a Cohort plc company

BAE SYSTEMS

The use of 'MNT' Technologies in Smart Microsystems - A Feasibility Study to Investigate Decentralising Space Systems with highly efficient Micronodes.

John Cornforth[(1)], Andrew Bacon[(1)], I Sturland[(2)], S Lake[(2)], Roland Trautner (TO) [(3)]

[(1)]SEA, [(2)]BAE Systems, [(3)]ESA

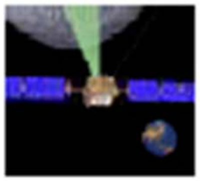
Presented by John Cornforth

[John.cornforth@sea.co.uk]

At 8th ESA ROUND TABLE ON MICRO AND NANO TECHNOLOGIES FOR SPACE APPLICATIONS

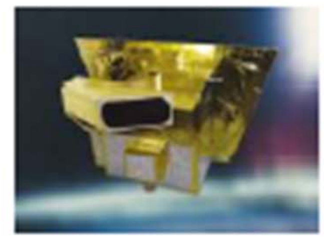
ESTEC 15th - 18th October 2012

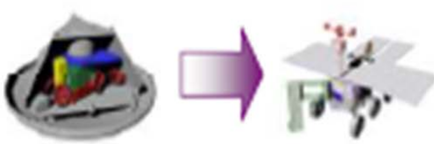
Company – SEA (Systems Engineering and Assessment Ltd)

- SEA
  - Approx 250 employees; 80% professional engineers.
  - Offices in ***Bristol*** and Beckington, UK
- Space Systems
  - Instruments; sensors; electronics; (studies and flight units)
- Ground Systems
  - Radar transponders
- Non-space activities
  - Naval Systems
  - Airborne radars/equipment health monitoring
  - Traffic enforcement systems
  - Training systems for helicopters





Study Partners

SEA

Prime Contractor

SEA House, Building 660, Bristol Business Park, Coldharbour Lane, Bristol, England.

BAE Systems

Sub-Contractor

Advanced Technology Centre, FPC267, Golf Course Lane, PO Box 5, Filton, Bristol, England

ESA Technical Officer; R. Trautner

'Smart Microsystems for Space Applications' Study
part of ESA's General Studies Programme (GSP)
Duration: Jan 2012 – Jan 2013

Content

- **Typical Centralised Architecture Overview**
- Benefits of De-centralisation
- Chosen Micronode Designs to take forward
- Summary of Micronode Advantages
- Packaging Solutions and MEMs Opportunities
- Micronode Potential for MNT Utilisation
- Examples for MNT Utilisation
- Usage in AIT

Content

- Typical Centralised Architecture Overview
- **Benefits of De-centralisation**
- Chosen Micronode Designs to take forward
- Summary of Micronode Advantages
- Packaging Solutions and MEMs Opportunities
- Micronode Potential for MNT Utilisation
- Examples for MNT Utilisation
- Usage in AIT

Content

- Typical Centralised Architecture Overview
- Benefits of De-centralisation
- **Chosen Micronode Designs to take forward**
- Summary of Micronode Advantages
- Packaging Solutions and MEMs Opportunities
- Micronode Potential for MNT Utilisation
- Examples for MNT Utilisation
- Usage in AIT

Content

- Typical Centralised Architecture Overview
- Benefits of De-centralisation
- Chosen Micronode Designs to take forward
- **Summary of Micronode Advantages**
- Packaging Solutions and MEMs Opportunities
- Micronode Potential for MNT Utilisation
- Examples for MNT Utilisation
- Usage in AIT

Content

- Typical Centralised Architecture Overview
- Benefits of De-centralisation
- Chosen Micronode Designs to take forward
- Summary of Micronode Advantages
- **Packaging Solutions and MEMs Opportunities**
- Micronode Potential for MNT Utilisation
- Examples for MNT Utilisation
- Usage in AIT

Content

Content

- Typical Centralised Architecture Overview
- Benefits of De-centralisation
- Chosen Micronode Designs to take forward
- Summary of Micronode Advantages
- Packaging Solutions and MEMs Opportunities
- Micronode Potential for MNT Utilisation
- **Examples for MNT Utilisation**
- Usage in AIT

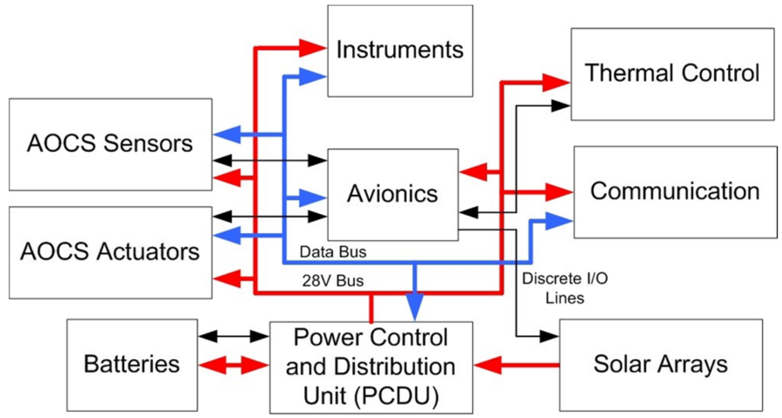
Content

- Typical Centralised Architecture Overview
- Benefits of De-centralisation
- Chosen Micronode Designs to take forward
- Summary of Micronode Advantages
- Packaging Solutions and MEMs Opportunities
- Micronode Potential for MNT Utilisation
- Examples for MNT Utilisation
- **Usage in AIT**

Centralised System Architecture

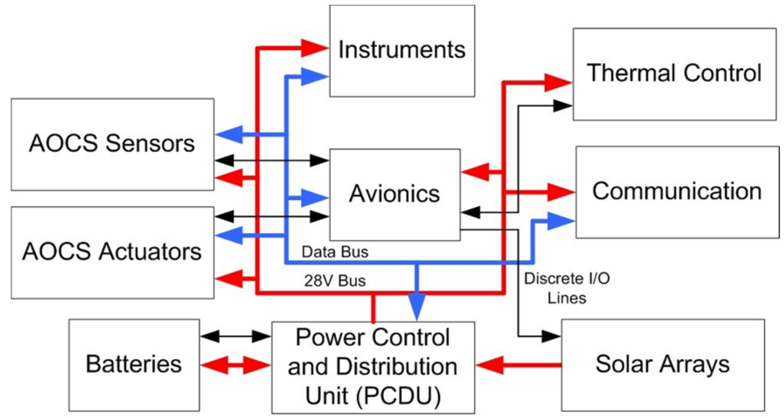
Traditional Centralised System

- Large Harness Mass (typically 9% of spacecraft mass).
- System Vulnerability to Failures.

