Special Presentation Session 3.4

Space Power Architecture
&
Power Electronics Research at SNL

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National Nuclear Security Administration

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Part 1

Distributed Space Power Architecture Based on Point-of-Load Power Conversion

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- Rex Kay (SNL - Sensors & Analog Electronics dept)
- Scott Dalton (SNL - Radiation Physics, Simulation & Tech dept)
- Daniel Levy (SNL - RRW & Advanced Systems dept)
- Daryl Butcher (Tech Applications Group - Rad-hard IC designer)

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Spacecraft Electronics Technology

- Spacecraft electronics technology lags terrestrial technology by about 10 years

- Space-qualified digital components today have performance specifications similar to commercial parts of the mid-1990's

- Spacecraft digital component power requirement trends are very similar to those of terrestrial systems

- Higher performance digital components are rapidly being qualified for satellite applications.

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Future of Space Digital Systems

Goals

- Increased computing performance
- Lower size/performance
- Lower power/performance

- Increased clock frequency
- Higher level of integration
- Smaller feature sizes

- Decreased voltages
- Increased currents
- Increased current slew-rates

Resulting System

- Low voltage, high current system
- Rapidly shrinking voltage tolerance
- Cannot meet regulation requirements
- Increased distribution losses
- Larger distribution cables & connectors
- Increased effects of crosstalk

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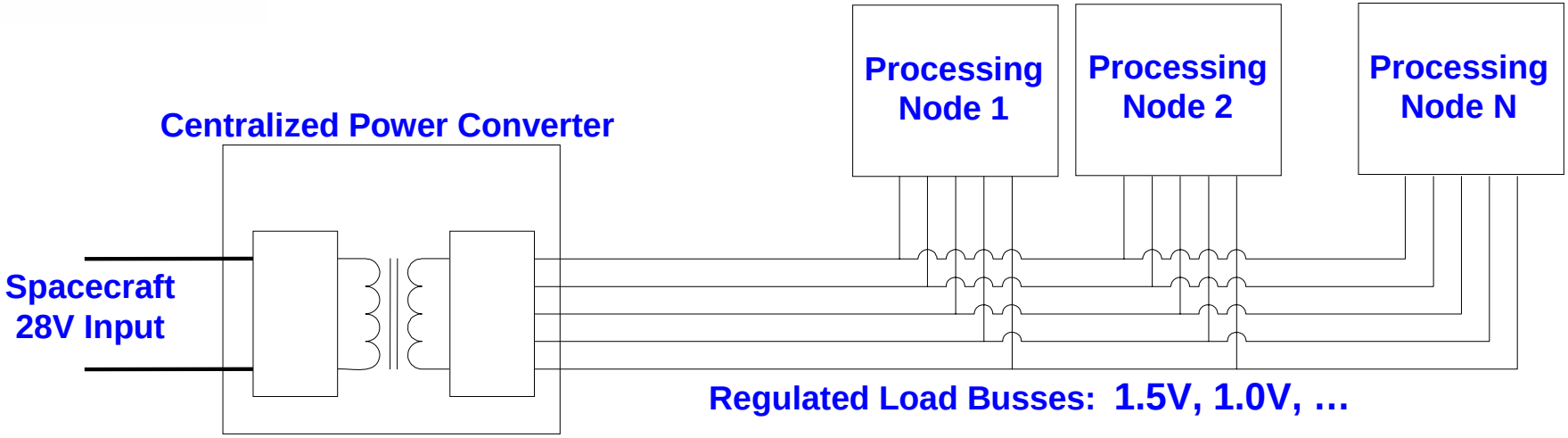
Traditional Power Architecture



- Single centralized power converter for entire electronics box
- Each processing node can consume 15W or more of power
- Central bus currents on the order of 10's of amps
- Large distribution power losses, low system efficiency
- Large, weighty cables and connectors
- Difficulty in meeting regulation requirements
- Significant node-to-node crosstalk

