CSS BUS FOR RAMPART

RAPidprototypedMicroelectromechanicalsystem
PropulsionAndRadiationTest CUBEflowSATellite

The evolution of PCBSat for the RAMPART Cubesat
History of PCBSat

- PCBSat originally PhD work of Dave Barnhart at U of Surrey
  - “Very Small Satellite Design for Space Sensor Networks”
- Objective: What is smallest satellite that can do practical work in space?
- Result: PCBSAT, a satellite on a Printed Circuit Board
  - Prototype built
  - Includes
    » Data Handling, data storage
    » Mesh radio
    » GPS
    » Camera
    » Power management
    » Solar panel
    » iMESA plasma measurement experiment (USAFA SPARC)
    » LiPoly battery
    » **Size: 1/3U Cubesat**
  - Ideal as a “SnifferSat” deployed in stacks from a P-POD, up to 9 per P-POD

9 PCBSats in a P-POD
CSS

RAMPART Deployed

Printed-in-fusion spring-hinge of solar panel
Printed AA Battery Holder
Printed bus and card cage, covers removed
Printed wiring boards
Printed Propulsion System (shown translucent)
Nozzle
Wire guide, 4 x
Fill Valve

Colorado Satellite Services, LLC
RAMPART is a tech demo and qual mission for several subsystems
2U cubesat into 450km circular, then raise apogee to 1500km
Demonstrating or testing several designs, components, methods
- “Printed” satellite including internal mechanisms, tank, nozzle
- PnP / CubeFlow test articles from AFRL
- Montana State DAVE experiment using original Van Allen Geiger tube
- AFRL high efficiency solar cell and control cell
- AFRL experimental cell cover glass on two of 8 panels
- “Printed” warm gas propulsion, including tank
Deployed solar panels with ‘printed’ deployment mechanism
U and S downlinks (9k6 GMSK, 38k4 BPSK)
V uplink
CSS Evolution of PCBSat -> CSSBus

• CSSBus = Colorado Satellite Services Bus
• Evolving the PCBSat DH and EPS designs into CSSBus
  – From LiPoly -> NiMH
  – On/off battery management suitable for LiPoly -> (PWM) BCR for NiMH
  – Four individual BCRs for four pairs of panels
  – Change to Atmel ATMega1280 chip to gain USARTS (4)
  – Add power switches for experiments
  – Add I/V sweep BCR and measurements for experimental cells

• Still a single PCB with DH, storage, and EPS
  – Saves one board space
Advantages of CSSBus Design

- Four true BCR strings for more efficient battery management
- Can recover from dead battery, unlike DET design
- Flash/EEPROM technology MPU and data storage for reduced RAD susceptibility
- Very low power consumption
- Can reload software on orbit if a boot loader is used
- Brown out detection and recovery for MPU
- 4 hardware USARTs for serial experiment and radio interfaces (could have up to 8 with some XMeg chips)
- All on a single PCB to save space
Disadvantages

- Somewhat RAD soft internal ADC
  - Will use tantalum wafers to mitigate
- 8 bit 10 MIPS processing power not enough for active ADCS, but more than enough for this mission
- No power draw protection for experiments
  - Satellite is mostly single string
CSSBus Software

• Software development options include
  – CodeVisonAVR (selected for RAMPART)
  – IAR
  – AVRGCC (free)
Solar Panels and BCR Operation

![Graphs showing solar panel characteristics: Short circuit current, maximum power current, and open circuit voltage vs. voltage.](image)
CSSBus BCR Operation

- MAX 1771 includes internal PWM to drive external NFET
- MAX 986 measures BAT V (state of charge) and signals 1771
- 1771 sets pulse width to change impedance of FET input which moves panels along the I/V curve
- If BAT V is low, cells are operated at peak power and max available power goes into battery charging and bus operation
- As BAT V climbs, 1771 changes impedance (pulse width) to slide cells down the slope of the I/V curve, BAT charging is reduced
- Power is left in the cells to be dissipated as heat
- Resistors are used to establish set point for 1771 for panel Peak Power Point and for 986 for BAT charge limit
• Amateur frequencies are desirable for a number of reasons
• RAMPART does not fit within the definition of an Amateur Radio Satellite in the Amateur Radio Satellite Service as defined in the radio regulations (ITU and FCC)
• License method recommended for this and similar cubesats or university satellites:
  – Do IARU coordination. Assures no interference and good relationship with Amateur Radio organizations.
  – Obtain FCC Part 5 Experimental license. Note interference rules and limitations. Both the satellite and ground stations must have Part 5 licenses.

• Notes:
  – There is no such thing as an unlicensed satellite under ITU treaties
    » Using WiFi radios (Part 15) in space without licensing is a violation of FCC rules and ITU treaty
  – To operate a satellite in the Amateur Radio Service it must fit within the “basis and purpose” of that service
  – See the IARU web site for further (http://www.iaru.org/satellite/ and click “Frequency Coordination”)
CSS

CSSBus Design for RAMPART

Questions
The purpose of an Amateur Radio Satellite should be to

(1) Provide communication resources for the general amateur radio community and/or

(2) Self training and technical investigations related to radio technique
Amateur Radio Satellites

- Radio technique means having a reasonable possibility of applications to radio communication systems. Examples:
  - Communications protocols
  - Attitude determination methods
  - Command and control procedures
  - Receivers, transmitters, and transponders
  - Antennas
  - Sensors to study spacecraft performance
  - Telemetry protocols
  - Power controls and supplies for use in space
  - Spacecraft computers, memory, operating systems, programs
  - Radiation effects on electronic components
  - Radio wave propagation
  - Meteor trail reflection
  - Measurements of the orbital environment
Rules

• For ANY satellite
  – Must be able to turn off its transmitter by ground command

• For Part 5 you are the bottom of the barrel on frequency usage
  – Must not interfere with ANY other user or use in any service
  – Must accept interference from ANY other user or use in any service