MemSat

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Challenges with Space Applications

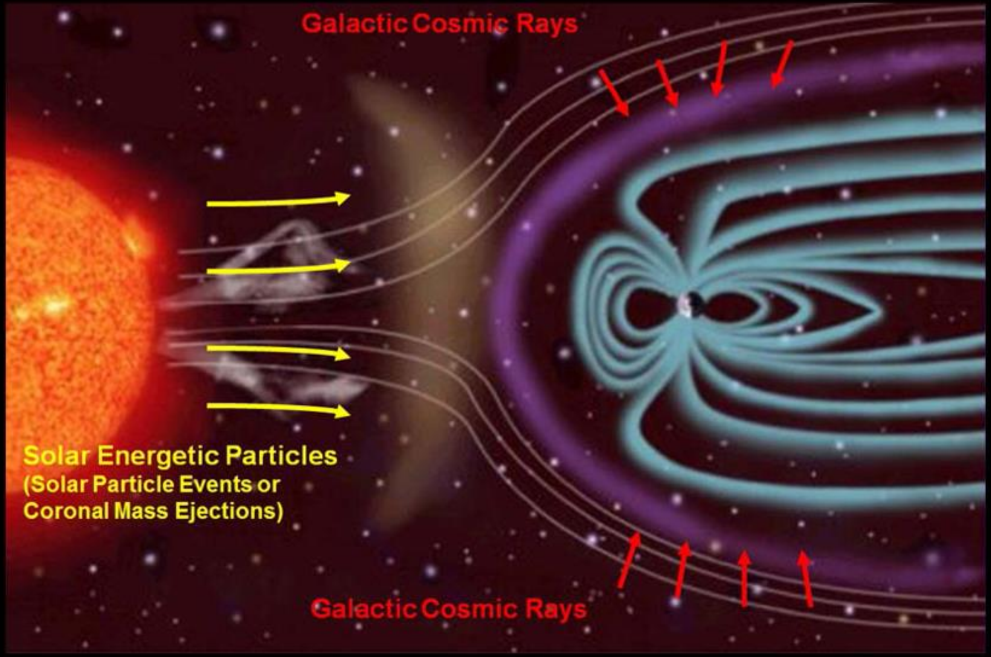
- **Space environment**
- **Reliability and lifetime**

- Environmental Challenges
  - Launch
  - Operation at temperature extremes
  - Space radiation effects
  - Etc.

- It is critical to address all aspects of reliability and known failure mechanisms prior to integrations into applications