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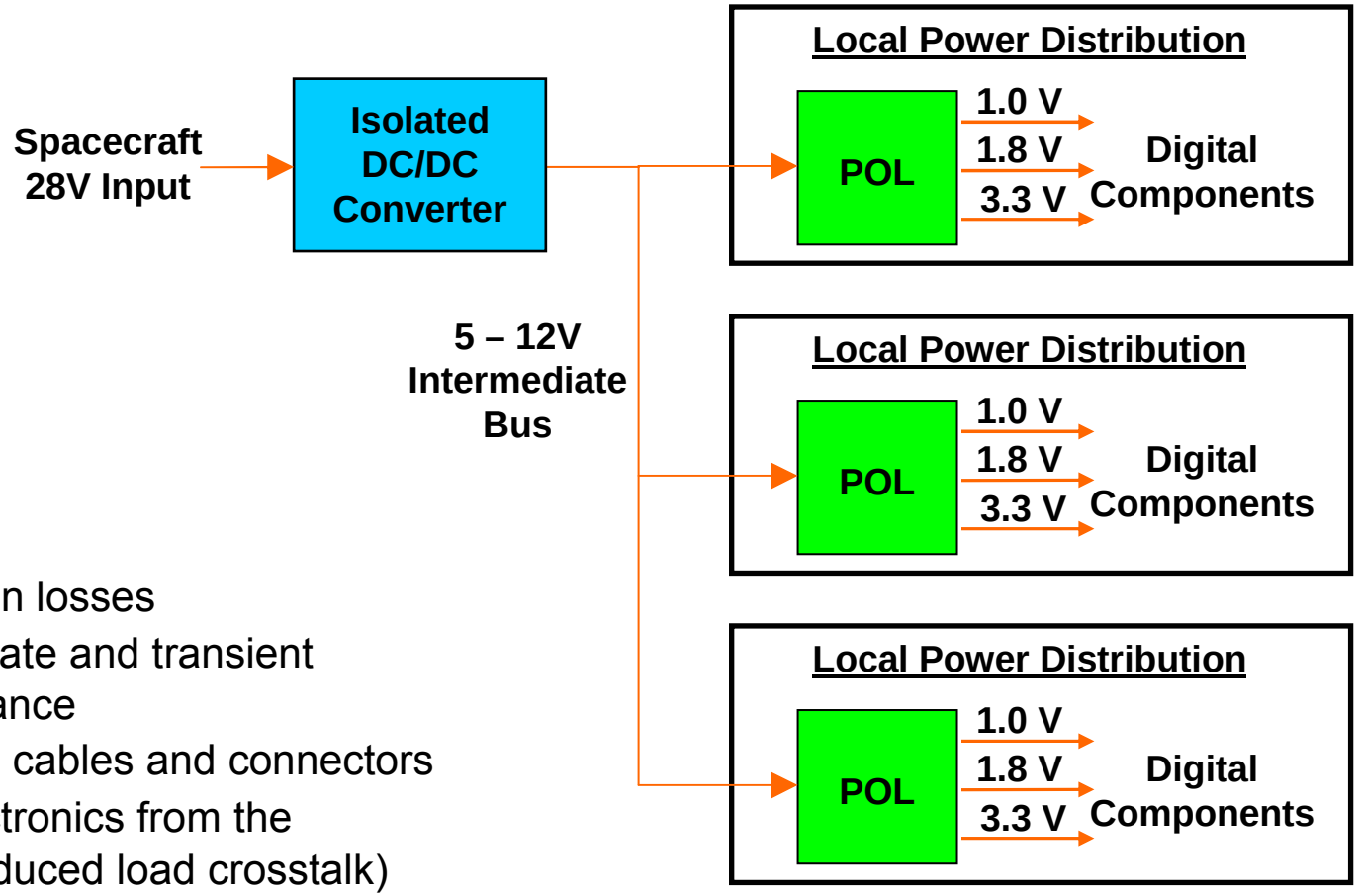
Distributed Power Architecture



