CSS BUS FOR RAMPART

RApidprototypedMicroelectromechanicalsystem
PropulsionAndRadiationTest CUBEflowSATellite

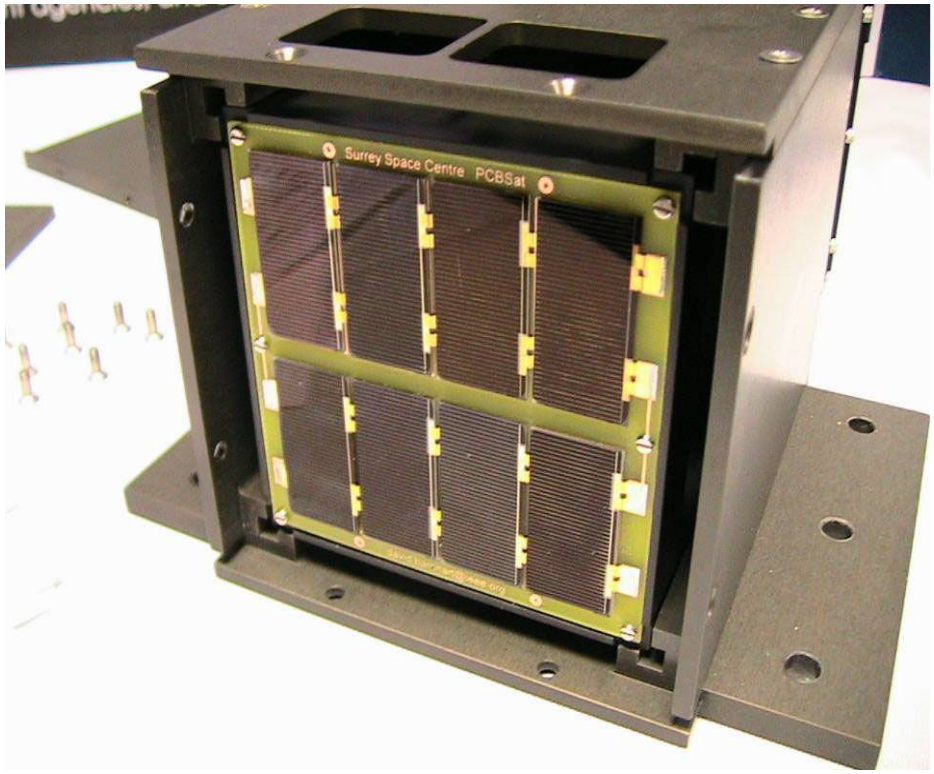
The evolution of PCBSat for the
RAMPART Cubesat