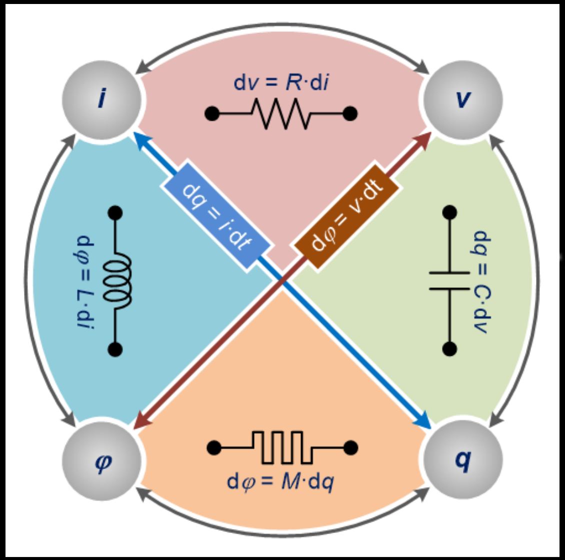
Space Radiation Effects

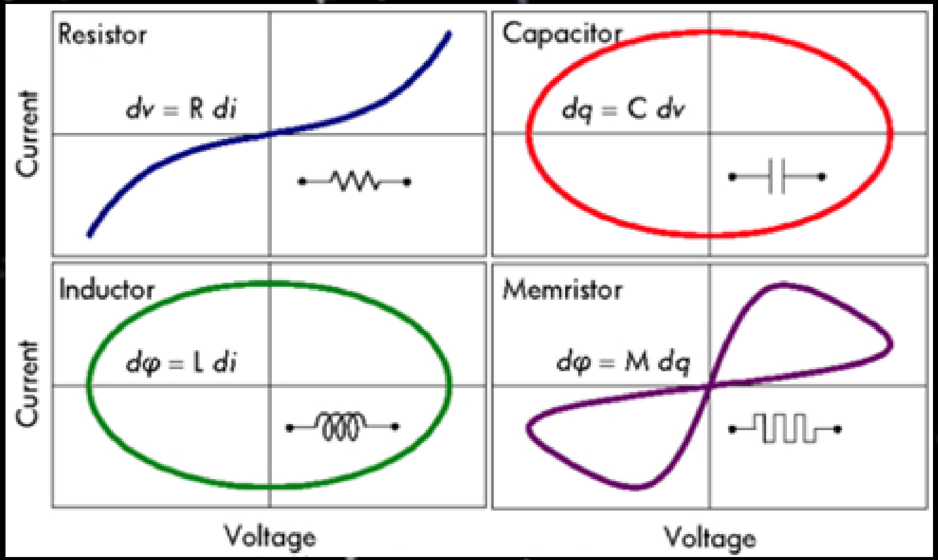
- Deep space
  - Galactic cosmic rays—heavy ions with extreme energies
  - Solar flares: primarily protons and heavy ions
- Trapped radiation belts
  - Electrons up to 7MeV
  - Protons up to 400MeV

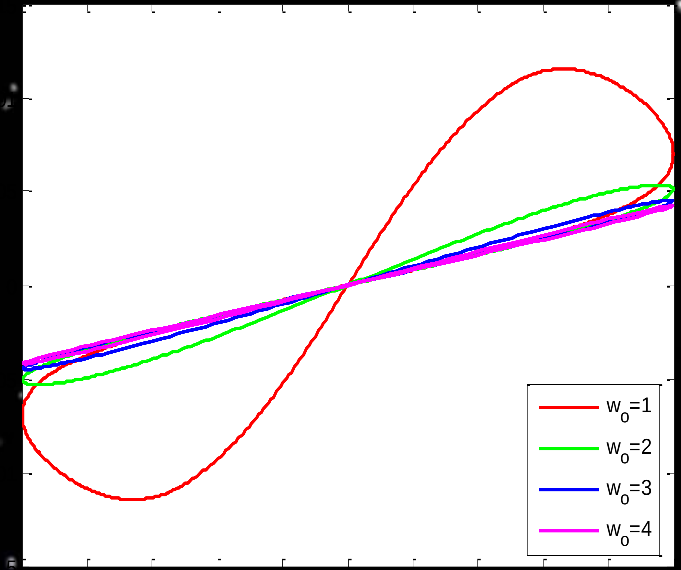


- Ionizing particles striking electronic systems cause frequent soft 'change of memory bit state'—SEU (Single Event Upset)

