Quotes for Environmental Test

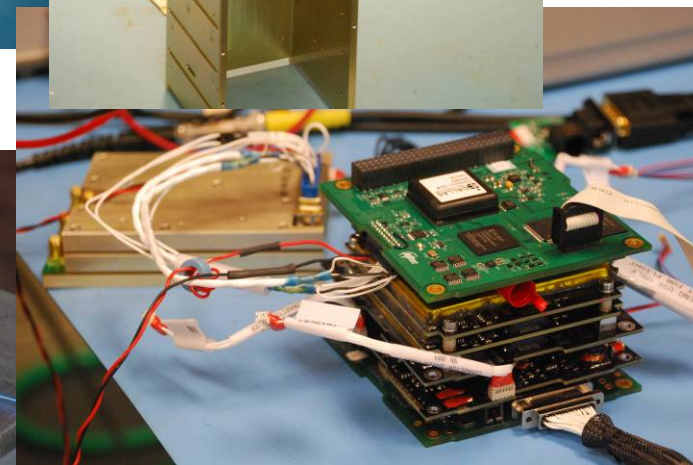
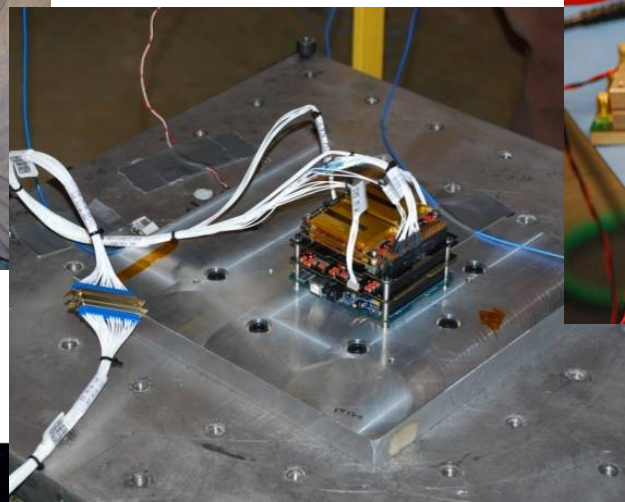
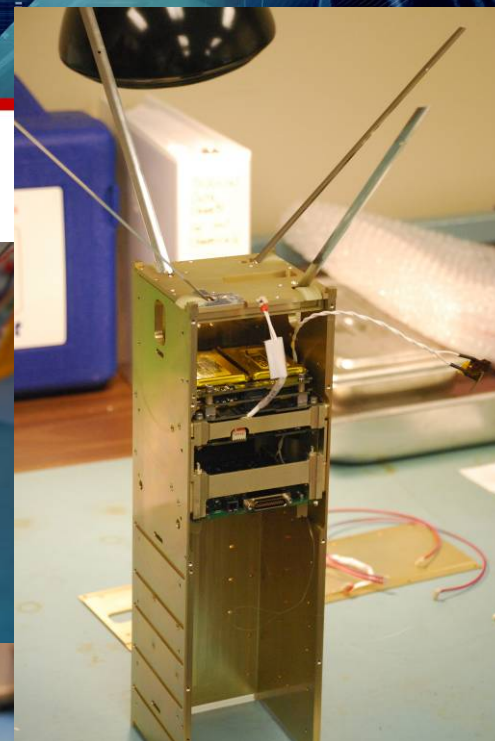
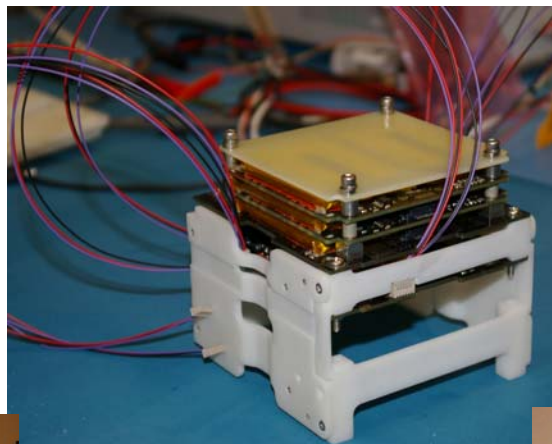
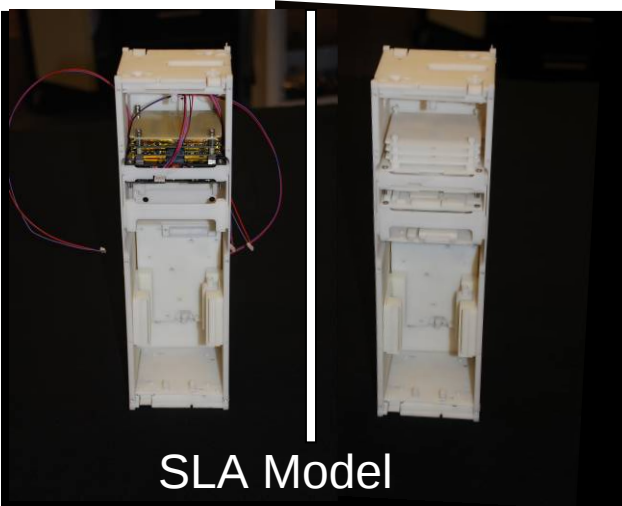
• Shock Test Fixture	\$4k
• Shock Test	\$22k
• Vibration Qualification testing	\$22k
• Vibration Acceptance Testing	\$14k
• Thermal Vac Qualification testing	\$43k
• Thermal Vac Acceptance Testing	<u>\$28k</u>
Total	\$133k

