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# Mobile CubeSat Command & Control (MC3) Ground Stations

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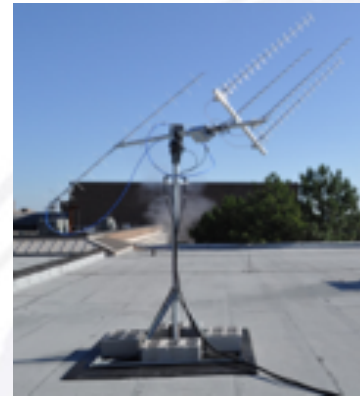
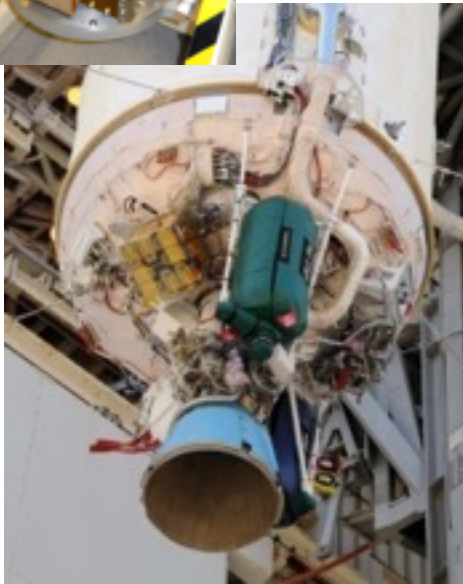
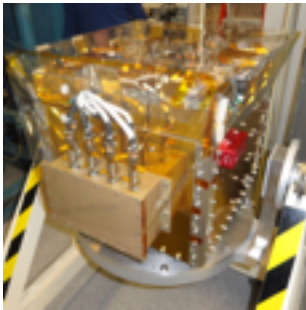
This Brief is Classified:

**UNCLASSIFIED**

*Excellence Through Knowledge*



The Mobile CubeSat Command and Control (MC3) ground station network provides infrastructure and research support for U.S. Government CubeSats



NPSCuL Infrastructure Research

MC3 Infrastructure Research



GPS Time Sync  
 VPN  
 Ethernet Switch  
 Laptop  
 GDP Receiver  
 S-Band Up Converter  
 ICOM9100  
 ICOM9100  
 Yeasu Antenna Controllers  
 UPS



