



# Off-the-Shelf, Deployable Solar Panels for CubeSats

Craig Clark and Steven Kirk

# Outline



1. The CubeSat power challenge
2. Power from a standard CubeSat
3. Deployable panels for CubeSats
4. Power Management
5. Conclusion

The engines  
cannae take  
it, captain!



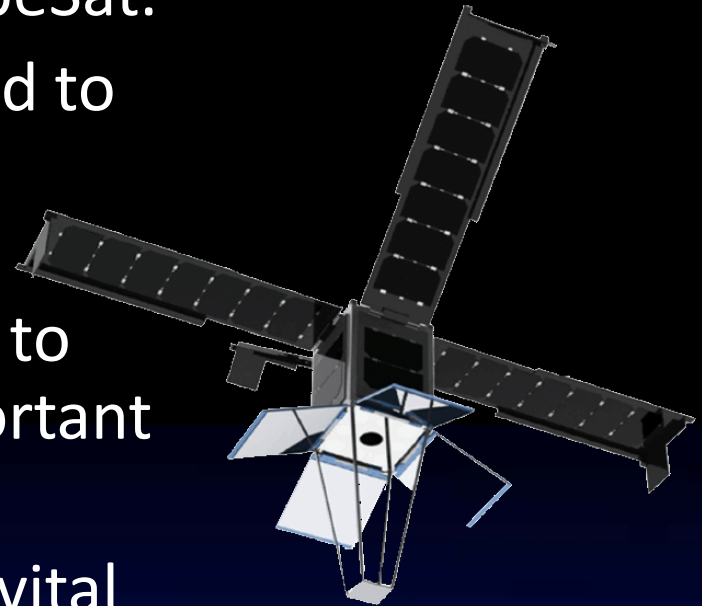


# CUBESAT POWER CHALLENGE

# Introduction



- Power is always precious on a CubeSat.
- Solar panel area must be increased to meet the orbit average power demands of new missions.
- Tailored solar panel configuration to match orbit/mission is more important than solar cell area.
- Good power management is also vital to maximise efficiency and safety on-board.
- The most common failure of CubeSats is negative power budget.

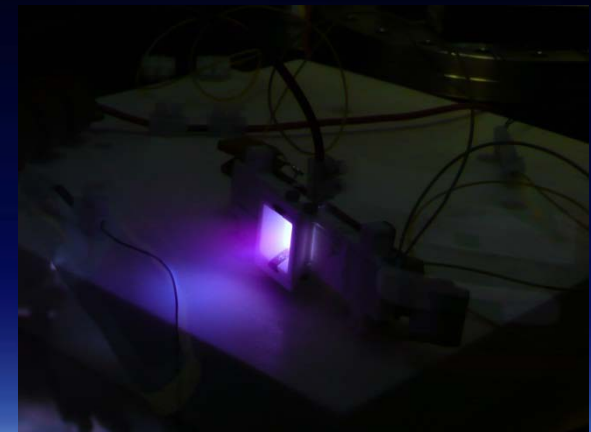


High resolution (<1m) 10km swath 3U CubeSat concept.

# Increased utility; Increased power demand



- CubeSat missions are becoming increasingly sophisticated.
  - Increasing payload power consumption and duty-cycles
  - More data storage and on-board processing
  - High downlink speeds
  - More sensors and actuators for attitude control.
  - Heaters, propulsion, etc.



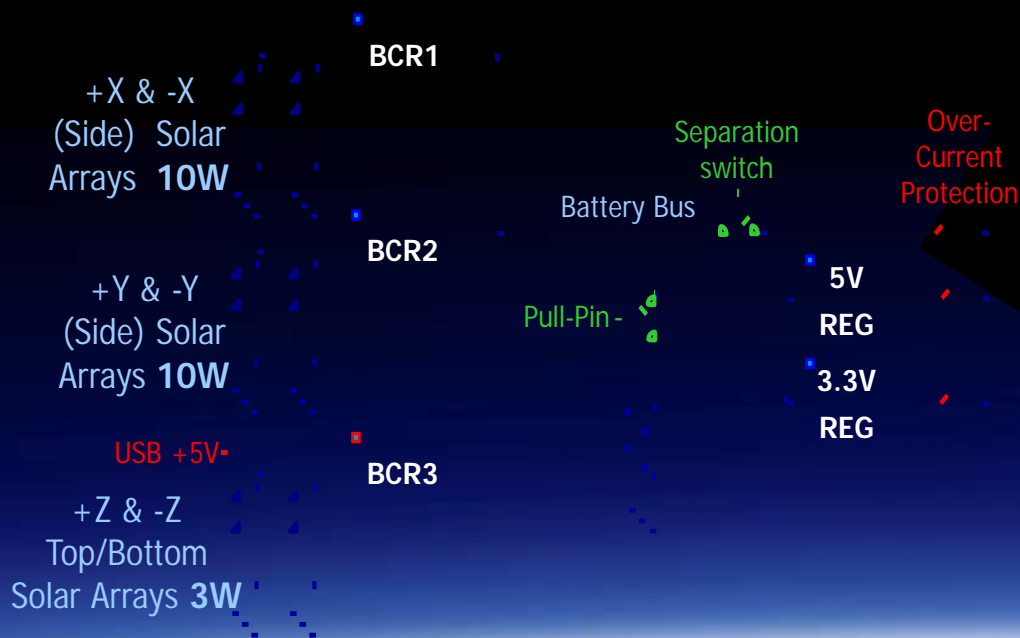
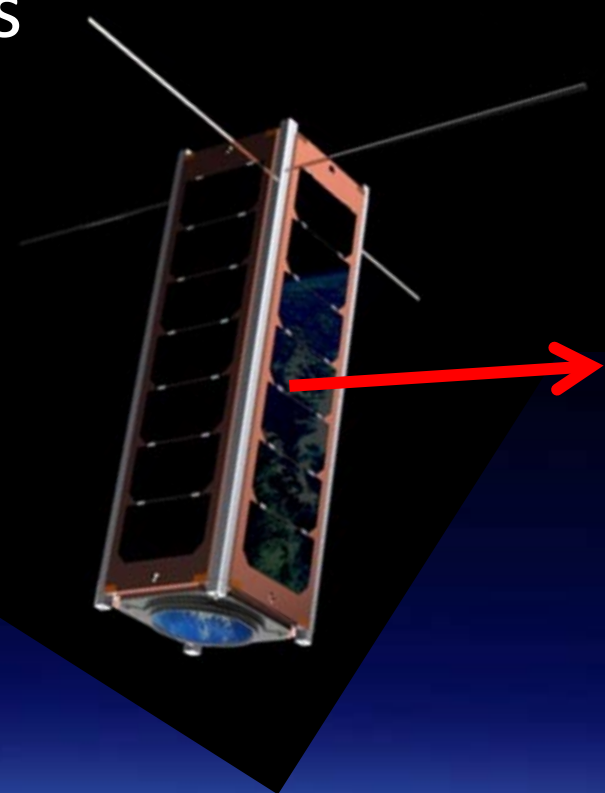
Clyde Space/Mars Space  
Pulsed Plasma Thruster



