AMSAT GEO Spaceflight Mission

Dr. Jonathan Black, Director, Aerospace Systems Lab and PI

Dr. Robert McGwier, Chief Scientist

6/17/2016
Hume Center – Snapshot

National Capital Region
10 faculty/staff
5 affiliated professors
15 graduate students

Blacksburg Campus
25 faculty/staff
15 affiliated professors
35 graduate students
150 undergraduates

Sponsor Profile

Department of Defense
DARPA
ONR
AFRL
NRL

Intelligence Community

Outreach/Education
Philanthropy, Industry, NSF

NSA/DHS Center for Academic Excellence
IC Center for Academic Excellence
CyberCorps Scholarship for Service Site
Leadership Team

Dr. Charles Clancy
Director
Associate Professor &
L-3 Communications Faculty Fellow
Electrical and Computer Engineering

Dr. Bob McGwier
Chief Scientist
Research Professor
Electrical and Computer Engineering &
Aerospace and Ocean Engineering

Dr. Jon Black
Director, Aerospace Systems
Lab
Associate Professor
Aerospace and Ocean Engineering &
Electrical and Computer Engineering

Dr. Alan Michaels
Director, Electronic Systems
Lab
Research Associate Professor
Electrical and Computer Engineering

[Vacant]
Director, Information Systems
Lab

Ms. Christie Thompson
Director of Finance and Operations

Ms. Christine Callsen
Director of Outreach and Education

Dr. Kira Gantt
Associate Director of Outreach and Education

Mr. Mark Goodwin
Deputy Director &
Chief Operating Officer
Small Satellite Programs

- Partnered with the Amateur Radio Satellite Corporation (AMSAT) to develop satellite capabilities for public safety communications
- Efforts underway for HEO and GEO satellites
- Numerous cubesat efforts
- Fully-featured ground station able to support command, control, and downlink from spacecraft
Joint Cubesat Projects w/ Space@VT

All Cubesats selected for NASA ELaNa launch

1. Lower Atmosphere/Ionosphere Coupling Experiment (LAICE)
   • Developing sensors which hope to reveal new information about the neutral ion coupling processes in the 150 to 325 kilometer atmospheric region. (VT PI: Dr. Greg Earle)
   • Launch: Late 2016, Planned

2. AMSAT FOX-1A (AO-85)
   • Primarily FM Voice Transponder for Amateur Radio. VT developed a 640x480 pixel jpeg camera payload for delivering images of earth from orbit over the high speed downlink. (VT PI: Dr. Robert McGwier)
   • Launch: 8 Oct. 2015 (ELaNa XII on NROL-55)

3. DUSTIE
   • Determine the global distribution of cosmic “smoke” in the atmosphere. (VT PI: Dr. Scott Bailey)
   • Launch: TBD

4. QB50
   • The Virginia Tech Ground Station will be supports the QB50 project by providing ground station services.

6/17/2016 AMSAT GEO
Low-Flying Space Weather Smallsat

• Possible collaboration with Naval Research Laboratory CARINA program
• Micro/Nano Ionospheric Science Instruments, HF Experiments and Ham Radio Networks
• Coordination with SuperDARN
• 150-300 km target orbit
• ~20 VT students have participated in AOE capstone spacecraft design courses and undergraduate research
Space Communications and Navigation (SCaN)

• Software Defined Radios operating at S, L, and Ka-band.
• On-board data management function and payload networking.
• Radio Science experiments using the unique capabilities of the SDRs
• Precise Navigation and Timing
• Experiment I – JPL SDR
  • A study and modeling of the unique Earth-To-Space propagation environment, including Shadowing, Path Loss, Diffraction, Scattering, and Doppler
  • Adaptive Waveform Switching to Mitigate Earth-To-Space Propagation Effects
    • Modeling and Simulation
    • On Orbit Experiment Execution
    • NASA Glenn Ground Station direct to ISS/SCaN (S-Band)
• Experiment II – Harris SDR
  • Signal Classification/Identification and Adaptive Waveforms to Mitigate Space-To-Space Propagation Effects
    • Phase I Considerations
    • Loss of Attitude Control
    • Interference Mitigation
    • On Orbit Experiment Execution
    • White Sands to TDRSS to ISS/SCaN (Ku Band)
Establish partnerships to develop and transition (commercialize) bus and payload technologies

- Space science – in-situ and remote sensing
- Navigation and timing
- Low-flyer
- Multi/Hyperspectral imaging
- On-orbit processing
- Cognitive radios and mission management
- Proximity operations and formation flying
- Cyber security

Establish partnerships to develop and transition (commercialize) ground station technologies

- Multi-phenomenology data fusion
- Distributed ground stations
- Tracking and SSA
- Outreach and educational development
- Automated change detection
  - Indications and Warnings
- Deep machine learning
- Predictive analytics
- Anticipatory collection
- Activity-based intelligence

Research and Development, Commercialization, and Workforce Development needs
C4ISR Station