Memristors—The 4^{th} passive circuit element

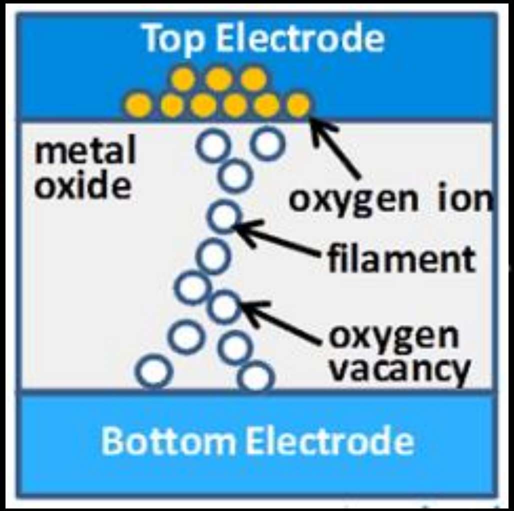


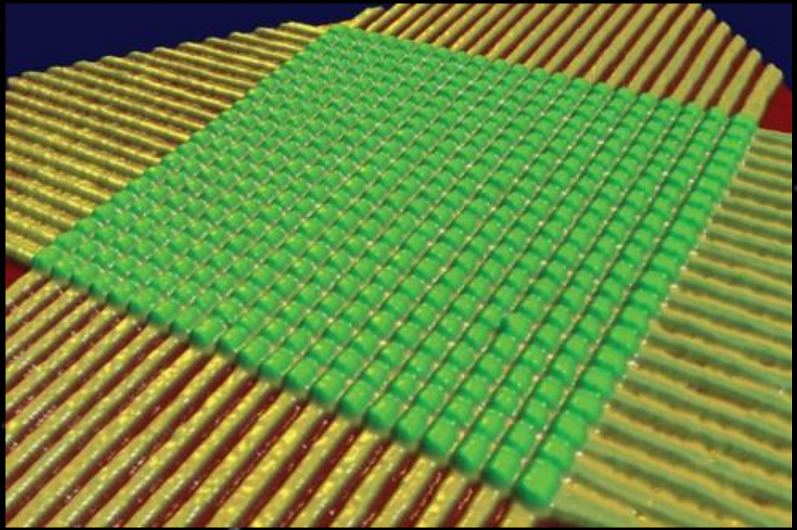


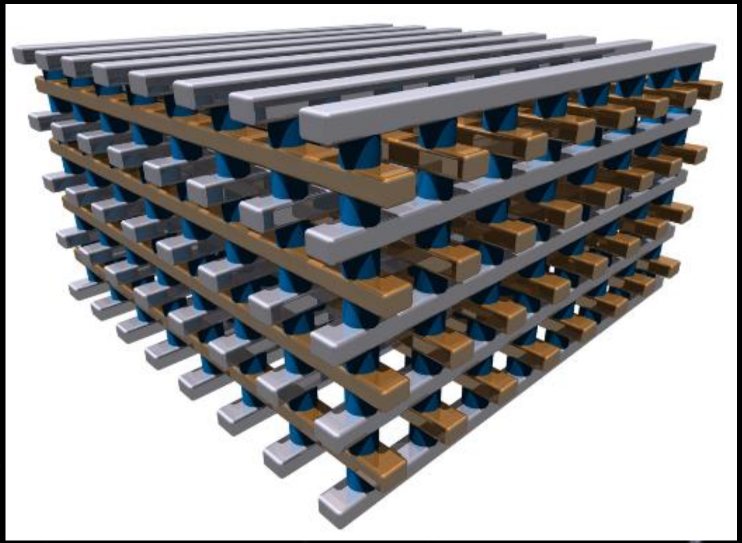


- Distinctive features of memristors
  - Resistance of the device is determined by the entire history of input
  - Manipulates "Pinched Hysteretic Loops" in voltage-current dynamics
  - Frequency dependent dynamics (linear resistor at high frequency)

Memristors—Realization as physical elements







- Simple device structure (Metal-insulator-Metal)
- Information is stored in terms of ‘resistance’, not ‘charge’
- Capability of ultra-dense 2D/3D devices array

Memristors—Space Capable Tech?

- Ultra-Dense non-volatile storage/computing capability
  - Enables small form factor, light weight, and high-dense functional integration
  - Enables long-term missions with energy-efficiency
- Lower voltage and faster access speed (>100x) compared to standard Flash
  - Enables energy-efficient space solutions
- Resistance as the state variable of information processing
  - Potential robustness against cosmic ray effects, e.g., SEU