**UHF Yagi**  
**450 MHz TX**  
**902-928 MHz RX**



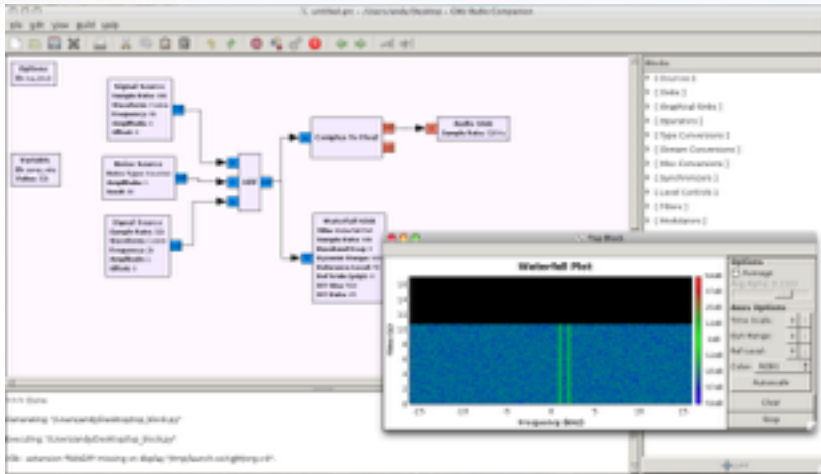
Software-defined  
 radios



**S-BAND 3m Dish**  
**2.1 GHz TX**  
**2.2 GHz RX**

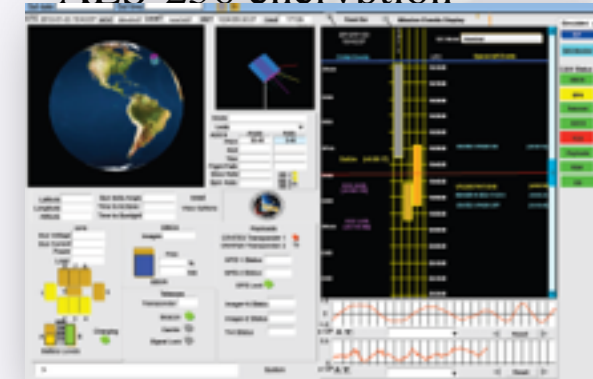
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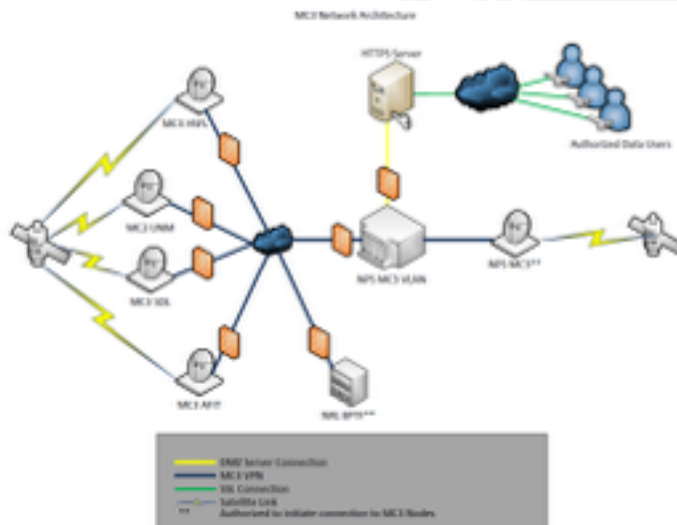
## Software integration

- Tyvak Satnet
- Interstel COSMOS
- SATRN
- Ball Aerospace COSMOS
- TCP/IP bent-pipe capabilities
  - AES-256 encryption



## GNU Radio applications for common modulations and protocols

- GFSK
- OQPSK
- AX.25, APRS
- TI CC1101 radios





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# Coverage





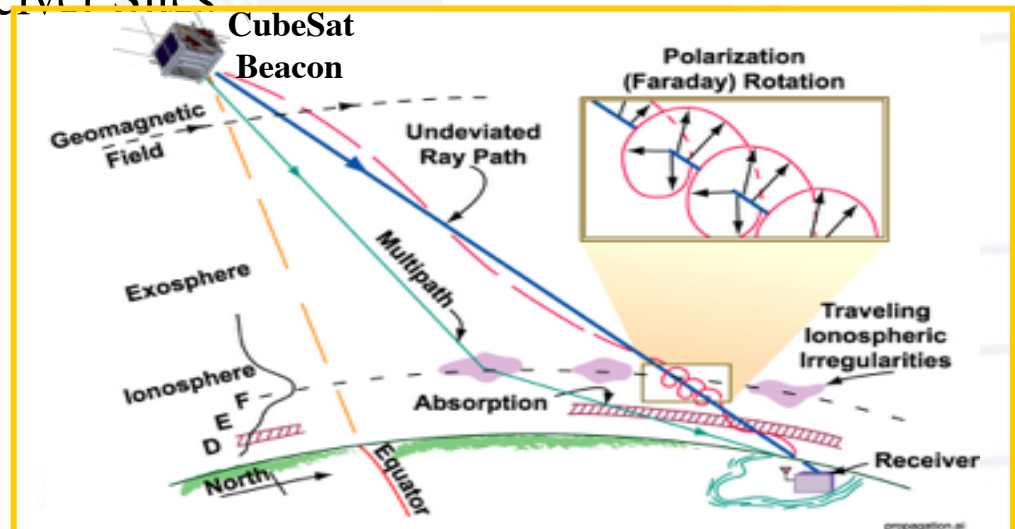
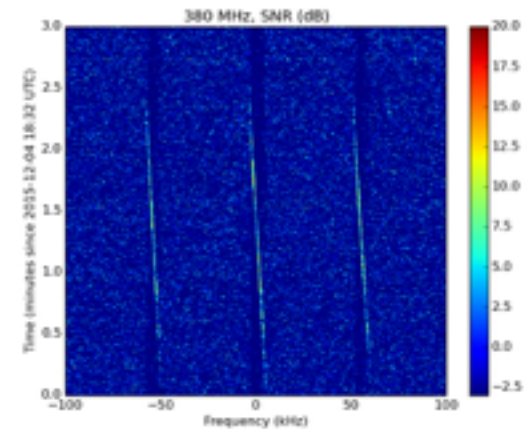
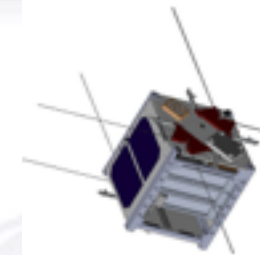
## PROPCUBE

