Power Subsystem Options for CubeSat OpComm

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Context

- Instruments are getting smaller but generating more and more data (multi-spectral imagers, particle detectors, etc.)
- In JPL concept studies, RF downlink spacecraft mode is frequently the sizing power scenario
- Optical comm can reduce the time and energy for downlink and/or allow more science data to be downlinked

Optical Comm Drivers on Power/Energy

By Ops Concept

<u>Goal: High Data Volume</u>
Sustained high power

→ Increased power generation

<u>Goal: Decreased Downlink Time</u>
Pulsed high power

→ Efficient energy storage

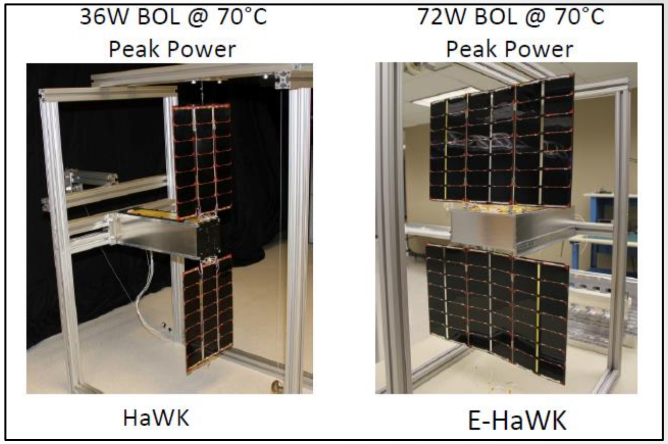
By Mission Type

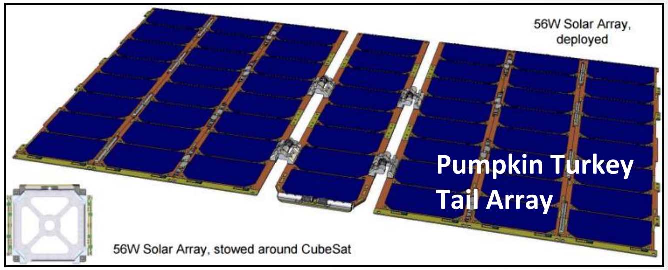
<u>Increased Power Demand and Decreased Insolation</u>