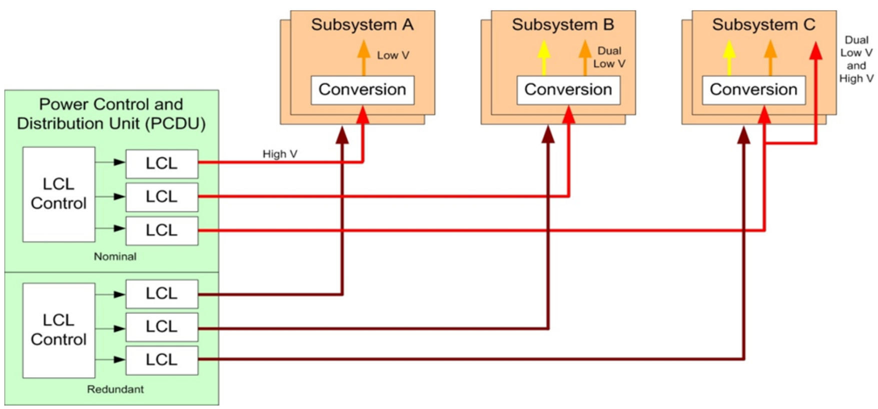


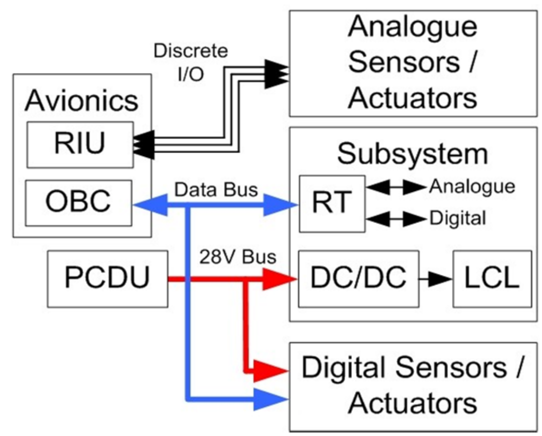
Centralised System Architecture

Traditional Centralised System



- Large Harness Mass (typically 9% of spacecraft mass).
- System Vulnerability to Failures.
- PDCU with separate Nominal and Redundant harnesses to each Spacecraft Module.

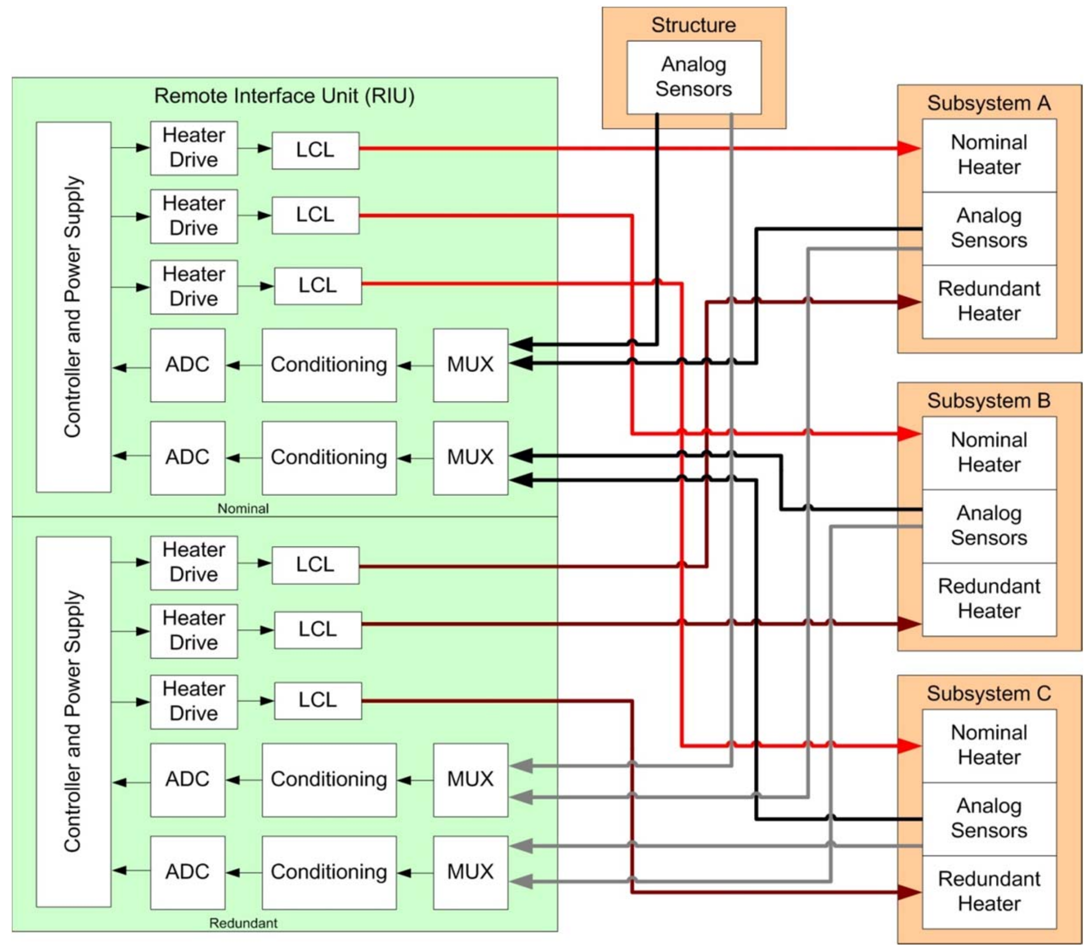




Centralised System Architecture including an RIU

BepiColombo MPO Remote Interface Unit (RIU) built by SEA illustrating a typical centralised system with 360 Thermistor inputs, 56 Analogue inputs, 144 Relay Status and 32 Bi-level digital inputs.
16 Thruster Heater outputs, 8 Thruster Valve outputs and 8 Latch Valve outputs.

