Plug-n-Play, Reliable Power Systems for Nanosatellites.

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The Power Problem

- The power system is probably the most underestimated system on a spacecraft.
  - It is required first for spacecraft integration.
  - It needs to work autonomously and seamlessly.
  - If doing its job properly, it should never be noticed.
  - It is not a ‘sexy’ subsystem so ‘perhaps’ doesn’t always get the attention it deserves.
Nanosatellite Programmes

- There is a growing number of organisations preparing or planning their own mission.
- The power system is a big problem for these missions.
  - The mission designers know they need one.
  - They know it needs to be reliable.
  - They are learning that it is not easy and a cause of concern.
  - Budget limitations prevent outsourcing.
- Clyde Space has recognised this issue and we are developing a standard solution for nanosatellites.
The Standard Interface

- One of the biggest cost drivers in space hardware is NRE.
- To avoid NRE costs, there is a need to adopt a standard mechanical and electrical interface.
- The CubeSat community have done an excellent job of introducing a standard that can be used for this purpose.
- For this reason, Clyde Space decided to adopt the CubeSat Kit standard for our power system.
Power System Architectures

• Many different approaches to configuration.
  – Battery Bus DET
  – Fully Regulated DET
  – Hybrid
  – MPPT
  – Etc.

• Our challenge was to select an architecture that works across the board.
Battery Bus DET

Solar Panel

Battery
Solar Array Characteristic

Increasing Temperature

Maximum Power Point

Eclipse exit operating point

Increasing Temperature

Array Voltage

Array Current

$V_{MPP}$ $V_{o/c}$

$I_{S/c}$ $I_{MPP}$
Regulated Bus

Solar Array Sections

Bus Voltage Control

BCDR1

BCDR2

S3R

Regulated Bus

PDM

Lithium Ion Battery
Maximum Power Point Tracker
Benefits of MPPT

• Maximises power when it is needed most.
• Can interface to multiple arrays with different characteristics.
• Reduces solar array size.
• Manages charge control effectively and simply.
• Battery bus is stable, simple and offers excellent impedance characteristics.
• The MPPT technique that we are implementing does not require any user set-up; it is plug-n-play.
Solar Array Design and Selection

• For most nanosatellite missions, solar panels will be the most costly item.
• There are a number of solar cell technologies available.
  – Silicon (12% eff.)
  – Single Junction GaAs (19% eff.)
  – Multi-junction GaInP/GaAs/Ge. (27% eff.)
• A useable voltage must be achieved (4V or above).
  – Si ~ 0.5V. For a 4V array at least 10 cells are needed.
  – SJ GaAs ~ 0.9V. 6 cells needed.
  – MJ ~ 2.2V. 2 cells needed.
• Multi-junction technology is really the most obvious choice.
Battery Selection

• NiCd was the choice battery technology until recently.
  – Good cycling characteristics.
  – High discharge current capability.

• For today’s small and miniature satellites a more mass and volumetric efficient technology is required.

• Lithium Ion and Lithium Polymer are the choice technologies.
  – 100+Whrs/kg (li-ion) vs 25Whrs/kg (NiCd).
  – Lithium Polymer offers geometric flexibility.
  – The technology is now mature enough to be used in space.
Lithium Ion/Polymer

• Commercial lithium ion cells are used by ABSL
  – The SONY HC18650 cell is used.
  – SSTL and ESA regularly use the ABSL battery.

• Lithium Polymer cells look ideal for miniature spacecraft.
  – Initial life-tests have look good for some cells
  – Energy density of ~170Whrs/kg.
  – Structural configuration makes the technology inherently structurally robust and volume efficient.
  – ‘Bulging’ issues can be easily overcome.
  – End of Charge remains constant over temperature.
CubeSat Power

Solar Arrays

BCR1

BCR2

BCR3

BCR6

Battery Bus

Separation switch

USB Power

5V REG

3.3V REG

µC

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Key Features

• Versatile, non-sequential solar array interface
  – 6 Independently controlled maximum power point trackers.
  – Each interface handles up to 3W.
  – Compatible with multiple solar array configurations.
  – >90% efficient.

• Centralised battery charge control.
  – Compatible with Li-ion and Lithium Polymer cell technologies.

• Integrated 1Ahr (7.5Whr) Lithium Polymer battery
  – Battery Bus 5.5V – 8.4V
  – Integrated battery heater

• Regulated 5V and 3.3V buses
  – 1A output at >90% efficient.
Key Features Cont.

- Bus over-current protection
  - Retry until fault clears.
- Battery under-voltage protection.
  - With hysteresis to allow battery charge recovery.
- USB charge and power interface for ground test.
- Scalable, modular, stackable design to allow easy power handling and battery capacity increase.
- I2C digital interface.
  - Bus reset/run command facility.
  - Telemetries include Array Voltage, Battery Voltage, Battery Temperature, BCR output current Bus currents, Battery Current and Array temperature.
  - Battery state of charge indicator also available.
Schedule and Price

• Development activities well underway
  – Regulator and BCR prototypes in test.
• Full prototypes planned for October 06.
• Flight model production (25 units) in Dec 06/Jan 07.
• The system is being developed under a grant from the Scottish Executive called SMART.
• Target price is $2000 for complete CubeSat EPS (including battery).
Conclusion

• Clyde Space are using extensive small sat power system expertise to develop a reliable off-the-shelf EPS solution for nanosatellites.

• Our target specifications allow a great deal of flexibility, functionality, ease of use and scalability.

• The technology is robust and simple to understand.
  – The system is plug-n-play with no user set-up required.
Our Mission

• The mission of Clyde Space is to provide spacecraft hardware to customers with requirements for low-cost, reliable, small satellite subsystems.

• Within the next 3 years of operation we aim to be established as a leading provider of power subsystems for small satellites.
Clyde Space People

- **Director - Craig Clark:**
  - 11 years with SSTL: 7 years as head of the Power Systems.
- **Senior Engineer – Alex Lopez:**
  - Talented and respected Analogue Electronics Specialist.
- **Engineer – Andrew Strain**
  - Graduate electronics design engineer.
Our Facilities

• Located on the West of Scotland Science Park
  – Facilities are purpose built for technology companies.
• Office facilities
  – 400 sqft of office space
  – Typical usage includes design, documentation and administration activities.
• Lab facilities
  – 400 sqft of electronics lab facilities
  – Typical usage includes bread-boarding and general engineering activities.
• Cleanroom facilities
  – Class 10,000, open-plan cleanroom area.
  – ESD compliance for handling sensitive devices.
  – Clean compressed air and nitrogen throughout.
  – Typical usage includes flight assembly.