History of PCBSat

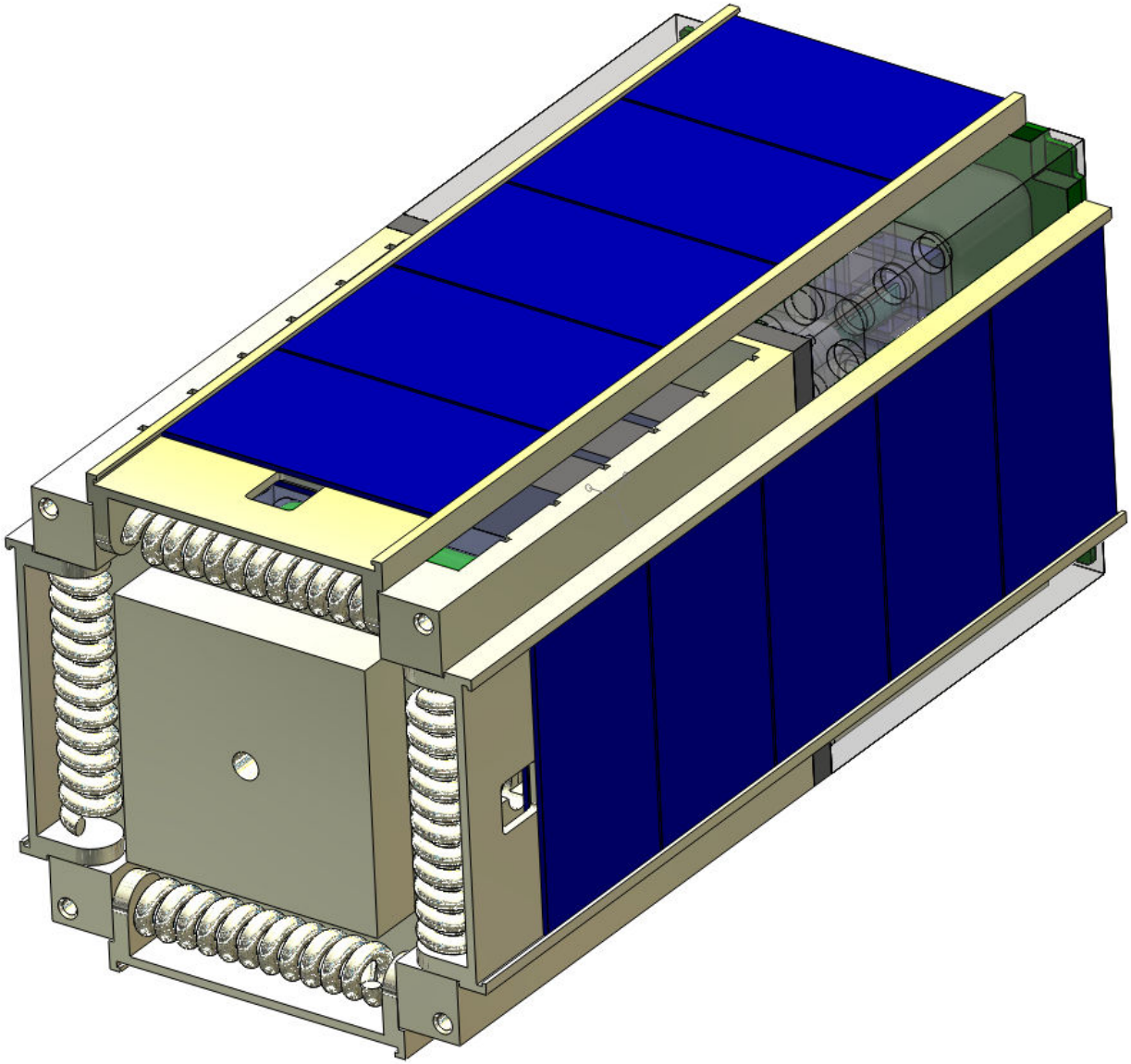
- PCBSat originally PhD work of Dave Barnhart at U of Surrey
  - "Very Small Satellite Design for Space Sensor Networks"
- Objective: What is smallest satellite that can do practical work in space ?
- Result: PCBSAT, a satellite on a Printed Circuit Board
  - Prototype built
  - Includes
    - » Data 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