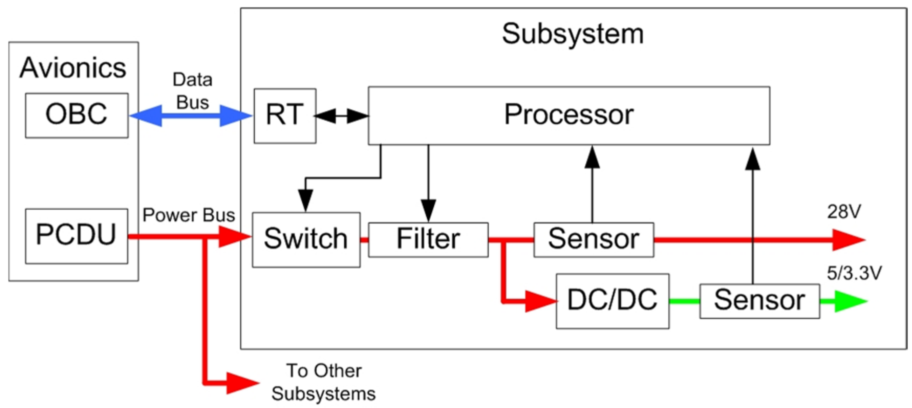
Connectors shown are nominal side only !



Why Use a Decentralised System ?

De-centralised System

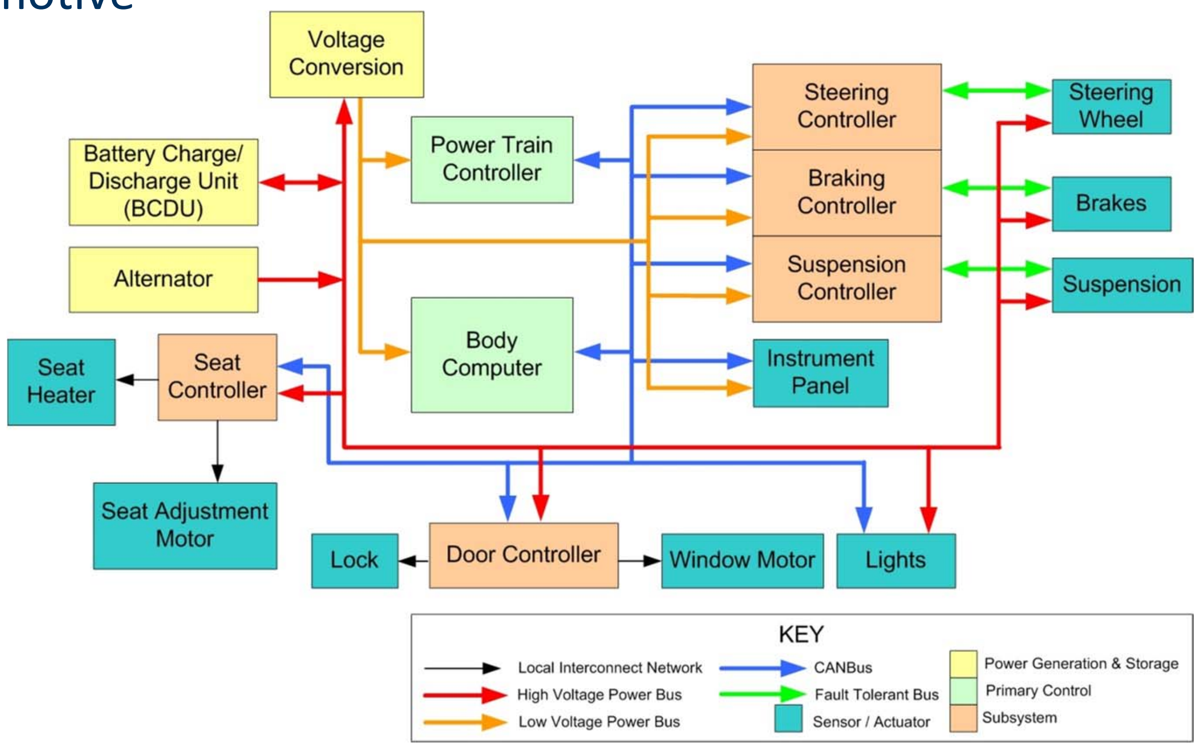
- Reduced Harness Mass.
- Localised Control Capability.
- Increased System Reliability due to less centralised architecture.
- Micronode design using Miniaturisation Technologies to achieve low mass, power & volume standardised modules.



Why Use a Decentralised System ?

De-centralised System

- Synergy with modern de-centralised Automotive Systems.



Micronode Selection

A trade-off was carried out to;