→Increased power generation and increased energy storage

Power Generation

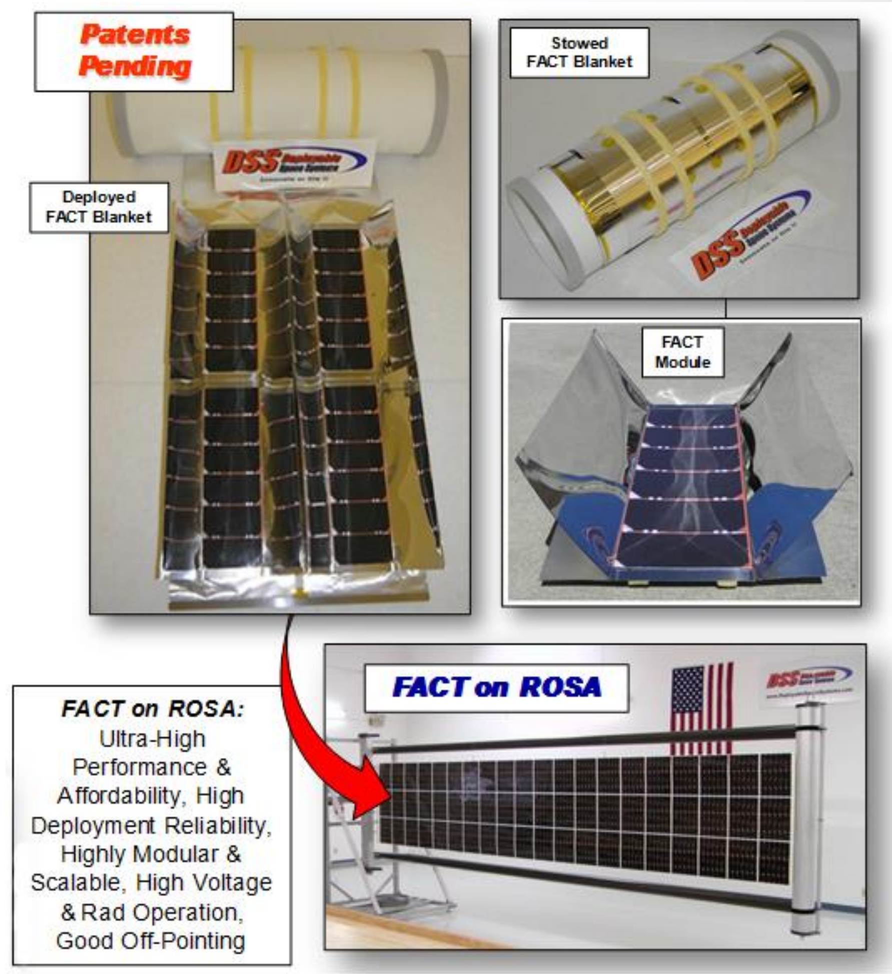
- MMA has become a leading provider of deployable Cubesat solar arrays
  - JPL missions: MARCO, Asteria, Lunar Flashlight, NEA-Scout
  - Modular wing approach allows expandability to meet mission needs
  - E-HaWk to provide ~70W BOL
  - Developing kW R-HaWK arrays
- Other vendors include Pumpkin and Clyde Space
  - Pumpkin partnered with JPL on ISARA mission
  - Some bus providers develop their own arrays (i.e. Millennium 3Ux9U ~100W array)
- Cell technology
  - CubeSat standard: UTJ (28.3%)
  - Larger missions: XTJ/ZTJ (29.5%)