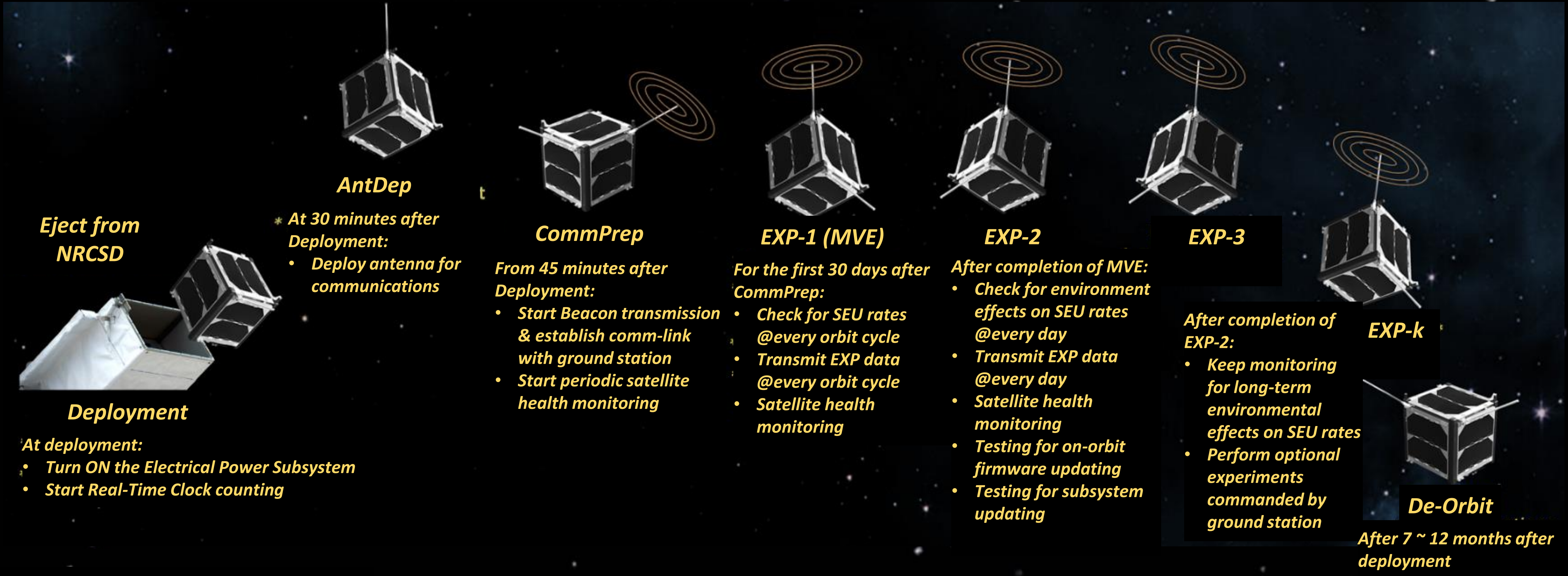
➔ Memristor technology may significantly enhance reliability and lifetime of spacecraft systems in space environment with temperature extremes and high dose cosmic rays.

MemSat is to experimentally confirm the postulated benefits of the memristor technology for space applications.

MemSat—Rowan's 1U CubeSat

- *Technical Goal:*
  - *Evaluation of memristor memory chips to determine potential benefits of memristor technology for space applications*
  - *Comparisons of cosmic rays induced Single-Event Upset (SEU) rate against standard, silicon-based memory technologies*
  - *Advancement of spacecraft design technologies*
- *Educational Goal:*
  - *Expose students to hands-on, cutting-edge, spacecraft design technology*
  - *Promote experiential engineering education with a perfect design platform of systems-on-a-system*