- Maximise Overall Mass Reduction
- Maximise Sensor/ Actuator Integration

Micronode Selection

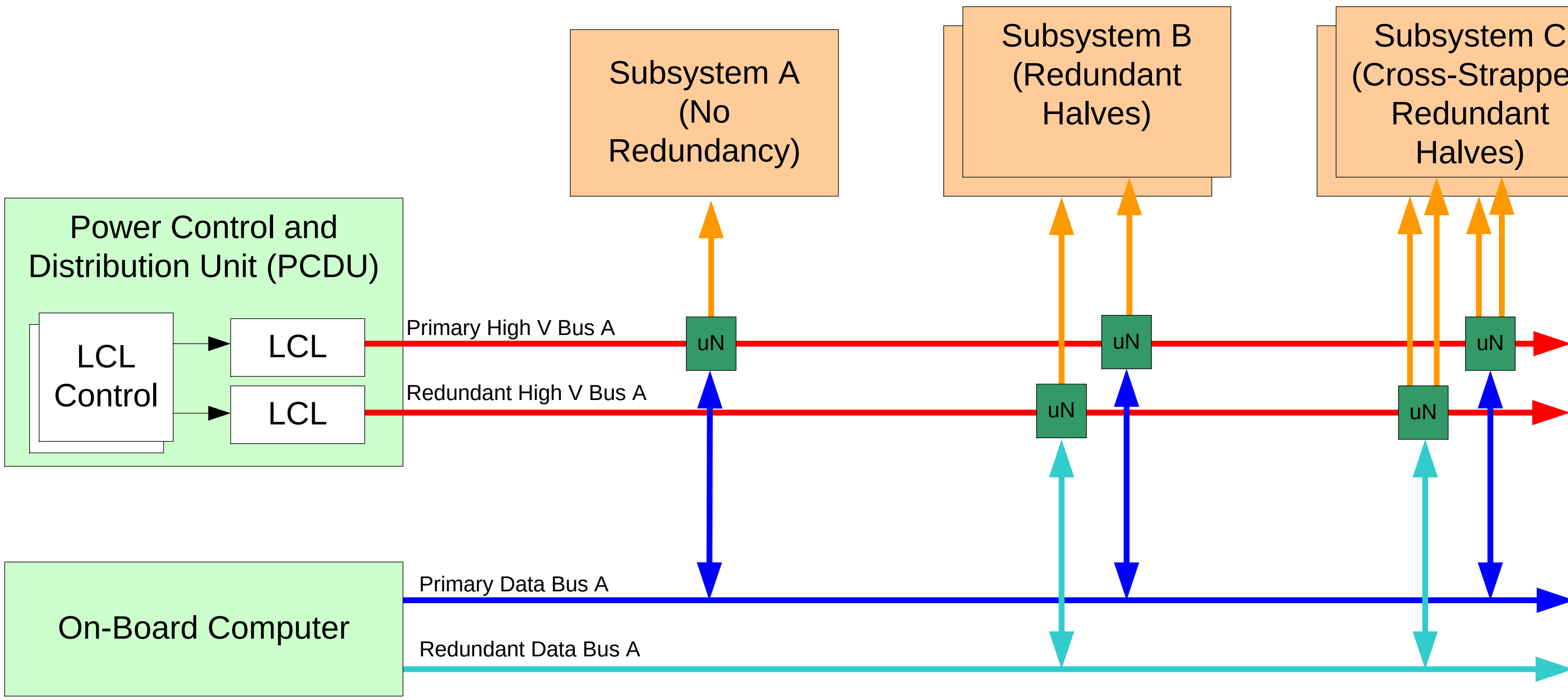
A trade-off was carried out to;

- Maximise Overall Mass Reduction
- Maximise Sensor/ Actuator Integration

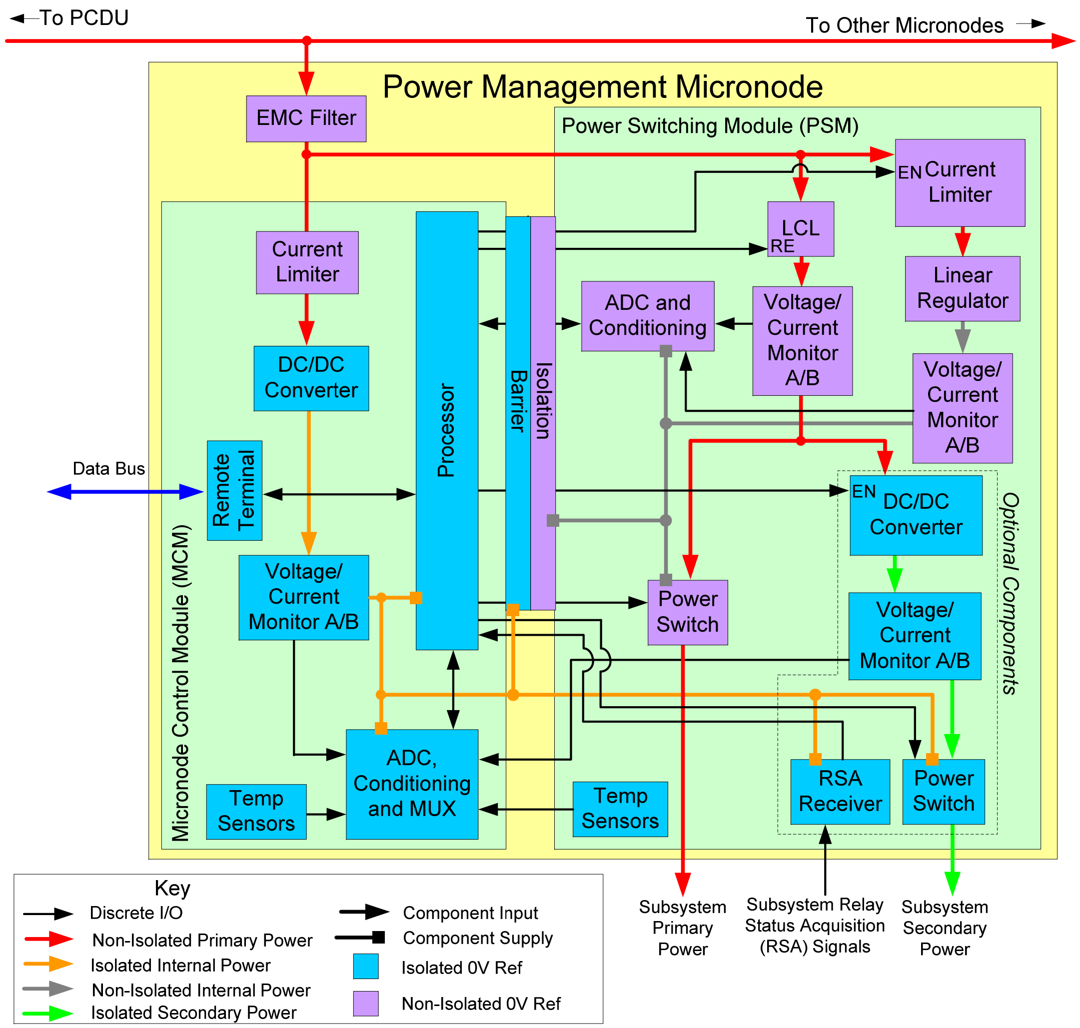
Trade-off Concluded on two types of Micronodes;