Advantages of POL

- Reduces distribution losses
- Improves steady-state and transient regulation performance
- Smaller distribution cables and connectors
- Decouples the electronics from the distribution bus (reduced load crosstalk)
- Inherent modularity
- Isolated converter and POLs separately optimized for their respective functions

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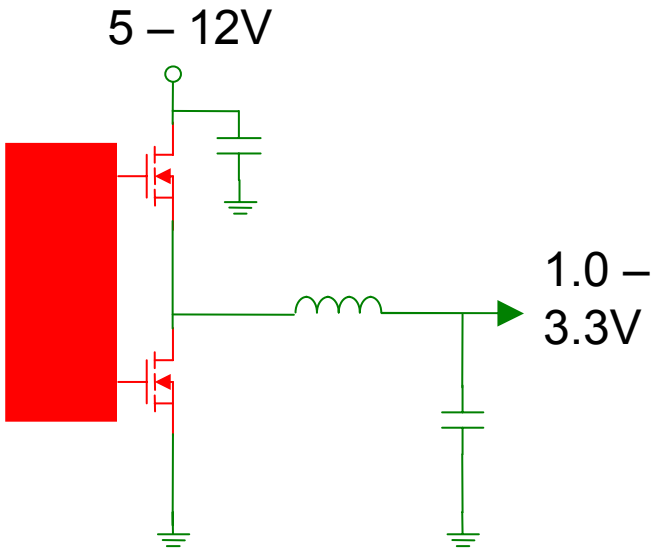
Radiation Tolerant POL Converter

Objective - Develop and evaluate the performance of Point-of-Load (POL) power converters for space processor applications



Synchronous Buck

Primary Requirements

- Total dose tolerant to > 100KRad
- Latch-up Immune
- No SEE to LET > 80 MeV-cm^2/mg
- Triple-output
- Switching frequency > 300 kHz each
- Target efficiency > 90%

We need suitable radiation-hardened power FETs and controller ICs!

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Rad-hard POL Research at SNL

- Design and evaluation of a 3-output radiation-hardened synchronous buck controller
- Evaluation of the radiation hardness of commercial power MOSFETs for use in POL power conversion applications
- Design of the local power regulation system to meet transient performance specifications
  - POL Converter
  - Decoupling capacitor network
  - Component placement
  - PCB design considerations
- How to choose the intermediate bus voltage for spacecraft distributed power systems
- System level stability analysis of the spacecraft distributed power architecture

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Summary and Conclusions

- The future of space data processing will require modern, high performance digital components to achieve mission success
- Space-qualified distributed power systems are necessary to meet the power requirements of modern digital systems
- Radiation-hardened point-of-load power converters must be developed
- We need suitable radiation-hardened power FETs and controller ICs
- SNL is investigating the necessary technologies to bring a space-qualified, high performance distributed power system to life

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Part 2

Power Electronics Research at Sandia National Labs

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Acknowledgements

- Power Sources Component Development:

  Stan Atcitty **T: 505-284-2701, e: satcitt@sandia.gov**

  (Funded by DOE Energy Storage Program, DOE manager: Dr. Imre Gyuk)

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Electric Utility Related Power Electronics Research

- High Voltage, High Current, and High Power
- Off-Grid and On-Grid
- 5kW $\rightarrow$ 10's MW
- Semiconductor Switches
- Silicon Carbide Materials
  - High V_{BD}, High I, and High T
  - Excellent for space applications
    - rad hard, which eliminates need for rad hard circuitry