MemSat—Concept of Operation



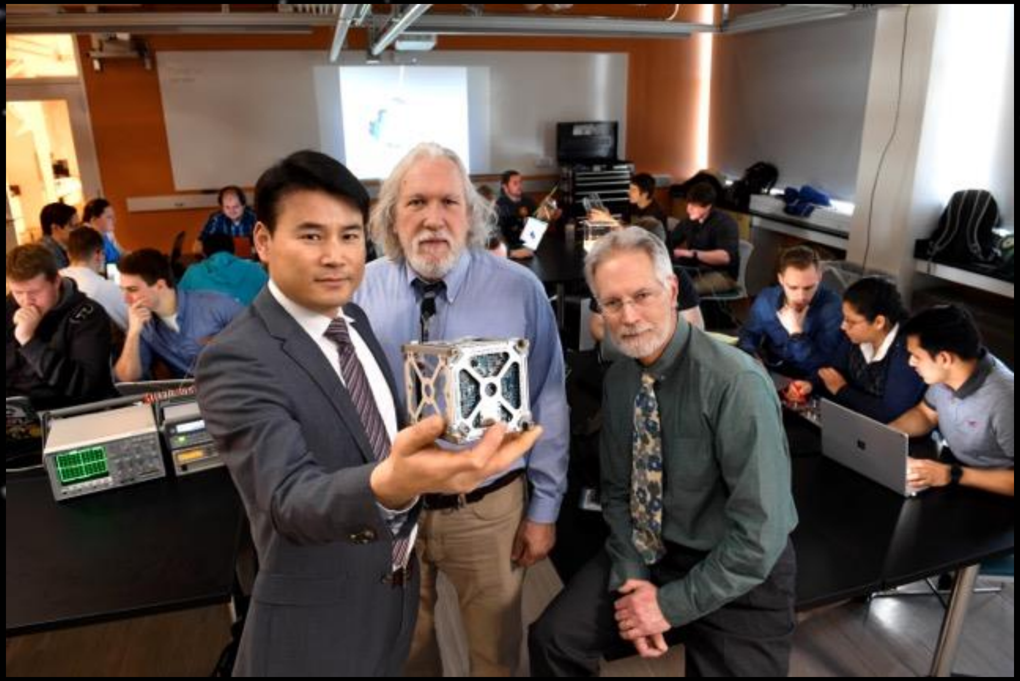
*NRCSD: NanoRacks CubeSat Deployer

MemSat Experiments

- Primary Experiment
  - Performance comparison of traditional and resistive memories
  - SEU/SEL Rates
- Secondary Experiment
  - Correlation with environmental conditions
- Tertiary Experiment
  - Performance of student developed subsystems
- Quaternary Experiment
  - Application of IEEE 1451 Smart Sensor Network Architectures in Space Systems
  - Educational Embedded Development Platform

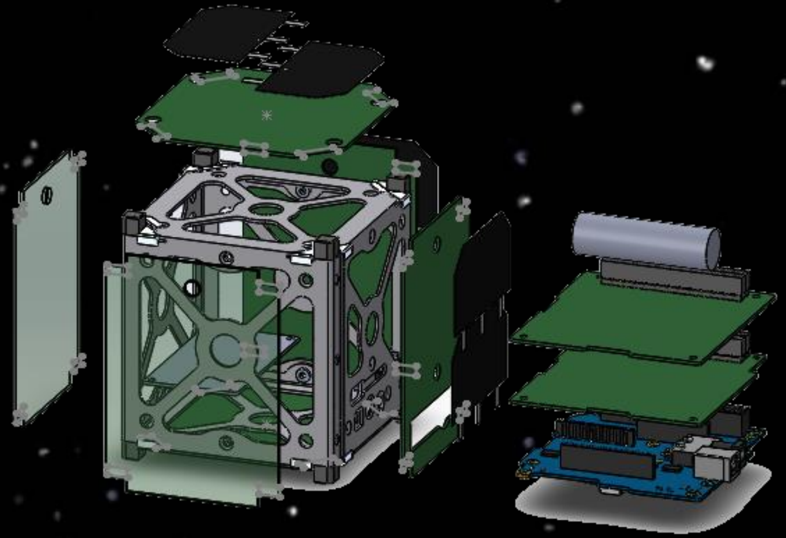
MemSat—Project Team

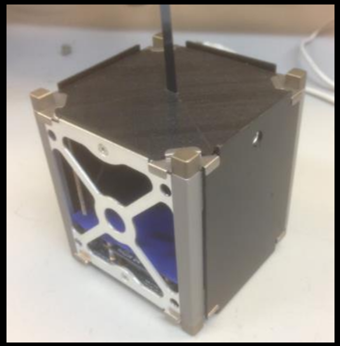
- 3 faculty
  - Drs. S. Shin, R. Krchnavek, and J. Schmalzel
- 6 graduate project managers
  - R. Trafford, A. Fifth, et al.
- 35 undergraduate student researchers
- 11 project subgroups
  - 7-physical satellite subsystems
  - System Integration
  - Ground Station
  - Environment testing
  - Safety, Mission Assurance, and Compliance (SMAC)