- Power Micronode
- Environmental Micronode

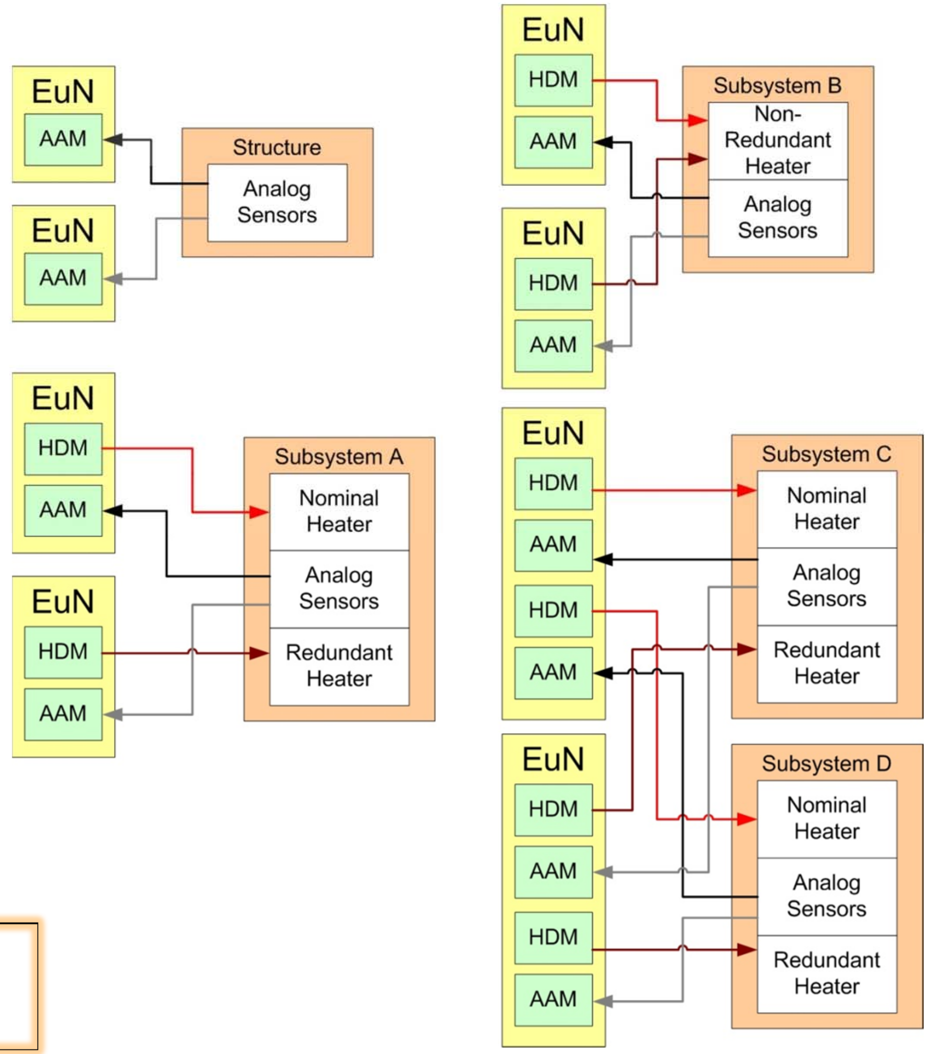
Power Management Micronode Architecture



Preliminary Power Management Micronode

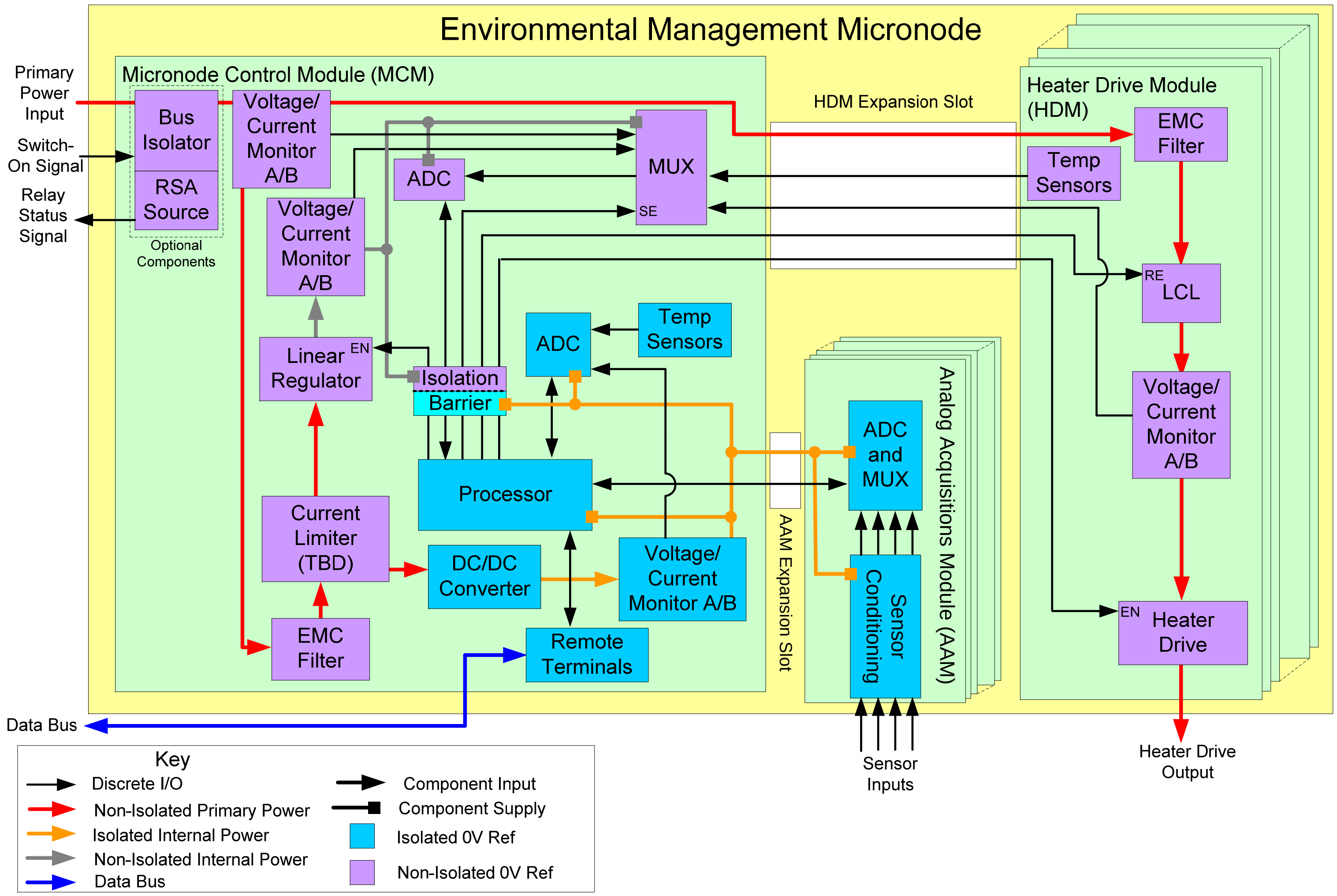


Environment Management Micronode Architecture



AAM – Analogue Acquisition Module
HDM – Heater Drive Module
EuN – Environmental Micronode

Preliminary Environment Management Micronode



Summary of Advantages

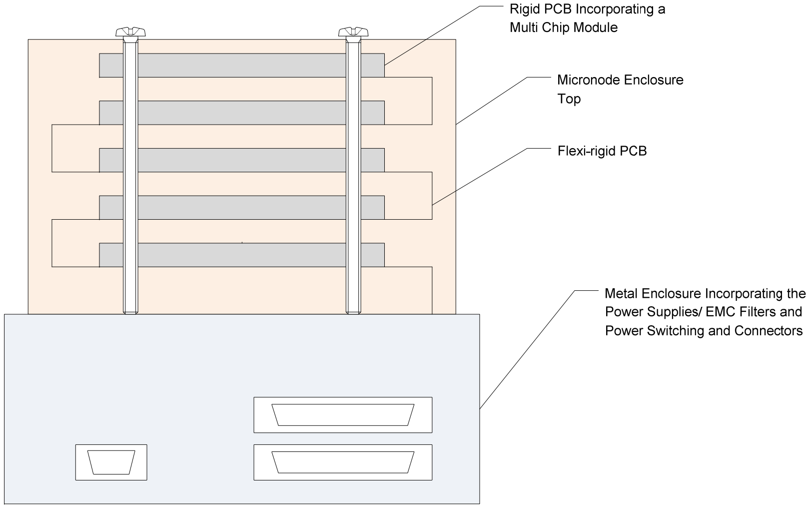
Decentralised Environmental Management Micronode

- Health/ Status Monitoring
- Harness Reduction
- Modular Architecture
- Autonomous Control
- Shorter Sensor Data Paths
- Can implement LCL's for Heater Control etc ….
- Large number of Compatible Environmental Sensors i.e. Accelerometers/ Strain Gauges/ Thermistors/ Humidity/ Corrosion...

Decentralised Power Management Micronode

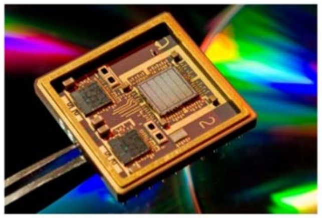
- Health/ Status Monitoring
- Harness Reduction
- Modular Architecture
- Design/ Verification Time Reduction
- Optional Standardised DC/DC Converters