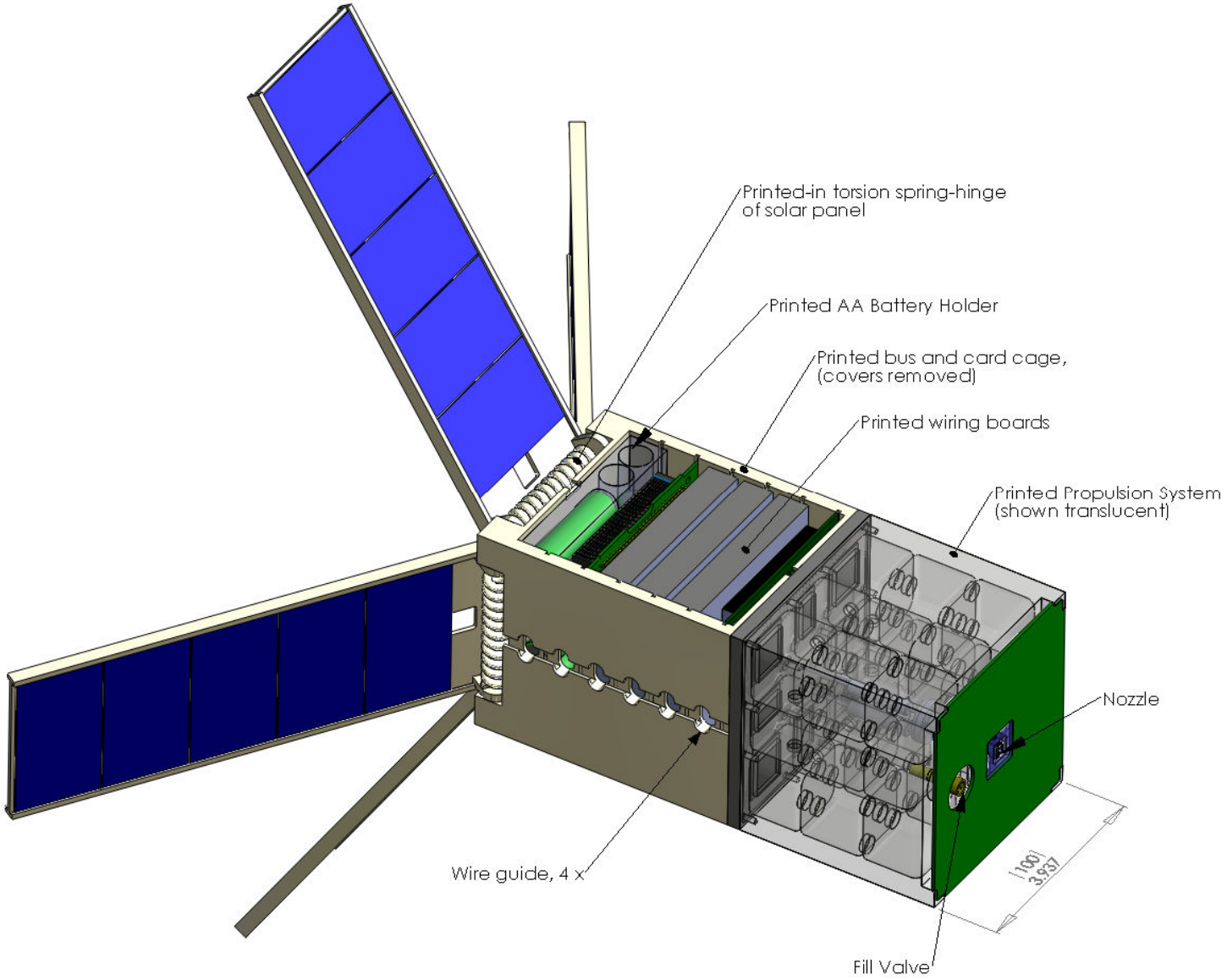
9 PCBSats in a P-POD



RAMPART Stowed



RAMPART Deployed



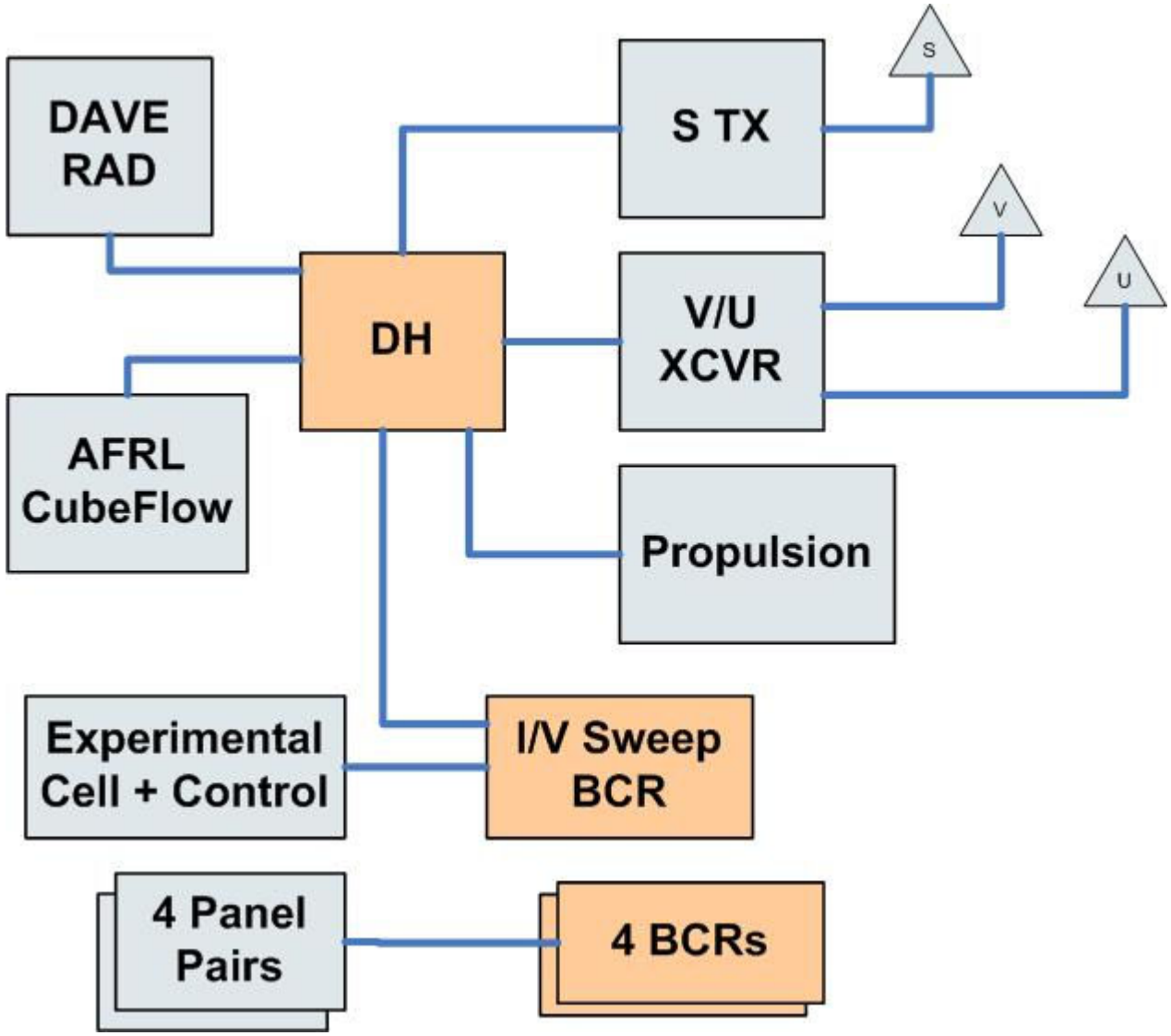
RAMPART Cubesat

- 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

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

RAMPART BLOCK DIAGRAM



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 XMega chips)
- All on a single PCB to save space