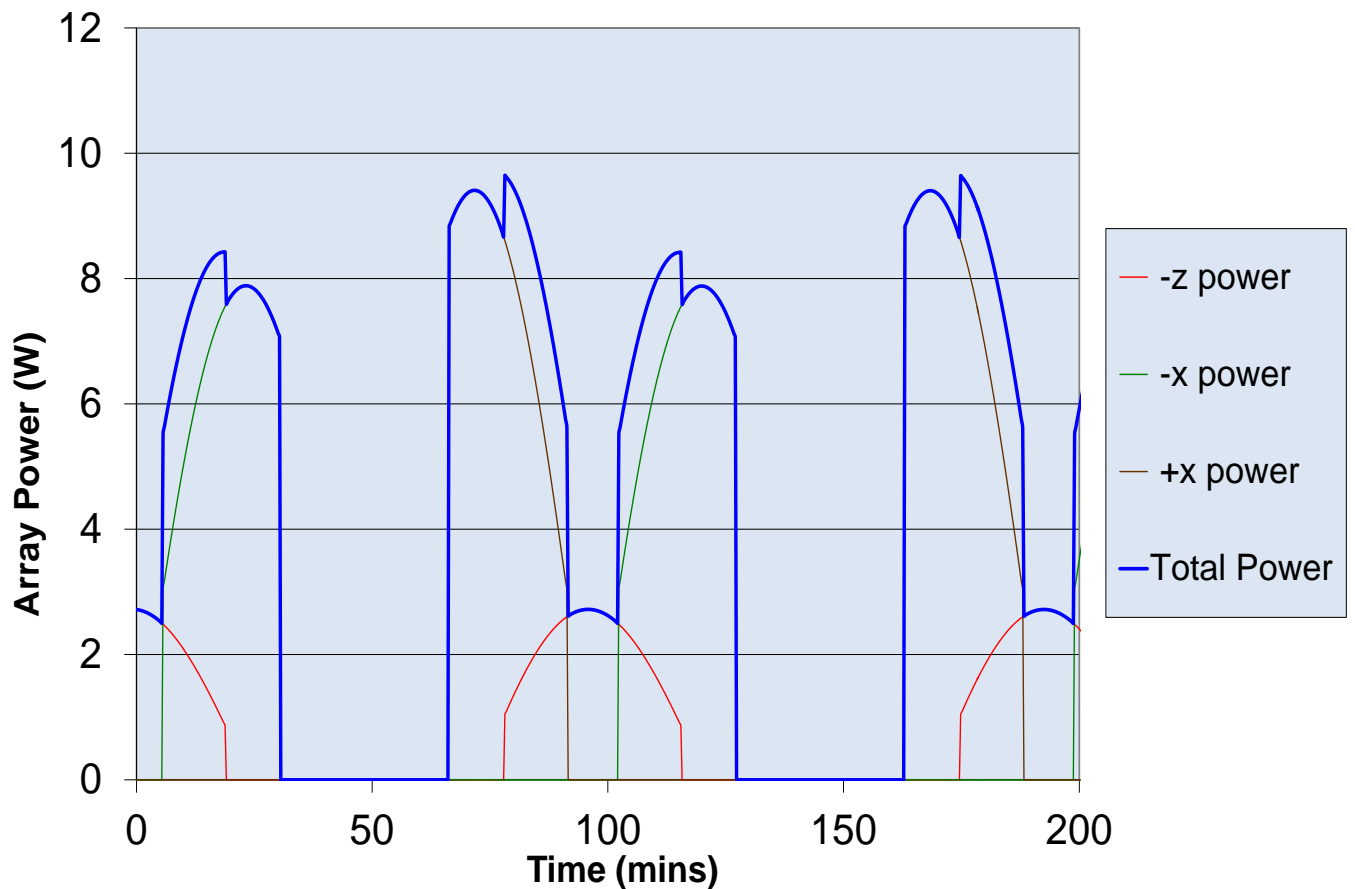
# POWER FROM A STANDARD CUBESAT

# 3U CubeSat with Body Mounted Solar Panels

- 3U Panels have 7 large area UTJs
- Top Panel has 2 UTJs



# Standard 3U Power Profile and Performance



- Orbit average power of 4.9W (including 10% Albedo).
- Peak power is 9W over the poles.