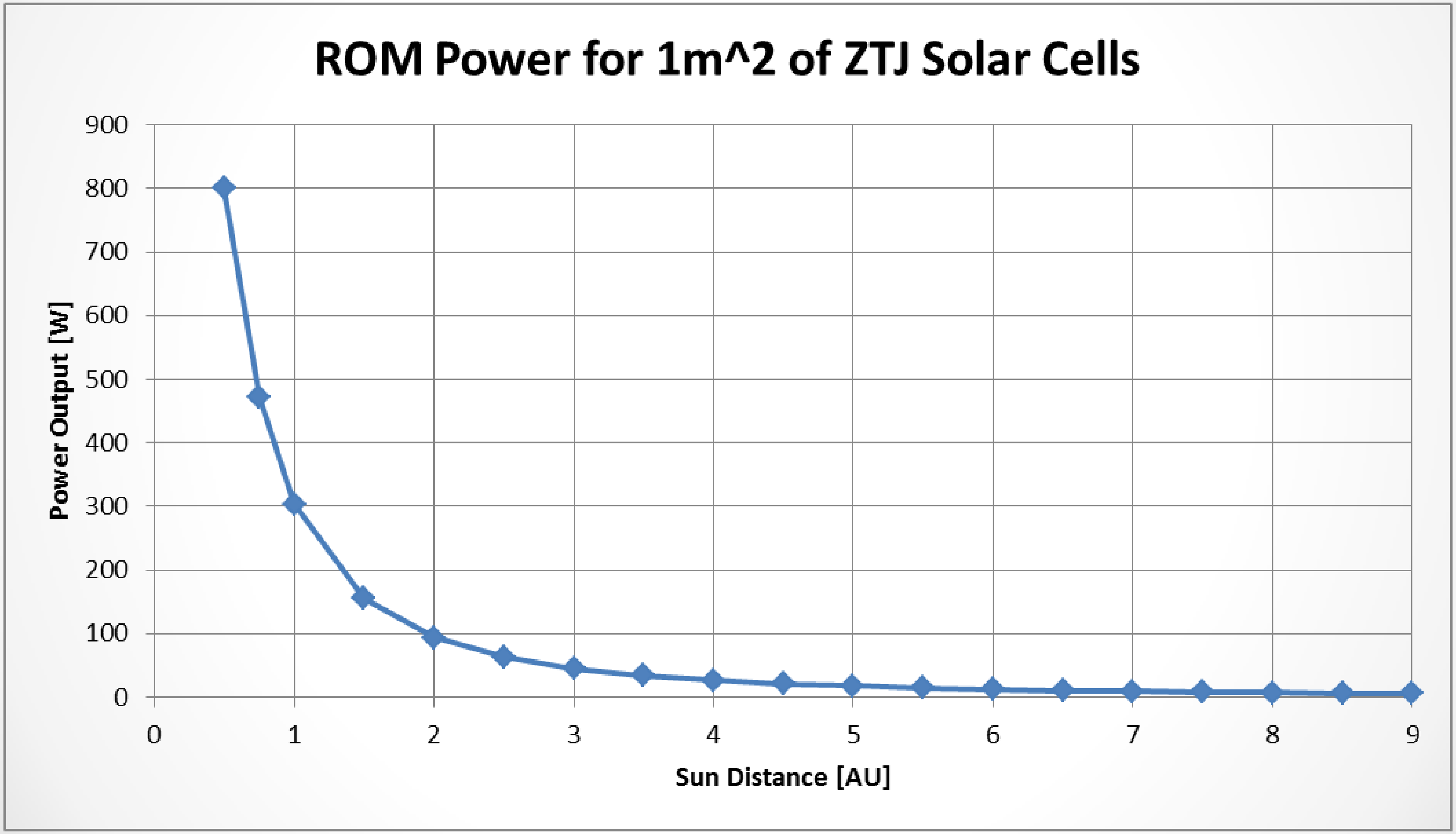
Power Generation: Future Technology

- Cell technology: IMM, 4J/5J (33+%)
- Flexible substrates with high efficiency cells
  - ATK UltraFlex and MegaFlex
  - DSS ROSA



http://www.dss-space.com/products_solar_array.html

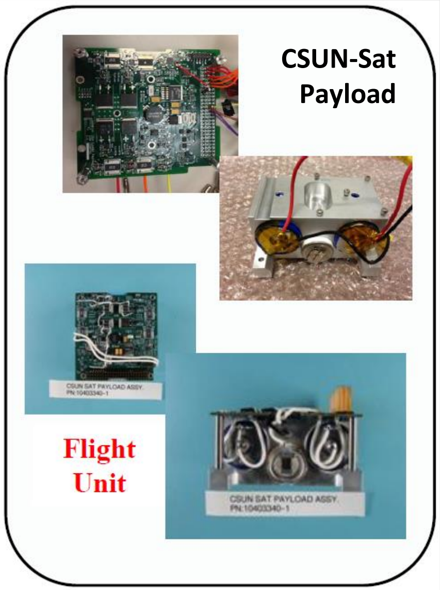
Power Generation: ROM Sizing Metric



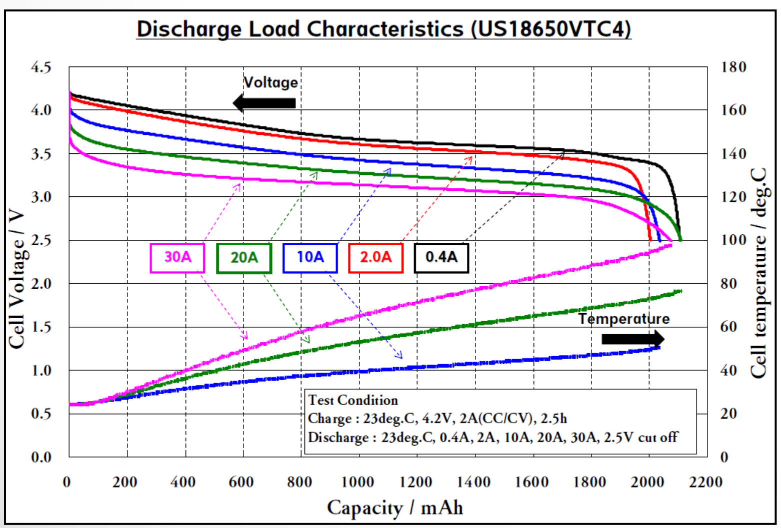
*** Note:** *Assumes deployed array with view to space and no albedo; notional degradation factors for UV, radiation, thermal cycling, etc.*