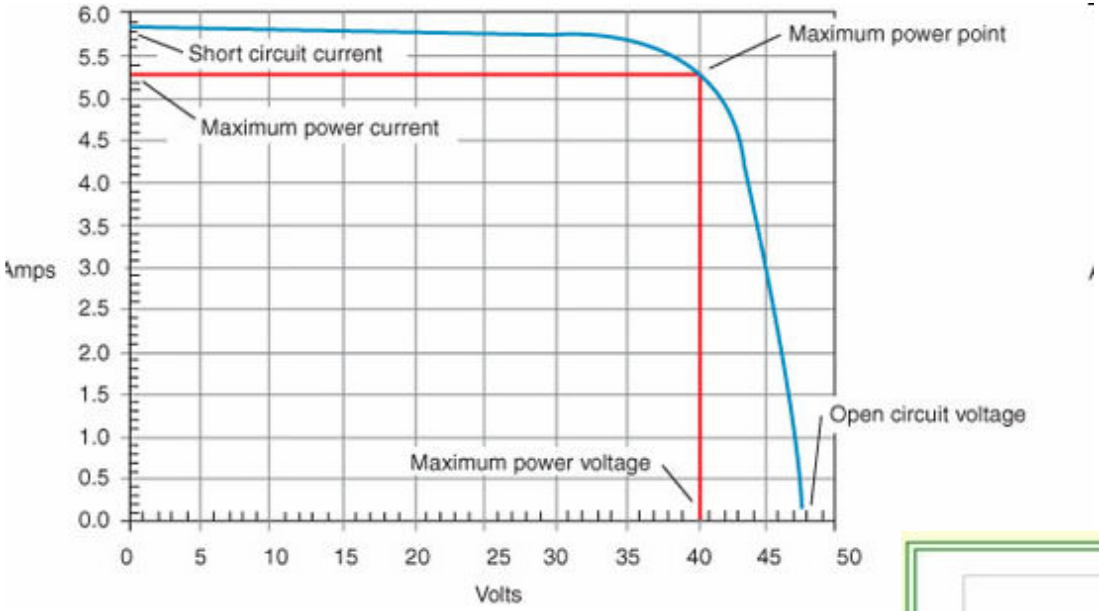
Disadvantages

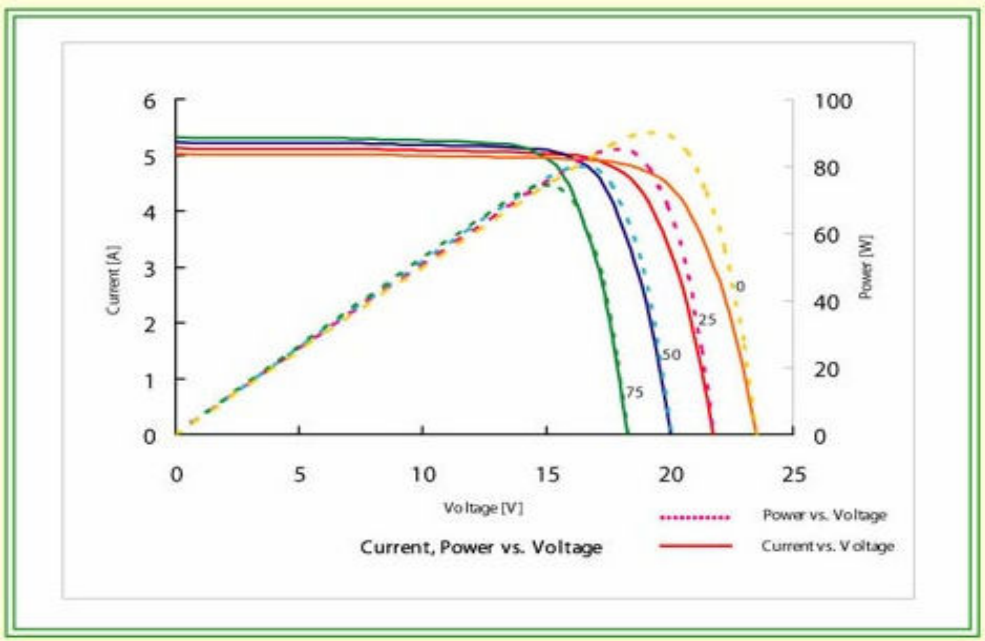
- Somewhat RAD soft internal ADC
  - Will use tantalum wafers to mitiagte
- 8 bit 10 MIPS processing power not enough for active ADCS, but more than enough for this mission
- No power draw protection for experiments
  - Satelite is mostlly single string