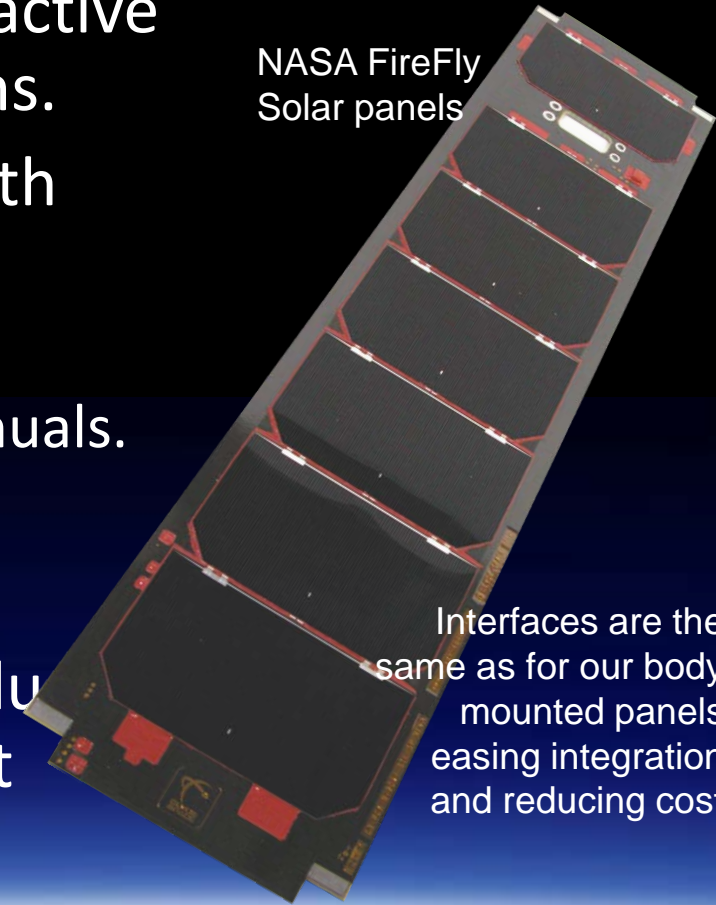
# DEPLOYABLE PANELS FOR CUBESATS

# Productization is our focus



- One reason that CubeSats are attractive is the product nature of subsystems.
- All panels are designed to work with standard structures and standard mechanical/electrical interfaces.
  - Standard documentation/User Manuals.
  - 3D models
  - Stock of components.
- This not only keeps down the production cost, it reduces the resource/effort required by the customer.

NASA FireFly  
Solar panels

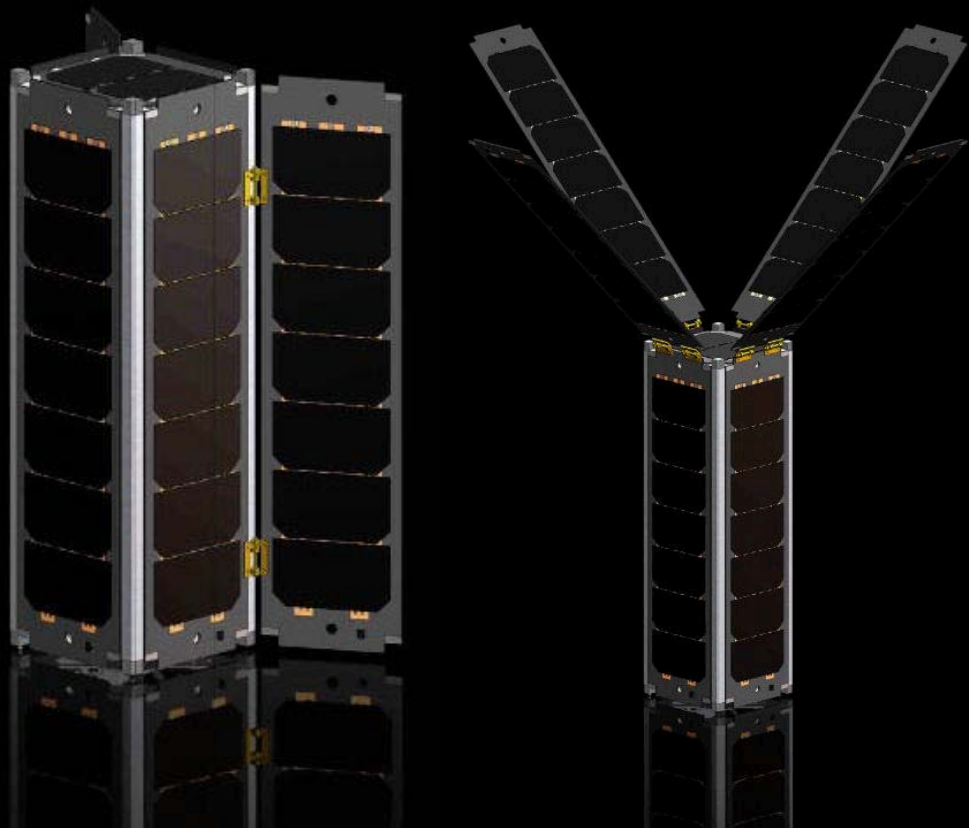


Interfaces are the same as for our body mounted panels easing integration and reducing cost.