MemSat—Physical Subsystems

- Structure
- Memristor Experiment Payload
- PWR (Electrical Power Subsystem)
- COMMS (Communication Subsystem)
- C&DH (Command & Data Handling Subsystem)
- ADCS (Attitude Determination and Control Subsystem)
- Ground Station

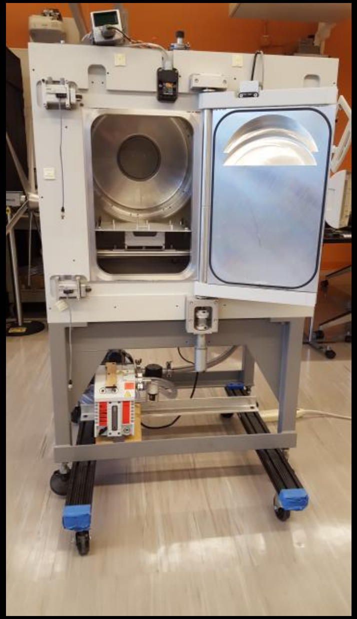


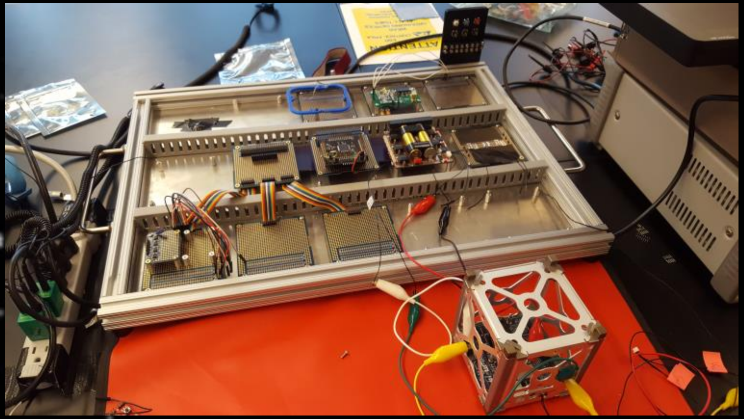


MemSat – Testing Subsystems

- Environment Testing (EnvTest)
  - “Shake and Bake”
  - Thermal Chamber
  - Vacuu-Thermal Chamber
  - Vibration Table

- Mission Simulation and Test (MST)
  - Develop scenarios on ground to simulate possible problems in the satellite.
  - Verify the ramifications of Murphy’s Law





MemSat – Management Subsystems

- Systems Engineering and Integration (SysInt)
  - Facilitate communication between subsystems
  - Document all interfaces and manage ICD’s
  - Manage the construction and testing of MemSat
- Safety, Mission Assurance, and Compliance (SMAC)
  - Graduate Student Managers for each subsystem
  - Works with Flight Providers and Regulatory Bodies
  - Liaisons between Subsystems and Project Manager/Faculty

Primary Payload - Design

- Memory IC’s placed on all 6 exterior panels
  - 24 M25P05 ST Flash Memory
  - 24 RM25C512C Adesto CBRAM
- Dedicated CPU
  - MSP430FR4133
- Environmental Sensors
  - Maxim Digital Temperature Sensor
  - Radiation Sensor
  - Orientation via Solar Panel Voltages

Primary Payload - Experiment

- Primary Experiment
  - Flash all memory to 0x00 and compare to 0x00
  - Read all memory after period of time
  - Flash all memory to 0xFF and compare to 0xFF
  - Read all memory after period of time
  - Repeat

Secondary Experiment

- Increase in reading rate
- Correlate to Environmental conditions on the MemSat

- When Event Occurs
  - Locate which chip the event occurred in
  - Determine current environment of CubeSat
  - Time Stamp the data and load into CDH memory