- 380 to 400 MHz UHF Band
- 2375 to 2390 MHz S-Band

## Ionospheric Electron Density and Irregularities

- Total Electron Content by Differential Group Delay
- Plasma Irregularities by Amplitude and Phase Scintillations
- Detection of Artificial Irregularities from High Power HF Waves
- Fielding of NRL Ground Receiver Sites

- HAARP, Alaska
- Millstone Hill, MA
- Arecibo Observatory, PR
- Jicamarca Radio Observatory, Peru
- Naval Postgraduate School, CA







Mass: 82 kg

Power: 60 W max, 25 W avg.

Dimensions: 55 cm. diameter, 93 cm. height

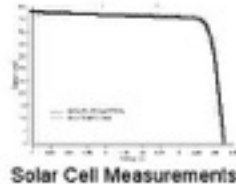
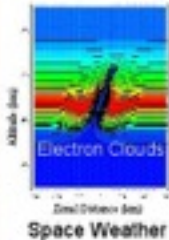
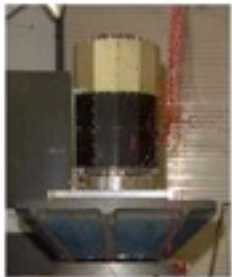
Launch: SpaceX Falcon Heavy, 2017

## Major Instrument or Equipment:

- Coherent electromagnetic radio tomography (CERTO) beacon
- Langmuir probe
- Solar cell measurement system
- Configurable, Fault-Tolerant Processor (CFTP)
- PC-compatible command & data handler (C&DH) with embedded Linux operating system (OS)
- Low-cost COTS for spacecraft technology

## Instrument or Equipment Operation:

- Solar cell measurement system for testing on-orbit performance (current vs. voltage plots)
- CERTO & Langmuir probe measurements taken in concert with fixed ground station receivers (NRL Experiment)
- Spacecraft technology flight demonstration
  - Li-ion battery
  - Simple, low-cost attitude control: MEMS rate sensor, GPS receiver, micro-momentum wheel, torquer coils, magnetometer
- Educational Value
  - 40 Masters Theses
  - Directed study courses



MEMS Rate Sensor



Li-ion Battery

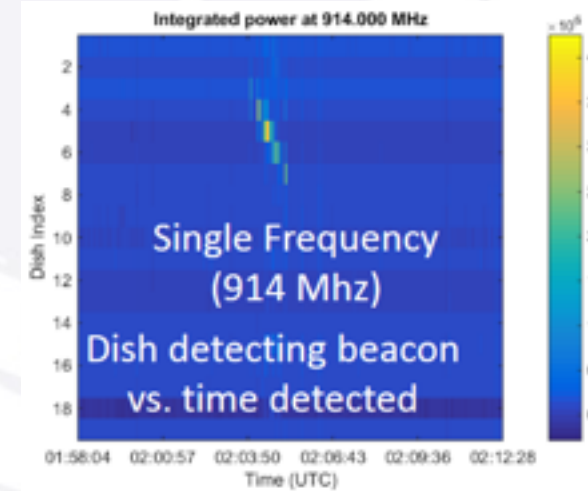
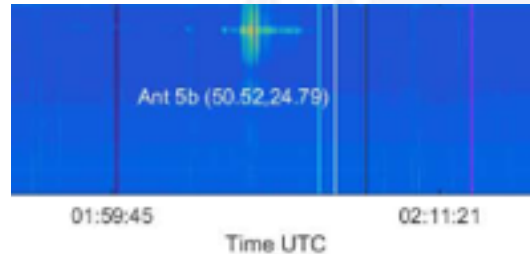
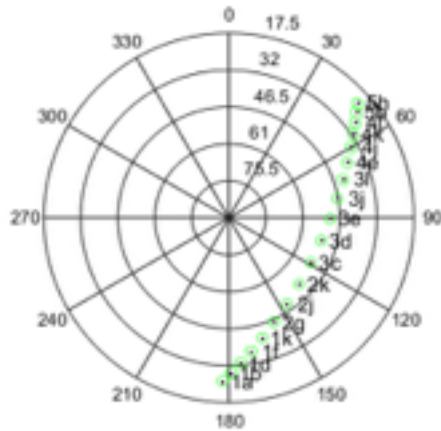