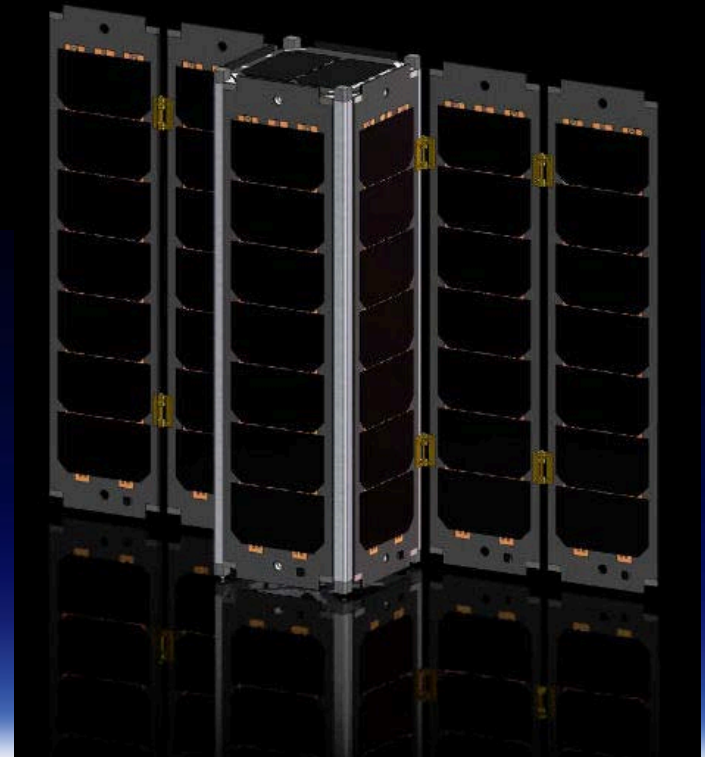
# 2 main deployable panel variants



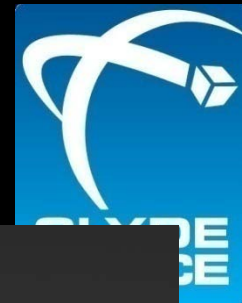
## Single Deployed



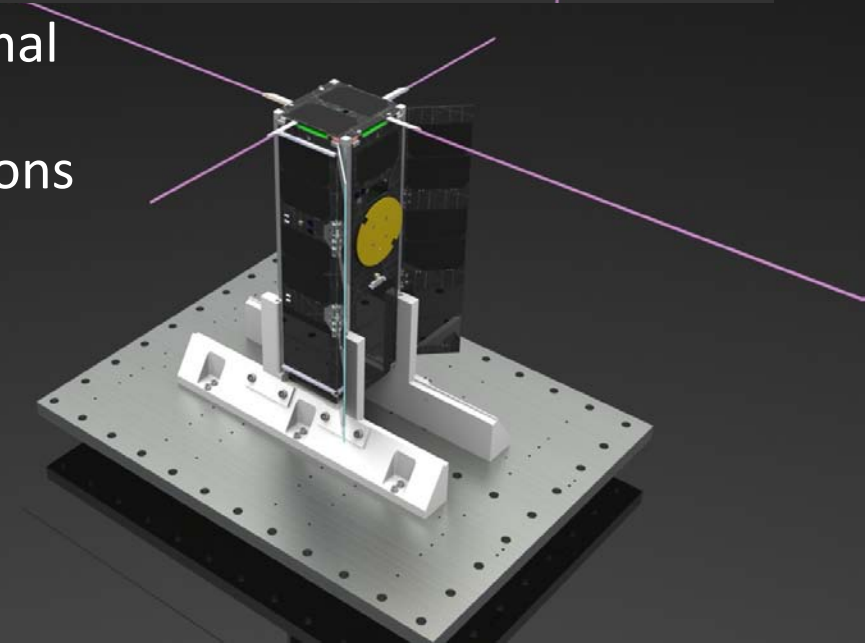
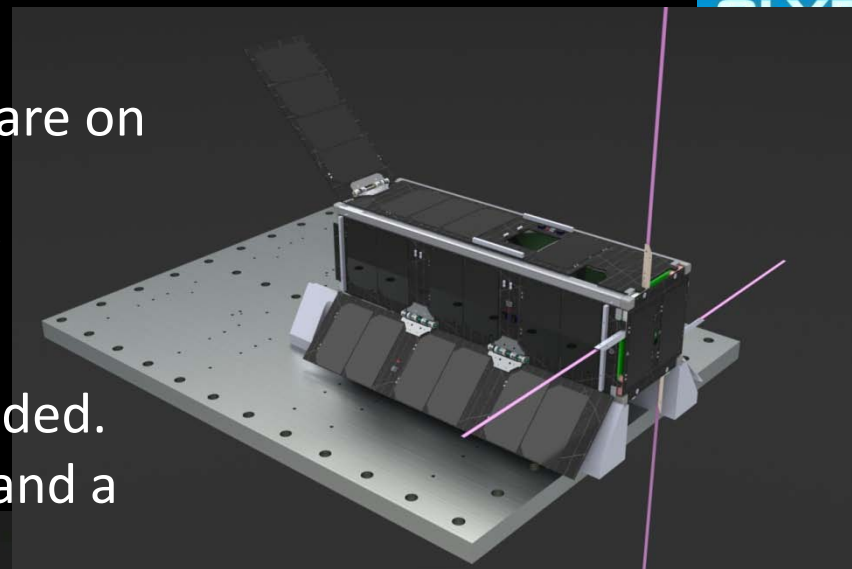
## Double Deployed