- EMC Filters and Switching

Micronode Packaging Options

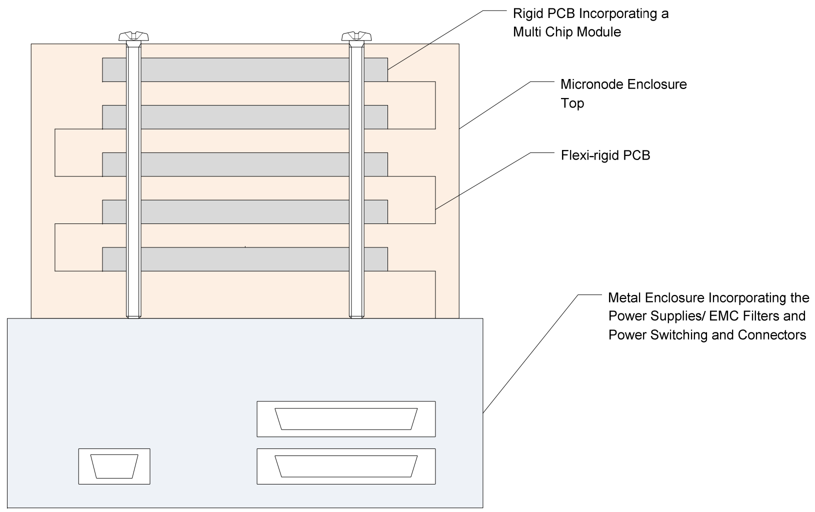


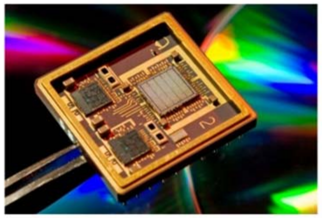
Potential Packaging Technologies;

- OTS but Bespoke Lid (thicker higher shielding)
  Standard (OTS) pin out for low NRE
- Flip Chip with Through Silicon Vias (TSV)
- System in Package (SiP)
- 3D Packaging
- Multi Chip Module (MCM) Packaging
- Wafer Level Packaging (WLP)



Micronode Packaging Options





Potential Packaging Technologies;

- OTS but Bespoke Lid (thicker higher shielding)
  Standard (OTS) pin out for low NRE
- Flip Chip with Through Silicon Vias (TSV)
- System in Package (SiP)
- 3D Packaging
- Multi Chip Module (MCM) Packaging
- Wafer Level Packaging (WLP)

- Internally add MEMS process to Si MCM for
  - Electrical Isolators
  - Temperature, V, I sensing
  - Thermal Breaks
  - Heat sinks
  - Active thermal management

Micronode Potential for MNT Utilisation

Realising a compact generic Micronode will benefit from the use of MEMS devices, MEMS "style" devices and MEMS packaging technologies