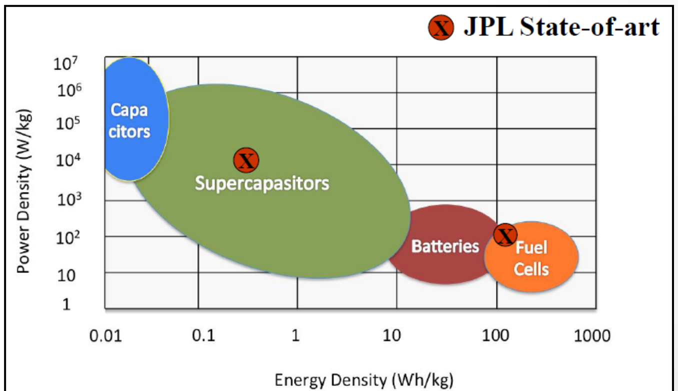
Energy Storage: High Power Density

- For pulsed power, desire high power density
- High C-rate secondary battery cells
  - Sony 18650 VTC4 (2Ah@10A) used on Mars Helicopter and Lunar Flashlight
- Supercapacitors
  - Very high power density
  - Long cycle life
  - Good low temp performance compared to batteries (particularly applicable to deep space)
- Hybrid battery-supercap system to be demonstrated on CSUN-Sat CubeSat



Keith Chin, JPL. "Advanced Power Sources for the Next Generation of Cubesats"





Energy & Power Density Summary
Li-ion Chemistries: ~300 W/kg, ~120 Wh/kg
Supercapacitors: ~3000 W/kg, ~0.5 Wh/kg

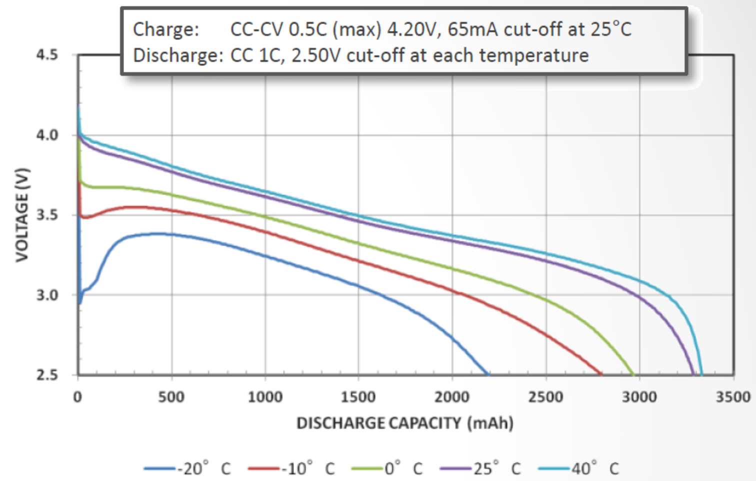
Energy Storage: High Energy Density

- Current state of practice: Panasonic 18650 NCRB
  - Min rated capacity = 3200mAh
  - Max discharge current = 7A
  - Mass/cell = 50g
    - Not including packaging, wiring, etc.