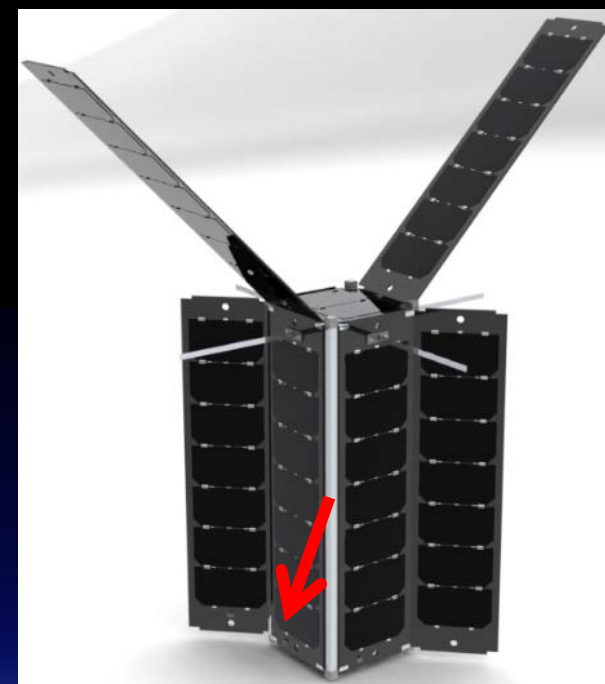
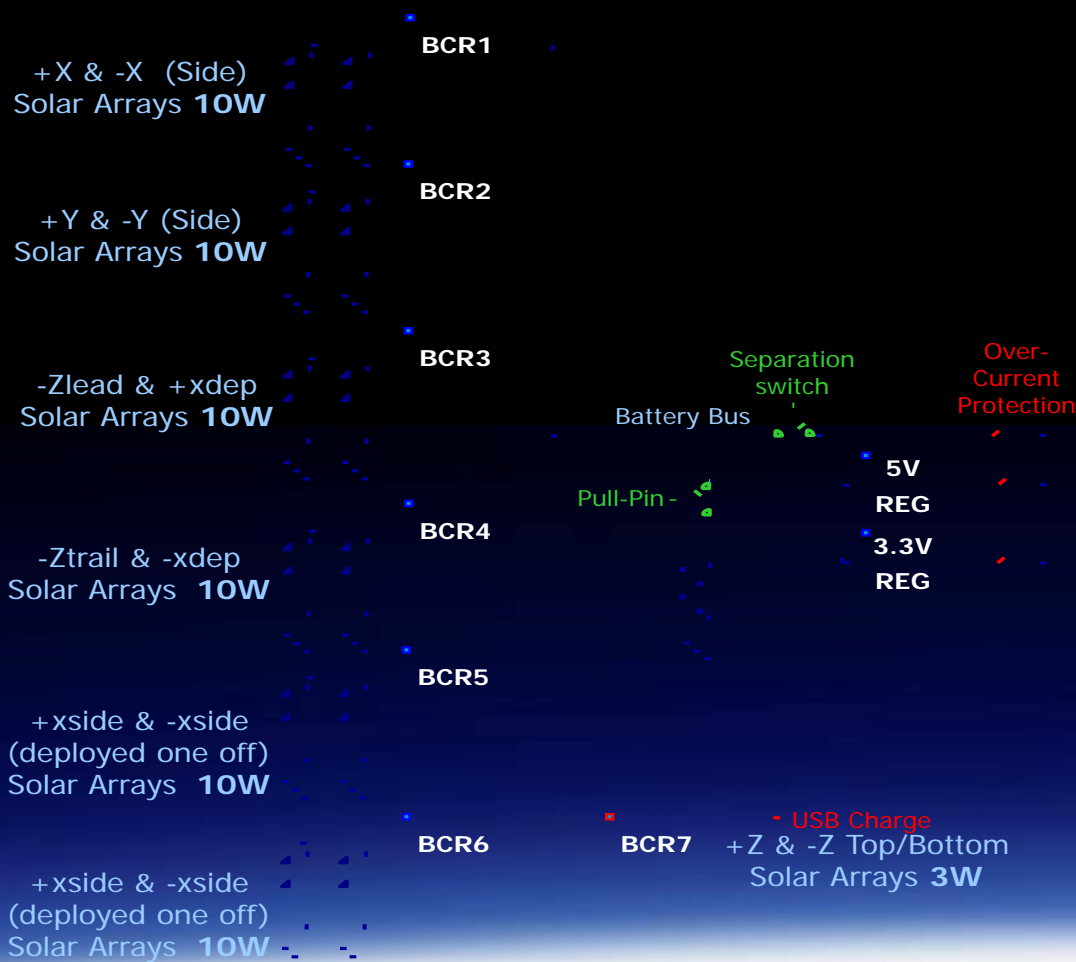
# Ukube-1 – Single Deployable