**TT&C and Data Download**
- Amateur VHF / UHF
  - C2 of VT spacecraft
  - C2 of third-party spacecraft
  - Telemetry monitoring of active Cubesats
- Ground-based Telescopes
  - Spectrometer
- 3.0 meter dish + L-band uplink
  - S-Band downlink (ISS HAMTV, high rate mission data, etc.)
  - L-Band uplink (Amateur Satellite Service)
- 4.5 meter dish
  - Earth Moon Earth (1296 MHz / 2304 MHz / 10.368 GHz)
  - Radio Astronomy (Hydrogen lines @ 1420 MHz)
- Weather (imagery) systems
  - GEOS geosynchronous (WEFAX, 1691 MHz)
  - NOAA LEO (APT, 137 MHz)
  - Tracking and fixed antenna system
- Commercial Systems
  - Earth sensing spacecraft with S-Band up/down and X-Band down

**Mission Design and Orchestration**
- Contested Space Operations
  - Cognitive automation
  - Agile RF with software/cognitive radio
  - Resilient Spectrum for SATCOM and PNT
  - Space situational awareness
  - High-fidelity control (formation flying, proximity ops)
  - Satellite maneuver detection and estimation

**ISR**
- Data fusion and big data analytics
  - Multi-phenomenology
  - Automated change detection
  - Indications and Warnings
  - Deep machine learning
  - Predictive analytics
  - Anticipatory collection
  - Operationally relevant
  - Activity-based intelligence
AMSAT GEO

RF Experimental Geostationary Platform
Block Diagram

P/L Receiver

P/L Transmitter

P/L RF Nadir Box

P/L Power Regulation Internal Box

S/C Unregulated Power
Preliminary Schedule

**Spring Semester 2016**
- Project Kickoff – 15 Jan 2016
- Preliminary Interface Control Document delivered (MSS to AMSAT/VT) – 19 Feb 2016
- Payload PDR – 17 May 2016
- Payload Accommodation PDR – 24 May 2016

**Summer 2016**
- Payload CDR – 5 Aug 2016

**Fall 2016**
- EM Payload Testing complete – 16 Sept 2016
- Payload Test Readiness Review – 4 Nov 2016
- Payload Integration Readiness Review – 20 Dec 2016
- Payload Delivery and Integration start – 2 Jan 2017
Preliminary Budget Breakdown

• Phase 1: Nov 2015 – May 2016
  • $200K
  • Accommodation study
  • Preliminary design
    • 4 grad students
    • 2 undergrad students
    • 2 members of technical staff

• Phase 2: May – Dec 2016
  • $1.0M
    • Flight and EM hardware build
    • Flight qualification testing
    • Flight payload delivery
  • $2.0M
    • Pre-Integration testing and analysis
    • VT will contract through NASA Ames

• Phase 3: Jan – Mar 2017
  • Delivery
  • Integration

• Phase 4: Apr 2017 – Mar 2018
  • $6.0M (TBR)
  • Launch
  • Operations
  • Dissemination and tech transition

$9.2M (TBR) Total Program
Publicity

- **FEMA Blog**
  - https://www.fema.gov/blog/2016-03-07/supporting-disaster-communications-space

- **VT News**

- **ARRL**
  - http://www.arrl.org/amateur-radio-emergency-communication
Central Payload System

- RINCON LPFE
  - All of the communications processing done in the Phase 4B system is carried out on this block
  - Determination during design phase if external processor needed but at this point, the need has not been justified. We believe, at this time, ALL processing for the entire payload can be accommodated on the LPFE system

- Reset receiver (mandatory) and/or independent command receiver (TBD if time available and needed)
  - On at least one of the antennas on the receive side will host a pick off to be fed to a digital receive system. A finite state machine, which can be as simple as a linear shift register with a Boolean function applied to the taps will output 1 or 0. If 1, reset of the receive system is asserted.

- Interfaces to the Bus, Receive System, and Transmit System are contained in this system.
Receive System

• Initially, a simple phased array with take-it-as-we-are-given-it coverage of the earth
  • Likely 17.5 dBi gain initially
  • 20+ dBi desired
    • Achieved by subdividing the phased array into quadrants and steering the quadrants after redesign of the quadrants.

• LNA amplifier as near to each antenna terminal as possible
  • Heater for LNA contained in this subsystem
    • Power for heater needs to be under spacecraft control and independent of our payload is ideal but if we must, we can provide this control but likely this is suboptimal since that would mean our central processing unit is POWERED UP even for emergency

• Phase shifters in the receive system under control of our Central Processing System
Transmit System

- Mixer from desired baseband to desired center frequency and the oscillator to feed LO to the mixer

- Power amplification Chain feeding one 17.5 dBi horn with combined power amplifiers
  - Upgrade to four horns
    - Phase control in each chain for four quadrant
    - One amplifier module in each chain
      - Amplifier module mounted on cold plate and feed line loss accepted as price of doing business
  - Provide 20+ dBi gain
Bus Interface

- Implementation of major portions of the ICD occurs here
- Likely contained in the same box as the “Central Payload System”
- Sensors for telemetry to main bus implemented here
- Emergency power from Bus distributed from here
Thank you for your support!

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