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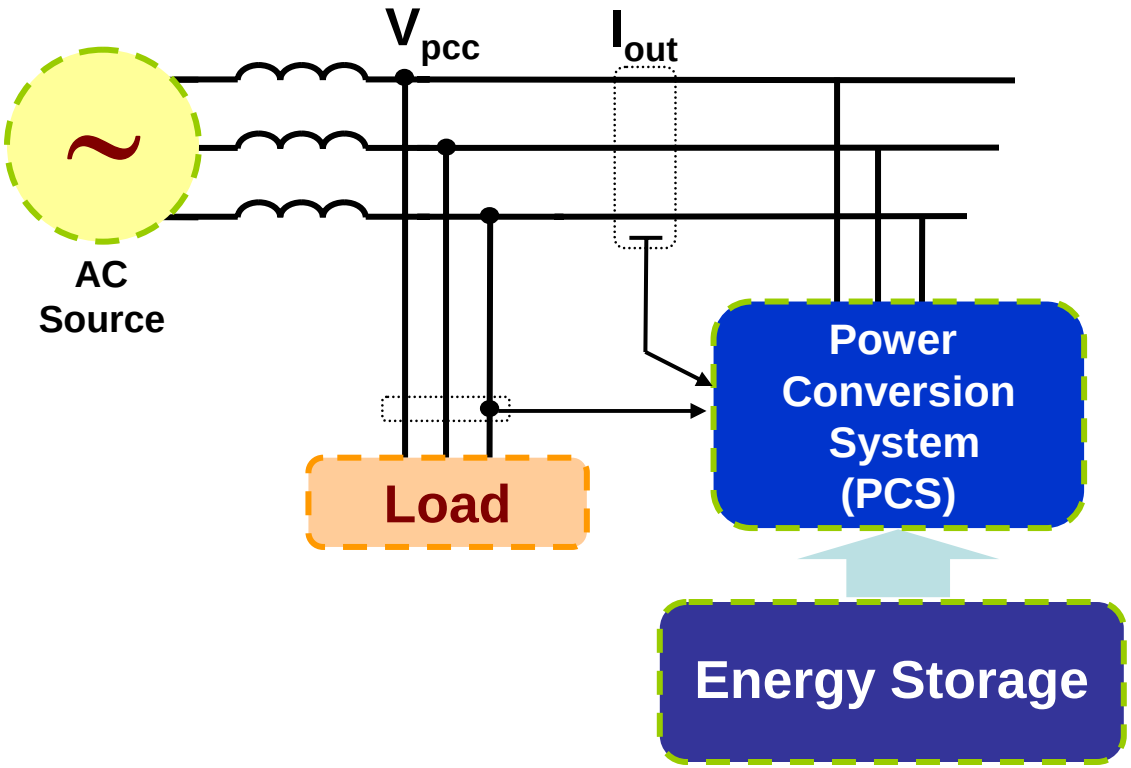
Why is DOE/Sandia interested in power electronics?



- **PCS can be 20-40% of overall energy storage system cost.**
- **Need for significantly reduced installed cost/kVA and footprint, improved control capability and increased reliability**