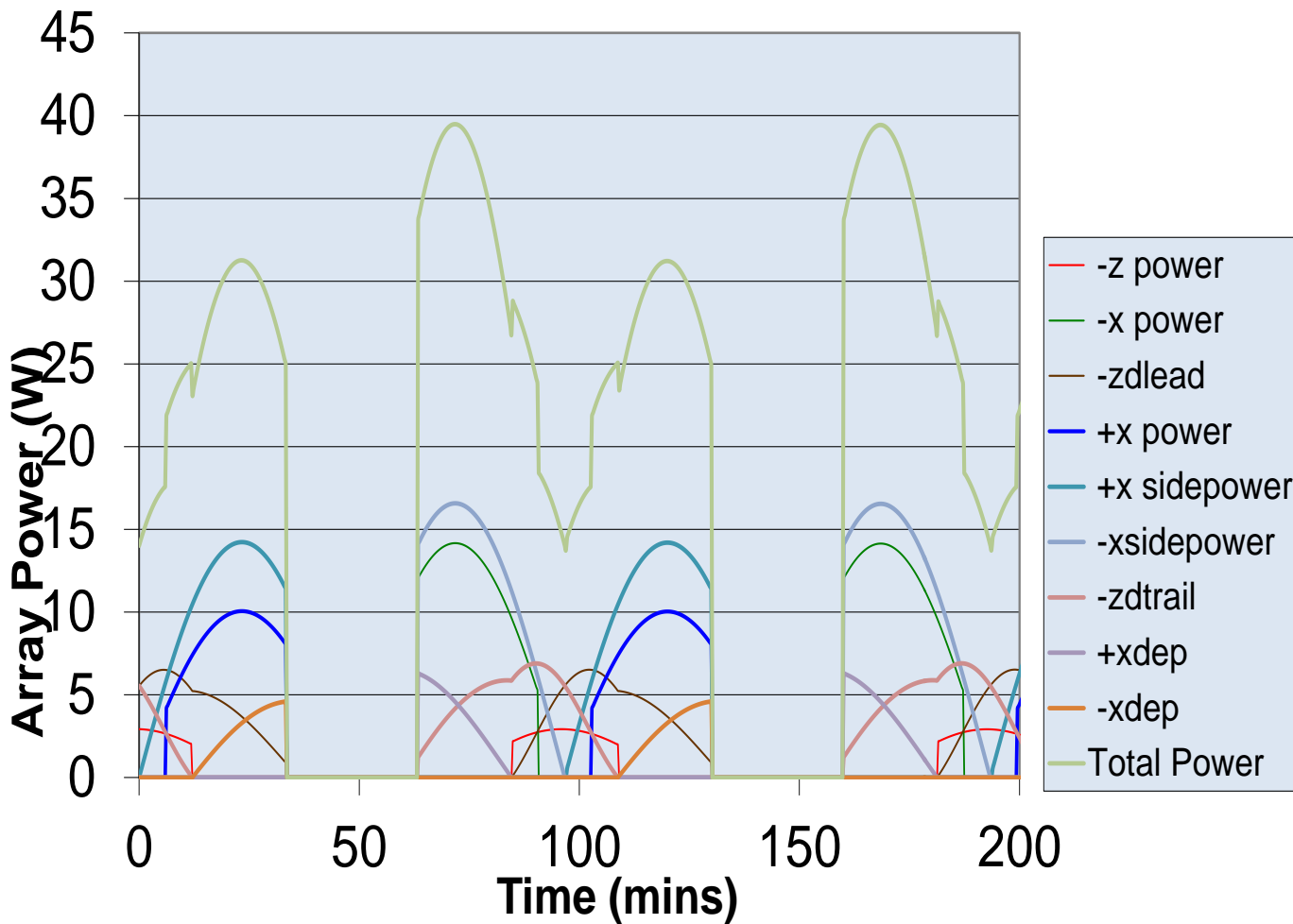
- Both variants of single deployed are on Ukube-1.
  - Our own mission for the UK Space Agency.
  - 3U CubeSat with 6 payloads.
- All deployed panels are double sided.
- Passed NASA GEVS qualification and a student encounter.
- Integrated Thermal Knives and thermal knife drivers (dual redundant).
- Available in 90° and 135° configurations
- Integrated MTQ and sensors.
- CubeSat assembly jig allows deployment tests
  - (also for antenna)



# Power from a CubeSat with deployed panels.



# Power Profile and Performance

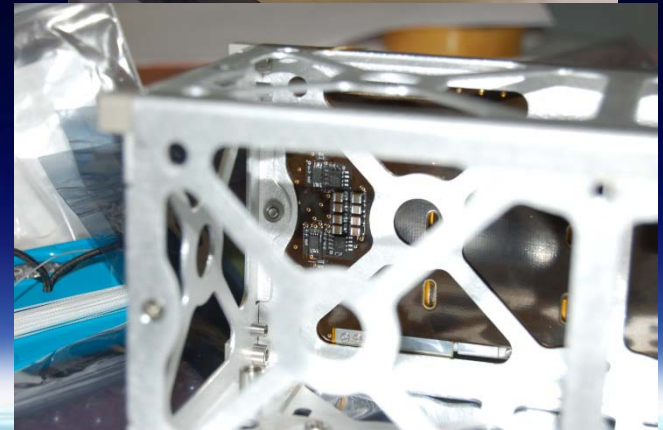


- Orbit average power of 20.8W (including 10% Albedo).
- Power profile more spread-out over orbit.
- Peak power is 40W.