CSSBus Software

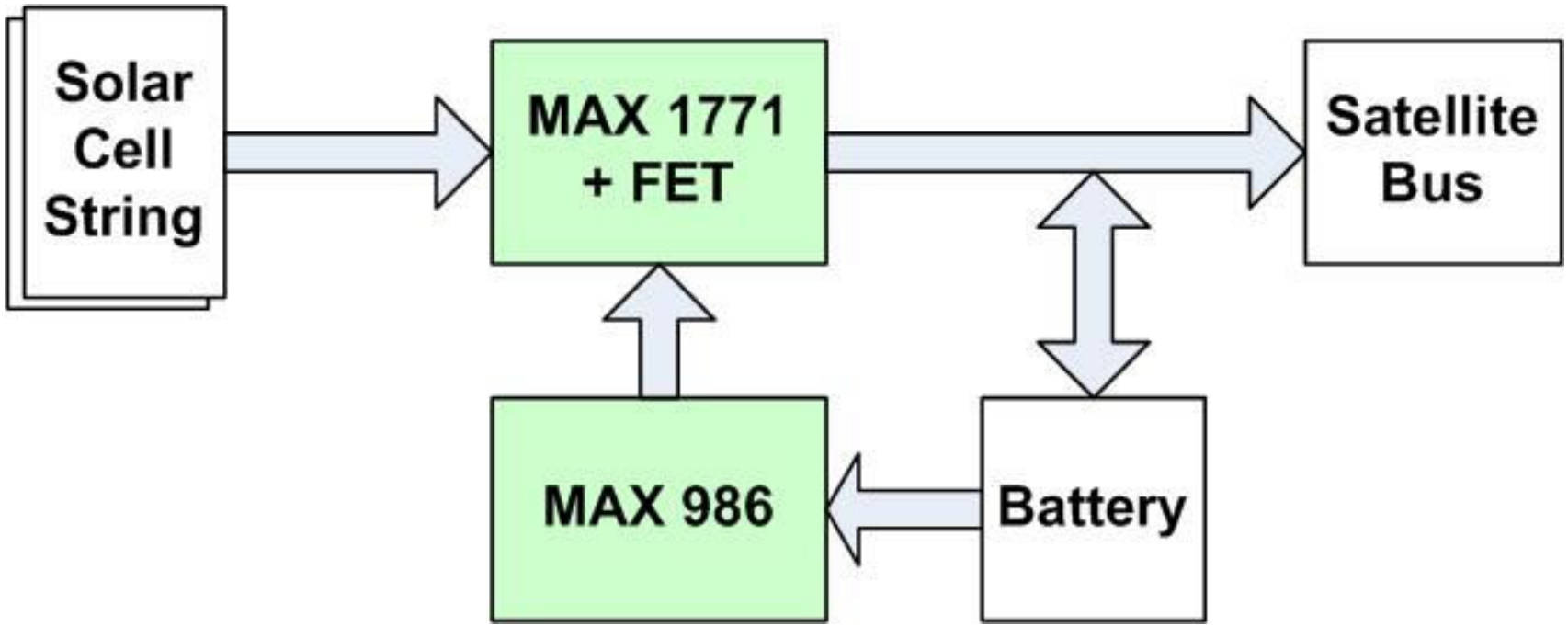
- Software development options include
  - CodeVisonAVR (selected for RAMPART)
  - IAR
  - AVRGCC (free)