- Event “Journal” will then downlinked when possible

Post-MemSat

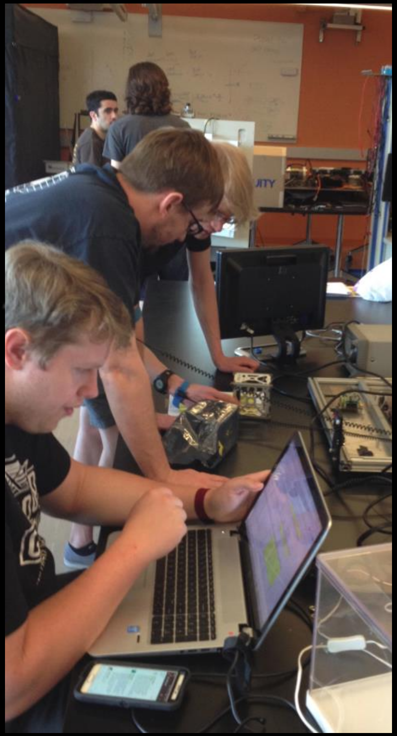
- Integration of CubeSat design within the Rowan ECE curriculum
  - Class Projects
  - Future Clinic Projects (equivalent to Senior Design)

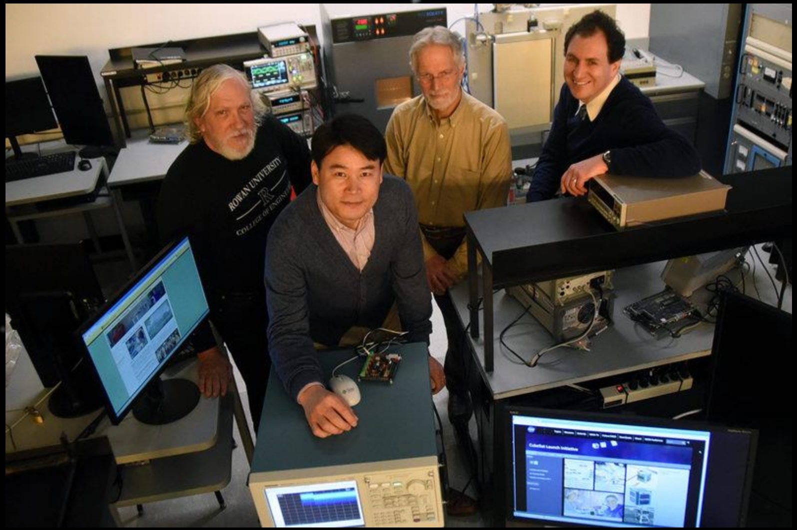
- Research into 3D printable CubeSat structures

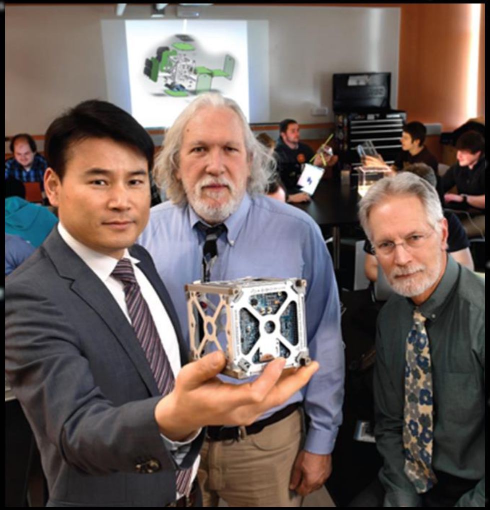
- Joint effort with AIAA to develop sub-orbital CubeSat test platform

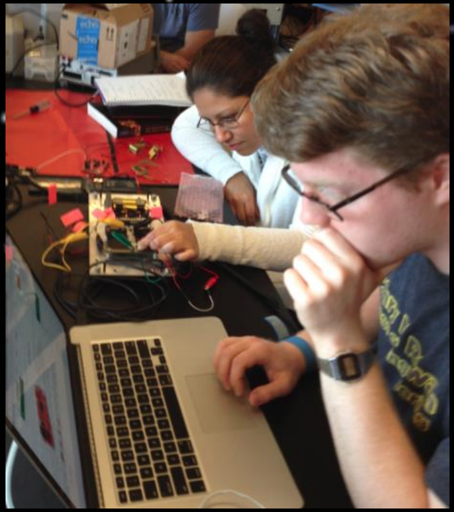
- Design of development tools for future CubeSat projects

ROWAN UNIVERSITY MEMRISTOR SATELLITE
2018









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