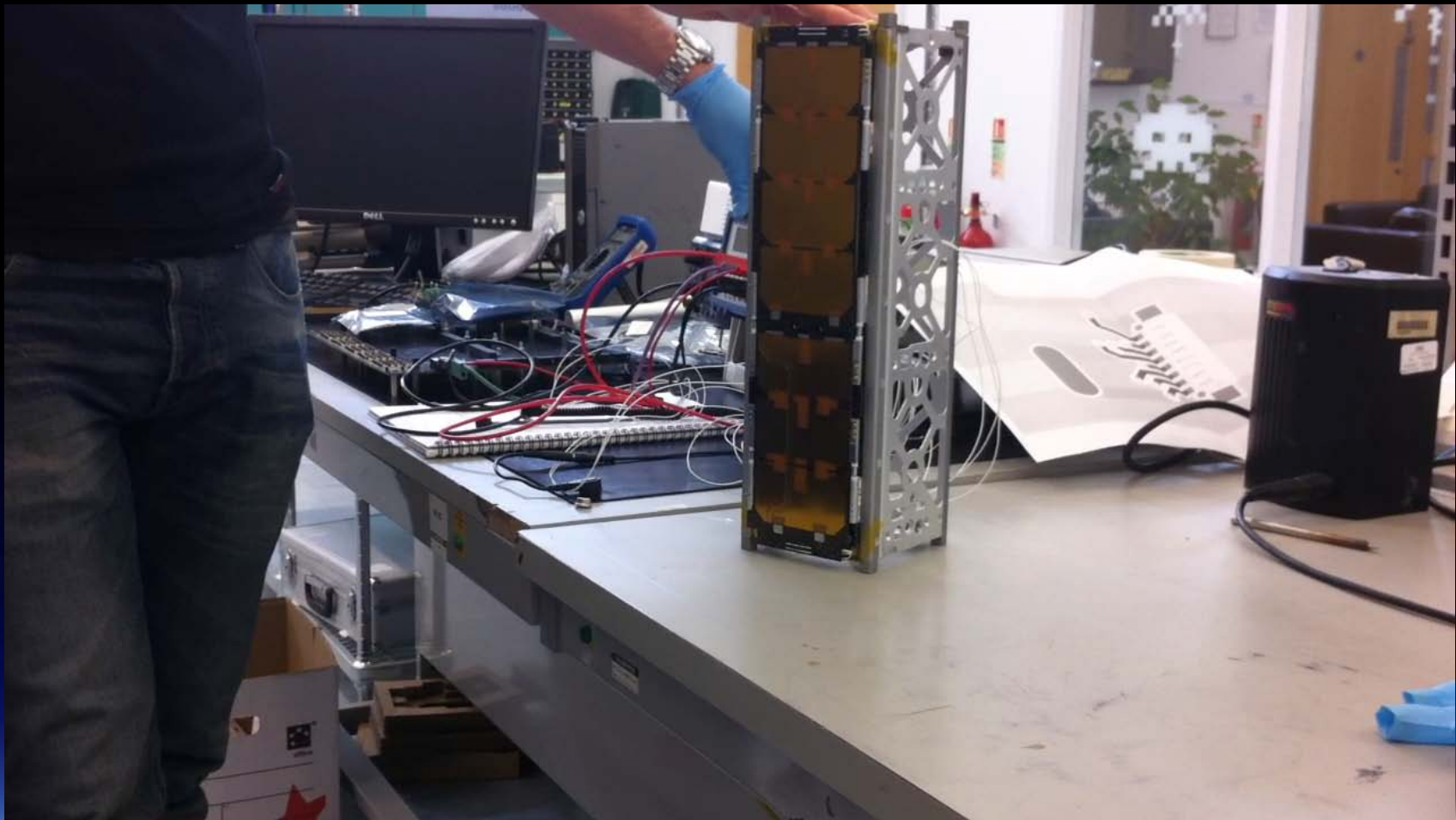
# Double Deployable



- Up to 4 faces of solar cells (front and back).
- Integrated MTQ, TKD and thermal knives.
- Tested at  $-40^{\circ}\text{C}$  and  $+80^{\circ}\text{C}$
- Designed for P-POD specification and clearance (fits within 6.5mm envelope).
- Works without need for modification to standard structures.



# Solar Panel Deployment





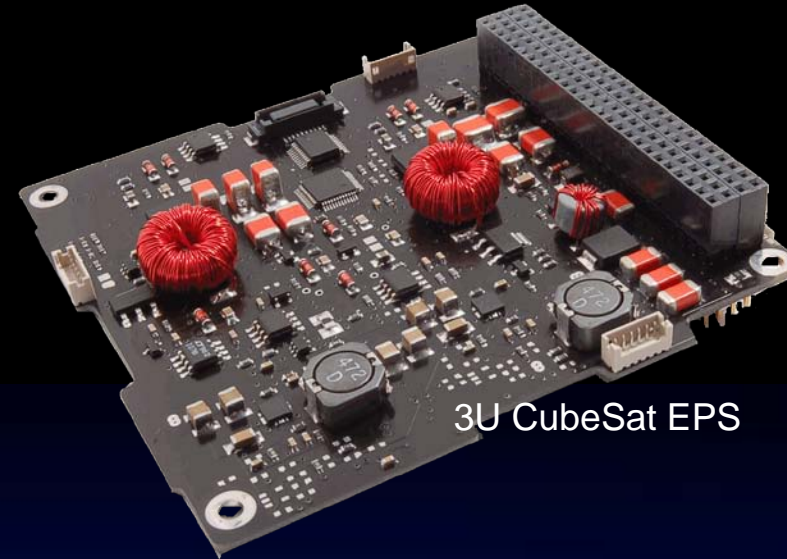


# POWER MANAGEMENT

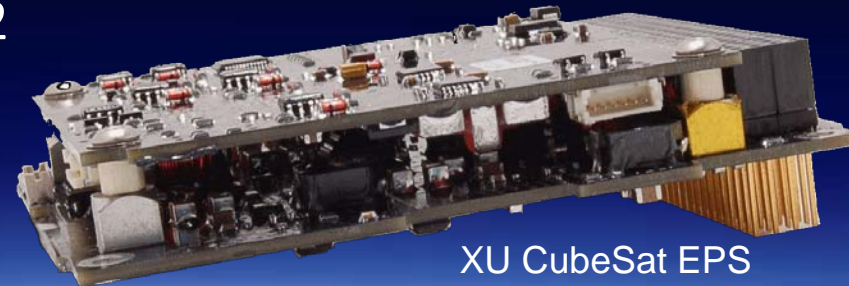
# EPS



- Over 200 Clyde Space CubeSat EPS shipped to date.
  - Many missions on orbit are now using our EPS, solar panels and battery very successfully.
- Now on 6th<sup>th</sup> Generation design.
  - Improved efficiency.
  - Solid state separation switches.
- BCRs 90%+ efficient and 95-98% efficient for 5V and 3.3V Regulators (2.5A nominal, 4A max)
- Multiple XUEPS variants can handle 12 Solar panels of 12W
  - For deployed panel systems and also 6U, 8U and 12U CubeSats.