- Small Size
- Low Power
- High Reliability

Generally MEMS devices demonstrated covering a vast array of

- Sensing
- Actuation
- Energy (harvesting, storage and distribution) domains

BUT

- Very few go on to commercial success (volume markets) even fewer have the potential to be space qualified

Notable successes with one off science experiments, but generic space qualified MEMS very rare

Micronode Potential for MNT Utilisation

Increasing Difficulty in Qualification

Micronodes are intended to be generic systems used on many satellites. This should alleviate some barriers to space qualification of MEMS in these applications

Barriers to Qualification;

- **Temp Range**
  - ➢ Not a big problem with many MEMS. Can be a problem with low cost packaging

Micronode Potential for MNT Utilisation

Increasing Difficulty in Qualification

Micronodes are intended to be generic systems used on many satellites. This should alleviate some barriers to space qualification of MEMS in these applications

Barriers to Qualification;

- **Temp Range**
  - Not a big problem with many MEMS. Can be a problem with low cost packaging
- **Shock/ Vibration**
  - Can be a problem for sensitive MEMS devices (pressure, inertial, switch etc). But many examples where this has been overcome – especially spin in from Aerospace/Defence

Micronode Potential for MNT Utilisation

Micronodes are intended to be generic systems used on many satellites. This should alleviate some barriers to space qualification of MEMS in these applications

Increasing Difficulty in Qualification

Barriers to Qualification;

- **Temp Range**
  - ➢ Not a big problem with many MEMS. Can be a problem with low cost packaging
- **Shock/ Vibration**
  - ➢ Can be a problem for sensitive MEMS devices (pressure, inertial, switch etc). But many examples where this has been overcome – especially spin in from Aerospace/Defence
- **Packaging**
  - ➢ Robustness hermeticity/outgassing Is a problem with the low cost commercial solutions

Micronode Potential for MNT Utilisation

Increasing Difficulty in Qualification

Micronodes are intended to be generic systems used on many satellites. This should alleviate some barriers to space qualification of MEMS in these applications

Barriers to Qualification;

- **Temp Range**
  - ➢ Not a big problem with many MEMS. Can be a problem with low cost packaging
- **Shock/ Vibration**
  - ➢ Can be a problem for sensitive MEMS devices (pressure, inertial, switch etc). But many examples where this has been overcome – especially spin in from Aerospace/Defence
- **Packaging**
  - ➢ Robustness hermeticity/outgassing Is a problem with the low cost commercial solutions
- **Radiation**
  - ➢ Almost universally the biggest barrier

Micronode Potential for MNT Utilisation

Which MEMS Devices could be used in Micronodes?

Increased Cost

- COTS MEMS
  Very few. Most commonly non-rad hard electronics is the main issue.

- Adapted MEMS
  Most easily adapted are bulk Si fabricated devices (surface micro-machined often have integrated "terrestrial" CMOS)

- Bespoke MEMS
  Beyond one off science experiments there may be examples with sufficient volume or benefit at System level to justify development/qualification

Increased Ease of Qualification

Examples for MNT Utilisation

Specific Example #1: Electrical Isolation Barrier

Main issue long term stability of Opto Isolators – RADIATION TOLERANCE & CTR Degradation

Potential Solution : replace with Capacitive Isolation Barrier

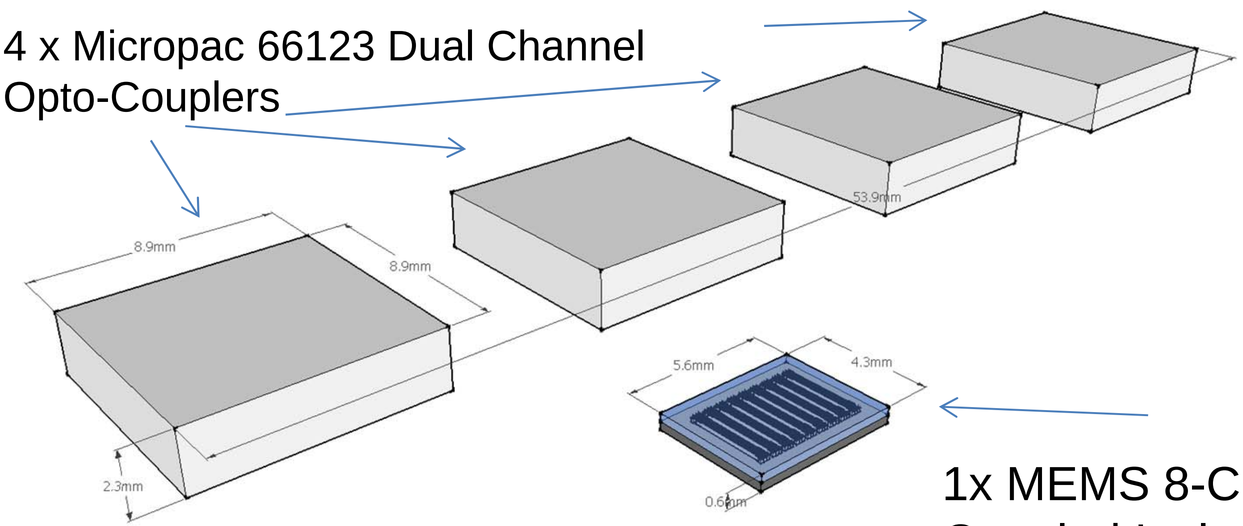
Examples for MNT Utilisation

Specific Example #1: Electrical Isolation Barrier

Main issue long term stability of Opto Isolators – RADIATION TOLERANCE & CTR Degradation

Potential Solution : replace with Capacitive Isolation Barrier

4 x Micropac 66123 Dual Channel Opto-Couplers



Advantages:
- Radiation Hard
- Much Smaller footprint
- JFET output
- Wafer level Packaged