- State of the art: LG INR18650 MJ1
  - Min rated capacity = 3500mAh
  - Max discharge current = 10A
  - Expected late 2016/early 2017

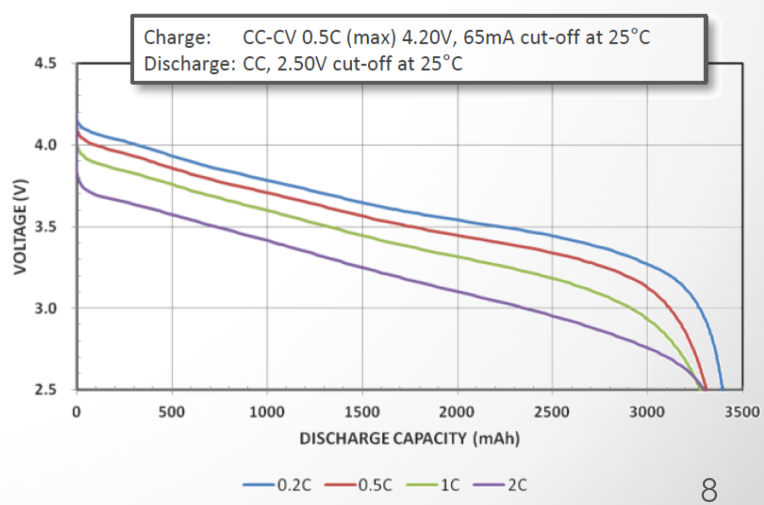
- Future technology:
  - Low temperature 18650 cells (discharge down to -30C)

Discharge Characteristics (by temperature)



Panasonic 18650 NCRB Discharge Curves

Discharge Characteristics (by rate of discharge)

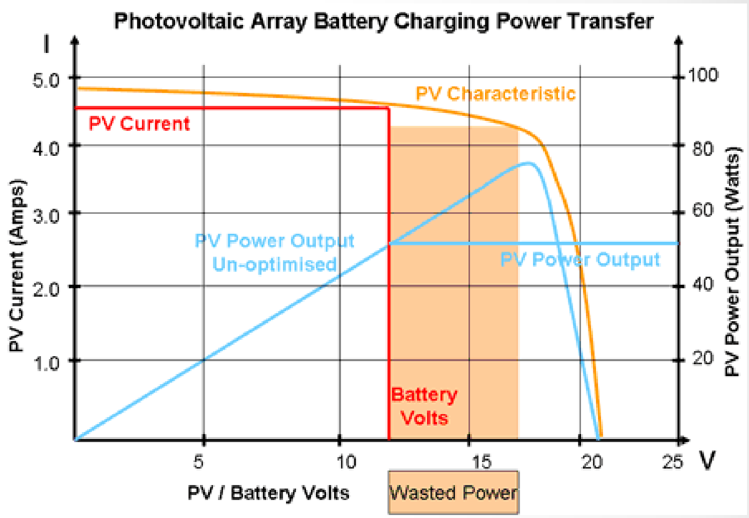


S/C Power Electronics

- Numerous COTS Electrical Power Systems (EPS) available (GOMspace, Clyde Space, SDL, UMich)
- Provides
  - Solar array and battery control
  - Power conversion and distribution
  - Health telemetry
  - LV safety inhibits
- Proposed missions are quickly meeting limits of COTS options
  - Most only built to handle up to ~50W max input
  - Radiation testing of COTS boards showed survivability of ~7-15krad

S/C Power Electronics: Max Power Point Tracking (MPPT)

- Well suited for applications where conditions change often (temperature, insolation, radiation)
- Disadvantages:
  - Adds complexity (HW or SW PPT algorithms)
    - Mass, power, volume, cost
  - Power converter losses
- Alternatives:
  - Direct energy transfer (string switching, shunting, varying string length)
    - Can restrict allowable string lengths
  - Voltage setpoint control



http://www.mpoweruk.com/solar_power.htm

Laser Electronics Considerations

- Voltage conversion and laser supply
  - Turn-key system possible?
  - Consistent laser interface?
- Thermal/packaging design
- Safety inhibits
- Health/performance telemetry

Future OpComm Planetary Application?

- Mother-daughter fleet on Mars surface
- Allow transfer of significant image data over crosslink to rover
- Allows more energy/time for flight
- Challenges:
  - Added mass
  - Pointing (beam steering + precision landing?)
  - Operational coordination