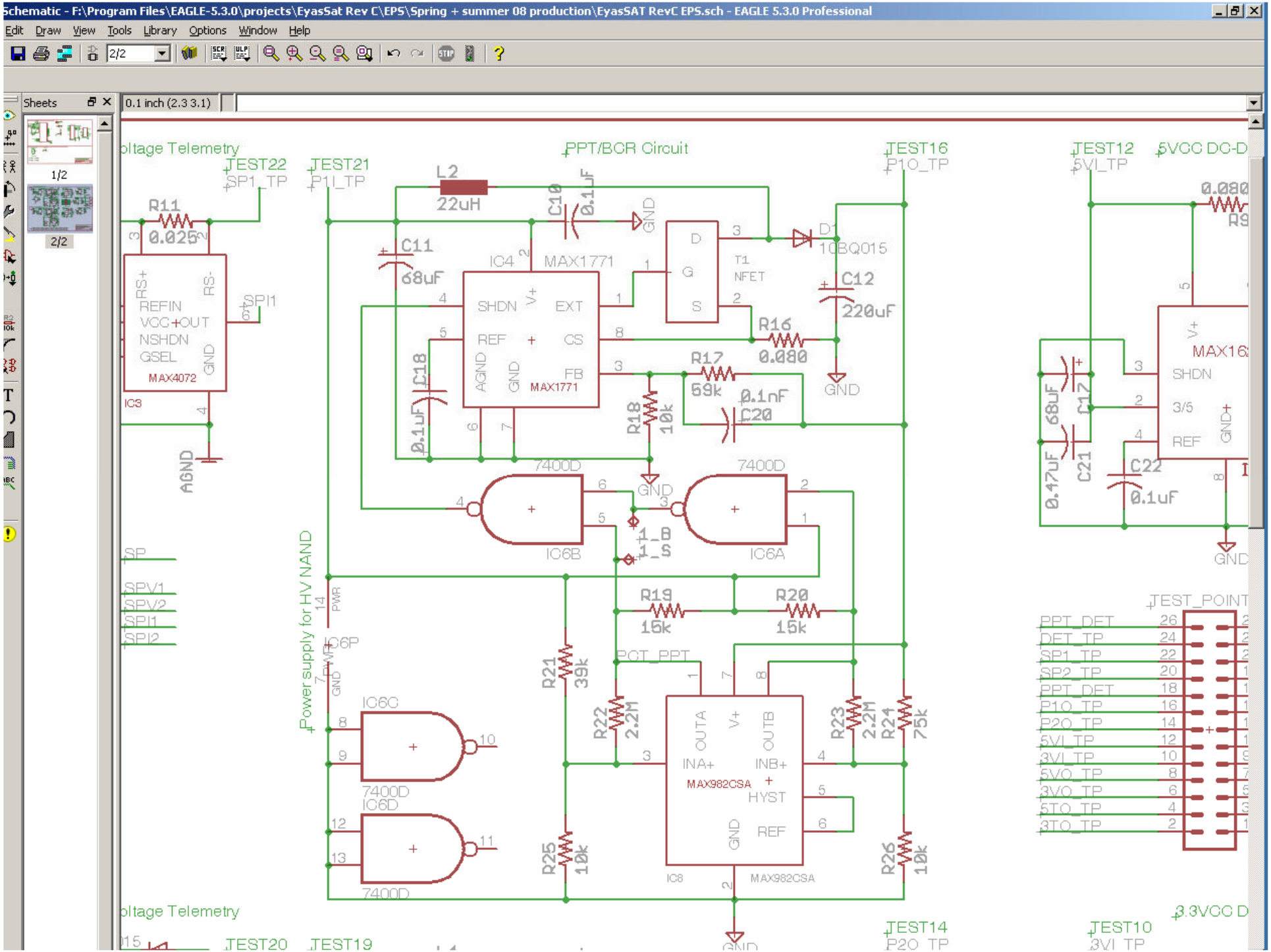
Solar Panels and BCR Operation





CSSBus BCR Design




Schematic - F:\Program Files\EAGLE-5.3.0\projects\EyasSat Rev C\EPS\Spring + summer 08 production\EyasSAT RevC EPS.sch - EAGLE 5.3.0 Professional
Edit Draw View Tools Library Options Window Help
Sheets
1/2
2/2
0.1 inch (2.3 3.1)
oltage Telemetry
PPT/BCR Circuit
TEST22
SP1_TP
TEST21
P1I_TP
TEST16
P1O_TP
TEST12
5VI_TP
5VCC DO-D
L2
22uH
C10
0.1uF
GND
R11
0.025
C11
68uF
IC4
MAX1771
D1
10BQ015
T1
NFET
C12
220uF
R16
0.080
R17
59k
0.1nF
C20
C18
0.1uF
R18
10k
SHDN
EXT
REF
CS
AGND
FB
MAX1771
RS+
RS-
REFIN
VCC
OUT
NSHDN
GSEL
MAX4072
IC3
SPI1
AGND
7400D
IC6B
IC6A
1_B
1_S
SP
SPV1
SPV2
SPI1
SPI2
Power supply for HV NAND
IC6P
PWR
GND
R19
15k
R20
15k
PCT_PPT
R21
39k
R22
2.2M
R23
2.2M
R24
75k
IC6C
IC6D
7400D
OUTA
OUTB
V+
INA+
INB+
MAX982CSA
HYST
REF
GND
IC8
R25
10k
R26
10k
MAX16
3/5
C17
68uF
C21
0.47uF
C22
0.1uF
TEST_POINT
PPT_DET
DET_TP
SP1_TP
SP2_TP
PPT_DET
P1O_TP
P2O_TP
5VI_TP
3VI_TP
5VO_TP
3VO_TP
5TO_TP
3TO_TP
oltage Telemetry
TEST20
TEST19
TEST14
P2O_TP
TEST10
3VI_TP
3.3VCC D

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

RAMPART Licensing

- 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”)

CSSBus Design for RAMPART

Questions

Amateur Radio Satellites

- See http://www.iaru.org/satellite/IARUSATSPEC_REV15.6.pdf
  for details on the frequency coordination process and the definition of an Amateur Radio Satellite

- The purpose of an Amateur Radio Satellite should be to
- (1) Provide communication resources for the general amateur radio community and/of
- (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