3U CubeSat EPS

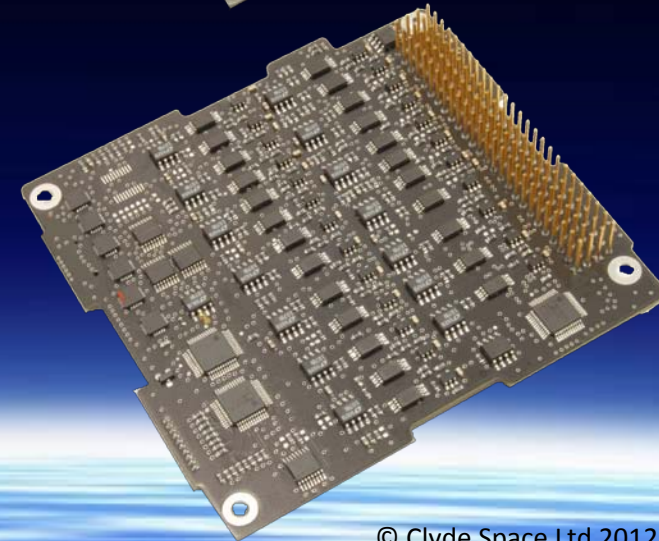


XU CubeSat EPS

# Power Distribution

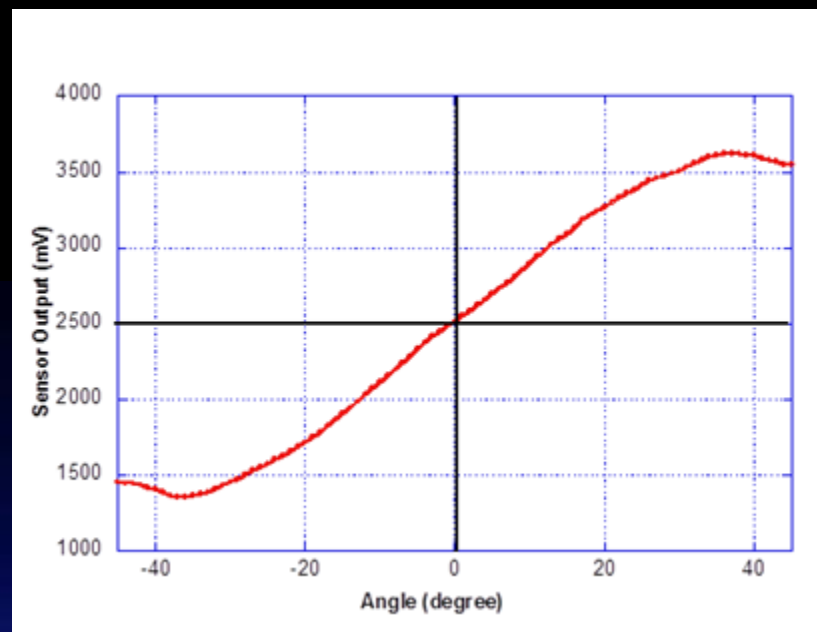


- Most satellites have a 'Power Distribution Module' (PDM).
- PDM provides functions essential to mission survival in times of anomaly.
  - Over-current protection.
  - Load management (switch things ON and OFF)
  - Battery under-voltage protection (or Unloading Function).
- Switch Board opposite has 24 power switches at 4 different voltages.
  - (Note, our EPS protects each power bus with a switch and this has under-voltage protection)



# In development: Fine Sun-sensor for CubeSats

- Analog output
- 2 axis (azimuth and elevation)
- Solar panel mountable (surface mount).
- Flying on UKube-1
  - We are in the process of widening the FoV of the sensor and doing some more testing.
- Expected performance better than  $0.1^\circ$  knowledge.
- Size is 16mm x 8mm x 3mm
- Mass of less than 5g
- Power consumption of a few mW (including interface circuit)



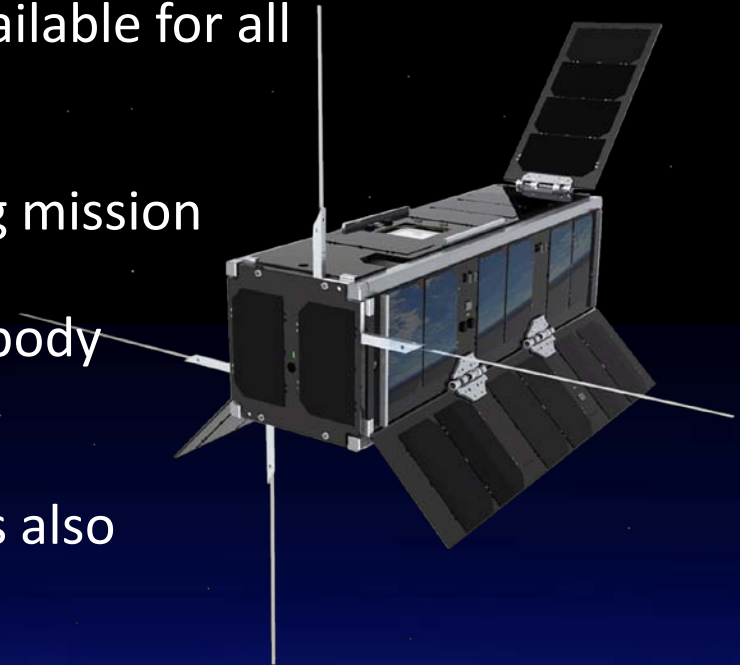


# CONCLUSIONS

# More Power!



- Deployed panels as an off-the-shelf product help increase on board power at an affordable cost.
- Single and double deployed panels available for all CubeSat sizes.
  - Can be single or double sided.
- Different configurations to suit varying mission requirements.
- Panel integration is the same as for a body mounted panel.
  - No need for custom structures.
- Scalable power management products also available.
- Problems:
  - Thermal management!



A small satellite, possibly a CubeSat, is shown in space. The satellite is rectangular with a metallic frame and a central panel displaying a satellite image of Earth. It is oriented diagonally. The background is the blackness of space with a thin line of the Earth's horizon and atmosphere visible at the bottom right.

# Questions?

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