Tactical Satellite 3
Mission Overview and Lessons Learned

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Overview

• Background
• Concept
• Technical Description
• Concept of Operations
• Program Phases and Lessons Learned
• Highlights
• Summary
Background

• TacSat-3 first of the Tactical Satellite (TacSat) series to go through formal selection process
  - Over 50 “white papers” submitted from services and Combatant Commands
  - Hyperspectral payload selected by the Undersecretary of the Air Force

• Planned as one year Science & Technology experiment
• Demonstrates Hyperspectral imaging with a low cost satellite
• Allows direct tasking by operational theater commanders
• Building block for Operationally Responsive Space
TacSat-3 Concept

Objective: Demonstrate rapid product in-theater Hyperspectral applications

Description:
- Payload has low-cost/modular interface Hyperspectral Sensor/Processor
- Modular/Low-cost Satellite Bus and Payload
  - Cost saving strategies applied strategically throughout program
  - First generation “plug n play” capability

Complementary Experiments:
- Office of Naval Research – Satellite Communications Payload (SCP) ocean data telemetry microsat link provides: Multiple, Tunable VHF and UHF Frequencies
- Satellite Avionics Experiment (SAE) – Modular computing & Plug-n-Play integration technology
TacSat-3/ ARTEMI S Capabilities
(Advanced Responsive Tactically-Effective Military Imaging Spectrometer)

**Capability Gaps/ Shortfalls Addressed**
- Intelligence Preparation of the Battlefield planning / improved Trafficability
- Material detection & Geolocation
- Camouflage detection
- Disturbed earth identification

**Collection/ Operational CONOPS**
- Theater commander task
- Collect Hyperspectral and High Resolution images
- On-board detection of multiple signatures
- Direct in-theater downlink of products

**Technology Objectives**
- Demonstrate spectral military utility
- Obtain global spectral backgrounds
- Validate full range of atmospheres
- Demonstrate maximum Plug-n-Play for rapid development and Integration & Test
- Autonomous satellite operations

**Responsive-Effective Payloads**
- Single Color
- MultiSpectral
- Hyperspectral

**Camouflage**
- Developing And Demonstrating Technology
ARTEMIS HSI Payload
Advanced Responsive Tactically Effective Militarily Imaging Spectrometer

Objectives/ Requirements:
• Hyperspectral sensor capable of supporting Tactical Warfighter
  - Aluminum Richey-Chretien Telescope
  - Offner grating Spectrometer and HRI/Pan Camera
  - On-Board Digital Signal Processor
    • Process an HSI cube, real-time target cueing
• Detect camo, BDA and IPB
• Panchromatic imager

Payload Activities:
• Payload mirror mounts upgraded to better survive launch environment
• Vibration testing, calibration, and functional checkout completed at AFRL
• Integrated with modular bus in Apr ‘08
Other TacSat-3 Payloads

 TacSat-3: Spacecraft Avionics Experiment (SAE) Plug-N-Play Demo

- Smart Deck with SPA-U host, SPA-U ports, and data handling system
- MST’s Intelligent Power & Data Ring with multiple processing nodes
  - Spacewire/SPA-S link between Sensor Processor and C&DH for backup downlink capability of HSI data
  - Backup GPS for spacecraft using duplicate Surrey GPS receiver
- SPA-U PnP experiments: IPDR – Sun sensor and Surrey GPS receiver; Smart Deck – temperature sensors, AC coupled interconnect

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ONR Space Communications Payload (SCP) Secondary Payload Data

Exfiltration/Infiltration to the Warfighter

- Ocean Buoy w/ ODTML Terminals
  - Miniaturized Radio/Computer/DSP Chips
  - Low Power, Programmable

- Ground Segment
  - In-theater Downlink to Portable Ground Station with Gateway to Internet, OR
  - Store & Forward to CONUS Ground Station

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TacSat-3: Spacecraft Avionics Experiment (SAE) Plug-N-Play Demo

- MicroSat = TacSat-3
- Space Communications Payload = ODTML

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AFRL “Smart Deck”

- MST IPDR Avionics
- Surrey Receiver
- Smart Deck with Applique Sensor Interface Module (ASIM) & X-scale Processor
- IPDR with Processor, Avionics 1/F Module, Power Switch Module, Power Plane

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AeroAstro Sun Sensor

- Systron Donner Rate Sensor
- NCSU AC Coupled Interconnect

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I & T, Launch, and Mission Operations

- All flight hardware delivered to KAFB AEF
- Assembly, integration, and test performed at AFRL Aerospace Engineering Facility
  - CDL, sensor processor, SAE payload completed thermal vacuum testing in AEF
  - Flight C&DH processor and ARTEMIS payload integrated with modular bus
  - Full vehicle completed vibe and TVAC testing in AFRL facilities
- Mission operations performed in conjunction with SMC’s Space Development & Test Wing

Launch Operations
- OSC Minotaur I launch vehicle procured by SMC Space Development and Test Wing
  - Launch from NASA Wallops Island facility on 19 May 2009
TacSat-3 Modular Bus

Background:

- **Contractor:** ATK Space (formerly Swales Aerospace)
- **First generation ORS modular bus**
  - Robust power capability
  - Bus top deck can support 160+ kg payload; adaptable payload interface
  - Zero momentum, 3-axis stabilized bus
- **Demonstrates modular spacecraft bus standards, interfaces, and processes to meet goals of ORS Initiative**
- **ICS-developed flight software being tested with ATK “FlatSat”**

Events of Note:

- Modular bus delivered to AFRL in Sept ‘07 with EM C&DH processor
- Flight qualified processor delivered along with final build of flight software in Apr ‘08
TacSat-3 Concept of Operations
Tactical - Real Time Downlink & Command and Control

TacSat breaks old paradigms and gives warfighter responsive, dedicated space capabilities at the operational and tactical level.