Lessons Learned

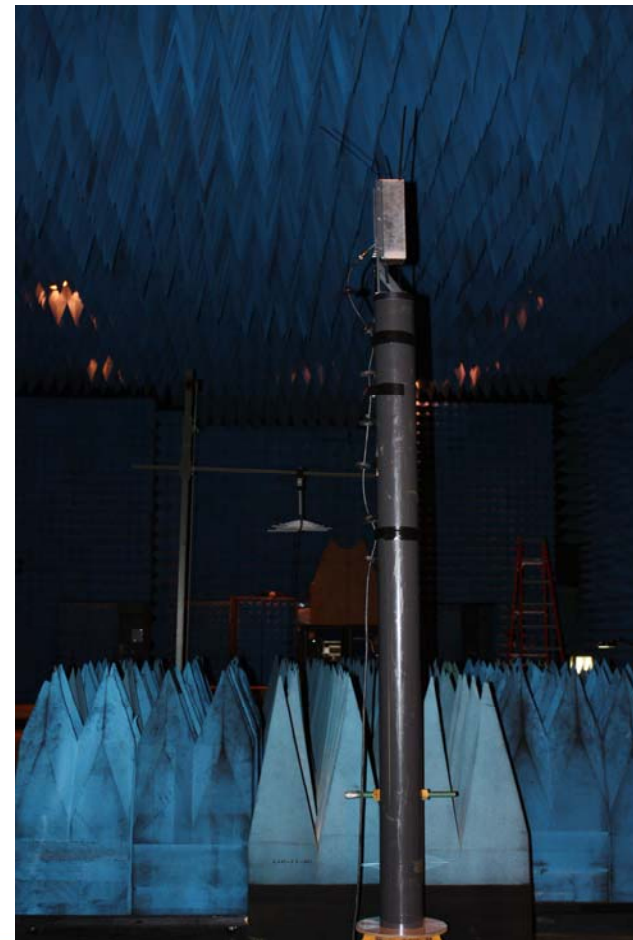
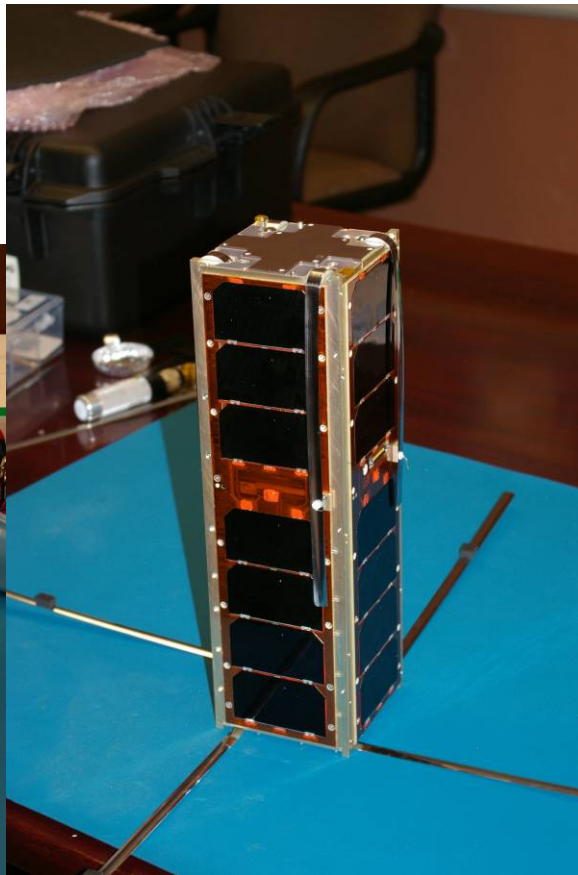
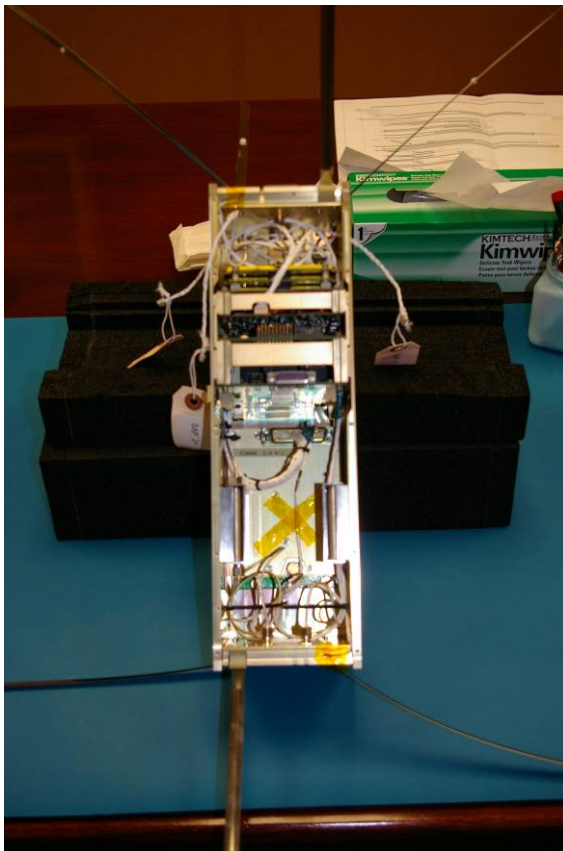
- Requirements are King
 - What is the desired mission?
 - To what degree can it be achieved in this class of spacecraft?
 - Are there other stakeholder desires outside of the mission requirements?
- Except ... when schedule is King
 - Schedule greatly influences capability decisions.
 - Managing stakeholder expectations is extremely important in these fast paced capability driven development activities.
 - Not all stakeholders have technology/acquisition background.
 - Plan program events to ensure that stakeholder expectations are in synch with the capability that can be provided within schedule and budget limitations.
- If you are used to “big space”, get ready to be uncomfortable
 - Measures of goodness for big space missions aren't necessarily the right measures for low cost rapid development missions
- Prototyping
 - One day with a prototype or in field testing is worth a month of analysis
 - Stereo lithography model of the spacecraft was invaluable in finding minute interferences and making corrections before flight Circuit Card Assemblies (CCA) and cables were manufactured
 - We paid the price for not developing prototypes of our CCAs earlier
 - Changes were technically minor, but threatened the delivery schedule



Virtual Tour



Virtual Tour



Conclusions

- The SMDC-ONE program has provided a tremendous opportunity for the US Army and Miltec to understand what capabilities are possible in the nano and micro class of spacecraft
- Customers, stakeholders, and developers must work together to establish measures of goodness appropriate to the nanosatellite mission
- Developers and Procurement Officials must streamline internal processes to enable greater technical achievement in this class of spacecraft

The Nano & MicroSat Promise is Real

- Militarily relevant missions on these small inexpensive platforms are possible
- Development times of 12 to 24 months can be achievable for specialized missions.
- Development of militarily relevant spacecraft for hundreds of k (\$) is probably not feasible, but production copies for low hundreds of k (\$) is feasible.