Space Computing  
(CFTP / C&DH)



## Allan Telescope Array (ATA) Hat Creek, CA

## SRI International SETI



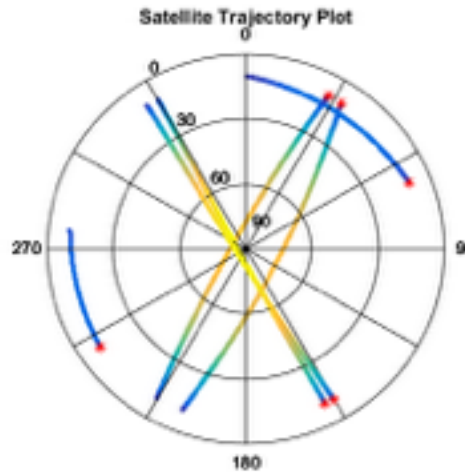
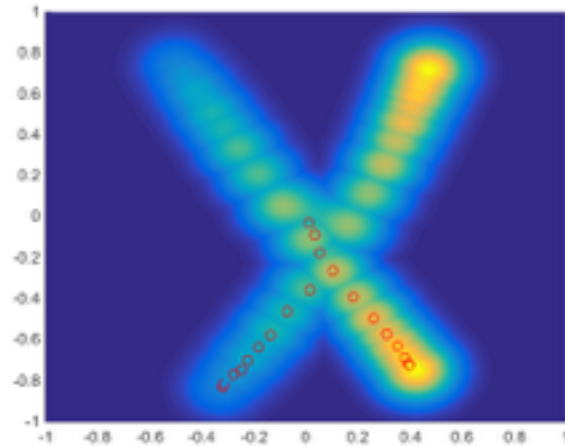




Space is congested, contested, and competitive

Traditional operational models for CubeSats don't scale!

Automation key to operating hundreds/thousands



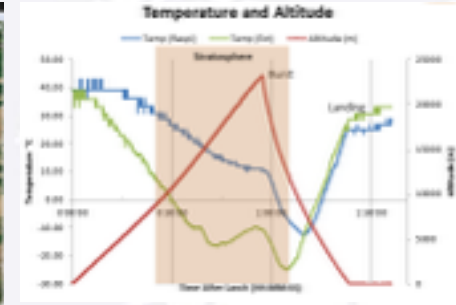
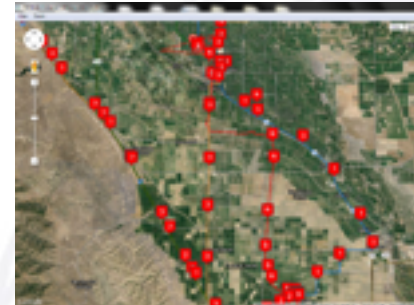
Utilizing DIDO®  
pseudospectral optimization  
software

$$\left\{ \begin{array}{l} \text{Minimize } J[x(\cdot), u(\cdot), t_f] = E(x(t_f)) + \int F(x(t), u(t)) dt \\ \text{subject to } \dot{x}(t) = f(x(t), u(t)) \\ x(t_0) = x^0 \\ t_0 = t^0 \\ t_f = t^f \\ e(x(t_f)) = 0 \end{array} \right.$$



## High Altitude Balloons (HAB)

- Military directed study graduate students
- Summer interns (high school / college)
- Aerospace career experience
  - Working in teams
  - Constraints:
    - Mass, power, volume, data, weather, launch criteria, risk mitigation
  - Failure is very possible!
- In-situ testing
  - Low-cost military communications experiments
  - CubeSat flight components
  - MC3 ground stations/ flight radios





## **Contact Information**

MC3 Mission Operations Team

Naval Postgraduate School

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