Spacecraft:
4. Collect Image
5. Process Product
6. Downlink Tactical Product

Tactical Ground Station:
2. Format Tasking
3. Uplink Tasking

Warfighter:
1. Send Tasking
7. Receive Product

In Partnership with Army
Acquisition Phase Overview

- Sensor acquired before the rest of the system
  - Needs of the system driven by sensor’s design
  - Insufficient allocation of volume for required bus GN&C hardware
- Government (AFRL) in role as prime integrator
  - Sensor Processor, CDL, and bus all on separate contracts
- Emphasis on COTS / commercial parts as opposed to Class S parts to save schedule and cost

- **Telescope**
  - Focus mechanism
  - On-board Health Monitor
- **Offner Spectrometer**
  - Precision Entrance Slit
  - Dual-blaze Angle Grating
  - Single Hyperspectral FPA
  - Tactical Cryocooler
- **HRI (Visible) Camera**
  - 7 µm, 1 x 4096 COTS
  - Ruggedized for launch / space survival
- **Design Life:** 1 year (goal)

**ARTEMIS: an Experimental Responsive Space Payload**
Acquisition Phase Lessons Learned

- Avoid risky parts in highly susceptible subsystems
  - TT&C and C&DH are critical
- Use targeted redundancy where possible
  - TS-3 carried 2 sets of cryocooler electronics
  - Redundancy must not reduce total system reliability
• Government must understand and prioritize risk; risk tolerance must be communicated well to contractors
  – Risk definitions may be widely different
  – Assumptions and priorities must be understood
• Radiation susceptibility testing and analysis can be effective tools
  – SP to CDL link had to be redesigned when COTS part failed
Integration and Test Phase Overview

- I&T performed at AFRL facilities by dedicated, experienced team
- I&T Lead reports directly to the Program Manager
- TS-3 payloads and modular bus were all designed and assembled by their contractors, then assembled on-site at KAFB

TacSat-3 Vibe Testing
Major Events in I&T

• Failure of ARTEMIS during random vibe test
  – Necessitated rebuild; 9-month delay

• Delay of the C&DH subsystem
  – Bus was delivered early so I&T could begin without it

• Star tracker redesign
  – Camera heads were glinted by Earth and sun reflection

• SGLS radio op-amp replacement
  – Critical part failure discovered two days before shipment to launch site; scarcity of good parts

TS-3 Prior to TVAC Testing
I&T Phase Lessons Learned

• ‘Test like you fly’
• Maintaining mission assurance
• Experienced test personnel were critical
• Innovation
  – Upscreening parts for the radio op-amp replacement
  – Using schedule slips as opportunities to bring down risk in other areas

TS-3 Star Tracker Glint Test
Operations Phase Overview

- Launch on 19 May 2009 from Wallops Island, VA
- Mission operations led by AFRL with many mission partners
- Three phases of experimental operations: Launch and Early Orbit; Calibration; Validation
  - LEO: Spacecraft and sensor checkout
  - Calibration: Sensor characterization and focus adjustment
  - Validation: Demonstrate utility of hyperspectral imagery

**LEO**
- Pointing and Control firmly established
- Nominal satellite operation and communication confirmed
- 1-14 Days

**CAL**
- Sensor Operations Normalized
- Telescope Focus Established
- Spectral & Radiometric performance Accuracy
- Processing Chain Validated
- 7-60 Days

**VAL**
- Technology Validation Plan Collections Complete
- Tactical Demonstration Complete
- Demonstrate Performance of all Payloads and Characterized Performance
- Complete Global Spectral Sample
- 180-360 Days
Operations Phase Lessons Learned

• Team unprepared for the level of mission planning required
  – Mission planning cell stood up to provide dedicated space and resources for mission planning
  – Weekly meetings and weekly ops plan initiated to provide better feedback to stakeholders
  – External Coordinators became Experiment Coordinators; took on most of the job of daily planning
Operations Phase Lessons Learned cont.

- **Role of scripting in operations was critical**
  - Commonly-used commands could be automatically generated with the needed parameters
  - Allowed minimal ops team to function more effectively; I&T personnel could return to their ‘day jobs’; minimized human error

- **Flight software design / configuration control**
  - GNC tables and FSW modules did not have unique identifiers
  - No indication in telemetry which was in use
  - Configuration control very difficult

TS-3 MOC

CDL Ground Station
Summary

- TacSat-3 space experiment supported Operationally Responsive Space objectives
- TS-3 has passed the one-year mark of successful operations
  - Over 2200 data collects taken
  - Over 75 tactical data collects
  - 2 successful secondary payloads
  - Proved utility of hyperspectral imaging from space
  - Engaged in efforts to assist Haiti and Chile earthquake victims

All Mission Objectives Met
Questions?