1x MEMS 8-Channel Capacitively Coupled Isolation Barrier
Rad hard JFET output

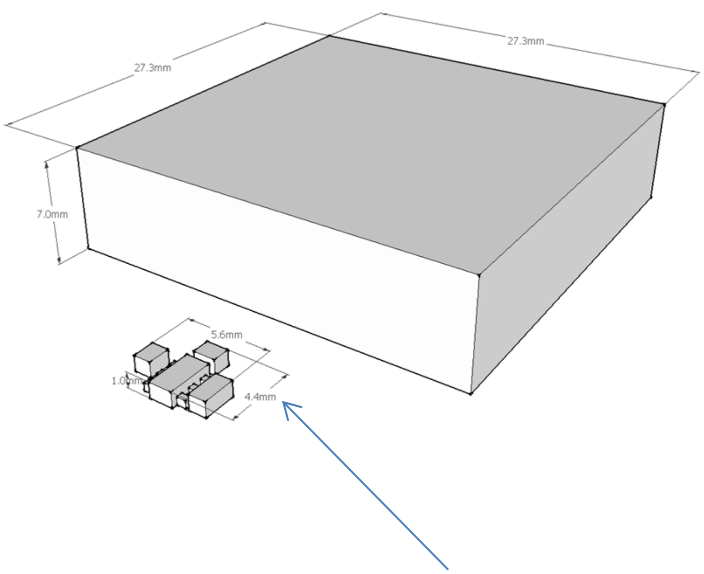
Examples for MNT Utilisation

Specific Example #2: DC-DC Converter

Main issue Space Qualified components – ITAR Free

Potential Solution : replace with Bespoke Rad Hard ASIC + MEMS Capacitors as SIP Chip

e.g. DC-DC Converters - SMSA 5W Series



Charge Pump (ASIC + 3 capacitors)

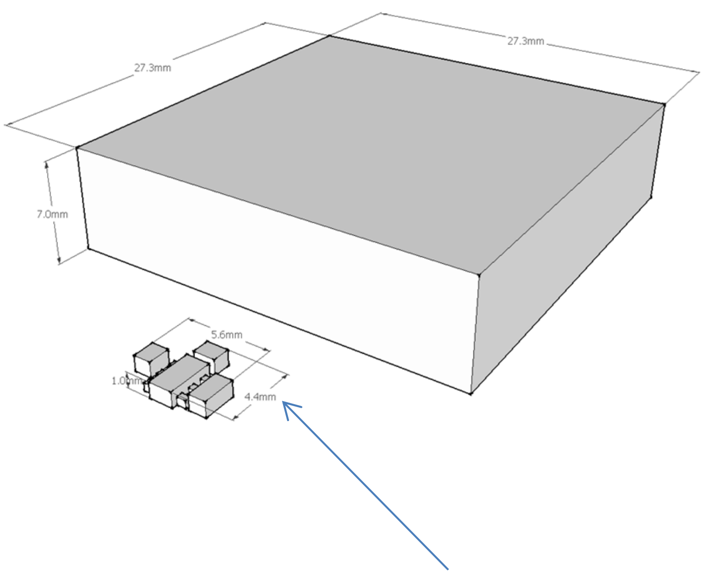
Examples for MNT Utilisation

Specific Example #2: DC-DC Converter

Main issue Space Qualified components – ITAR Free

Potential Solution : replace with Bespoke Rad Hard ASIC + MEMS Capacitors as SIP Chip

e.g. DC-DC Converters - SMSA 5W Series



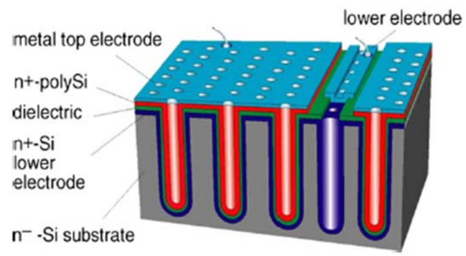
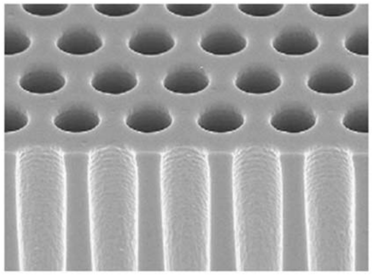


Fig. 2. Scheme of a 3D capacitor in PiCS technology.

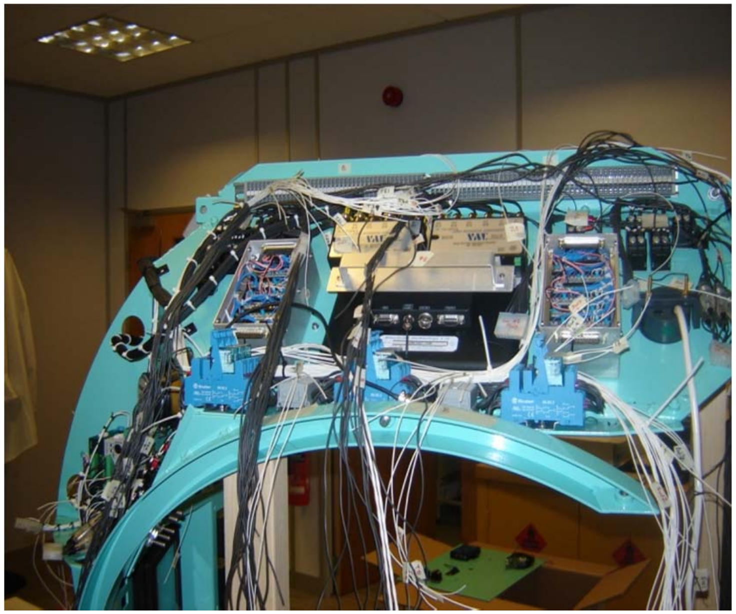


Advantages

- Radiation Hard
- ITAR Free
- Much Reduced Footprint
- Wafer level Packaged

Charge Pump (ASIC + 3 capacitors)

Harness Reduction during AIT



Micronode Modules could vastly simplify AIT environmental monitoring during Temp/ Vac for example when commercial options would not be a viable solution.

Decentralised Micronodes Conclusion

Summary of Advantages;

- Distributed System Health/ Status Monitoring
- Harness Mass Reduction
- Modular Architecture
- Allows for Autonomous Control
- Shorter Sensor Data Paths
- Compatible with a Large number of Environmental Sensors both MEMS and traditional.
- Suitable for Miniaturisation/ ASIC Technologies (Utilising the DARE Library)

THANKYOU !

QUESTIONS ??