Power Conversion System (PCS) is a key element of the Energy Storage System

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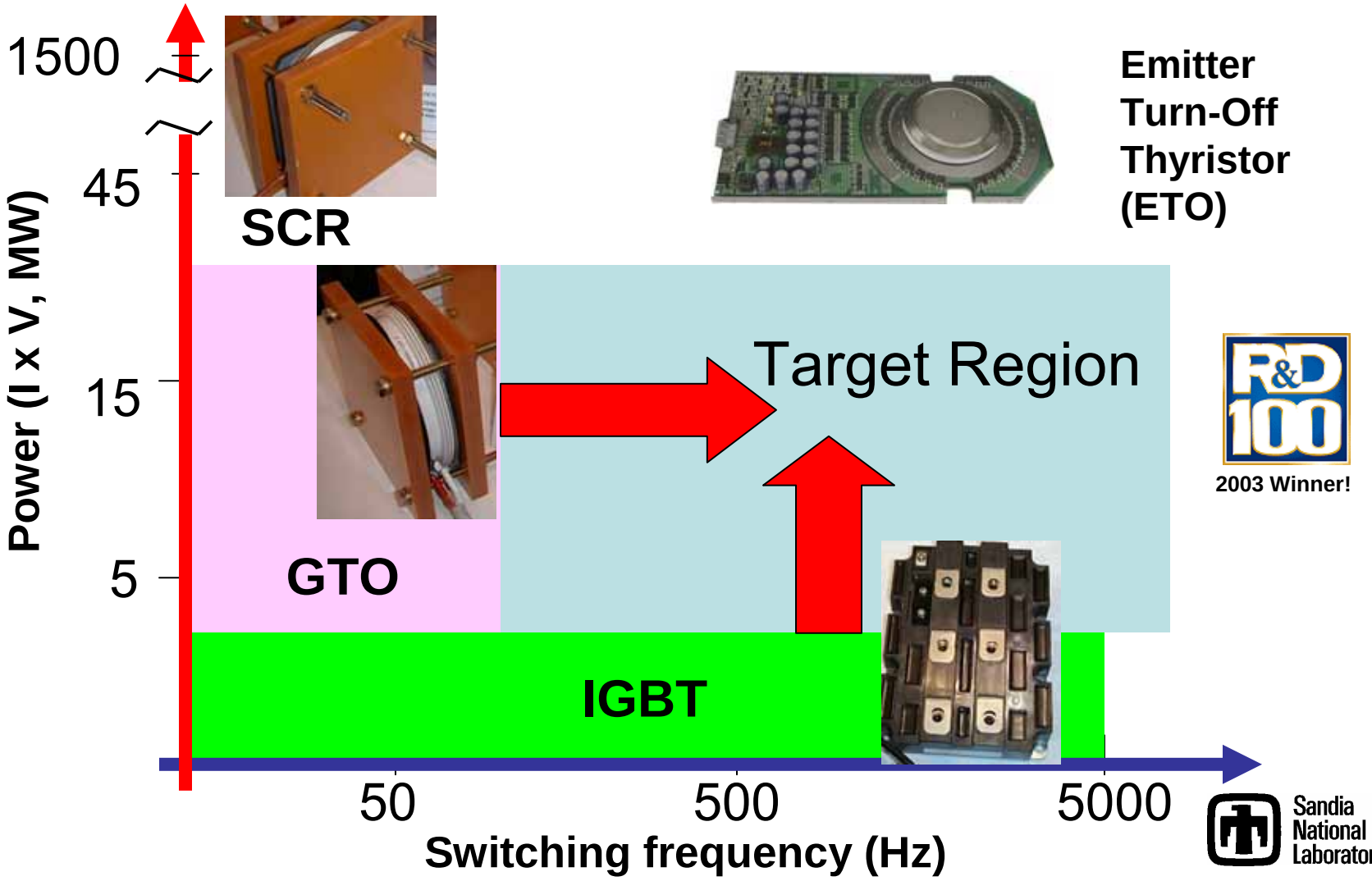
North Carolina State University ETO Project



PCS Projects

Airak, Inc. Converter Project

2003 Winner!

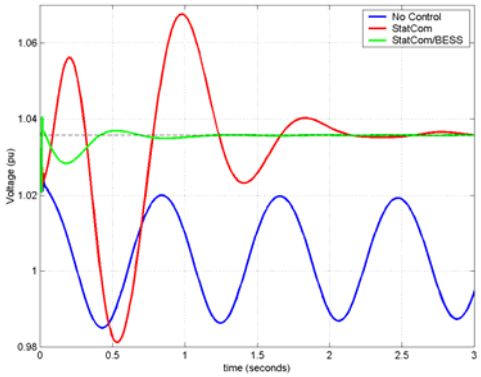
Develop 3 phase, IGBT based, MW inverter with optical current, voltage and temperature sensing and command/control interfacing.

Why Optical Sensors

- Intrinsic Safety
- Intrinsic Isolation
- Increased Reliability
- Higher Response
- Greater Dynamic Range
- Small Size and Weight

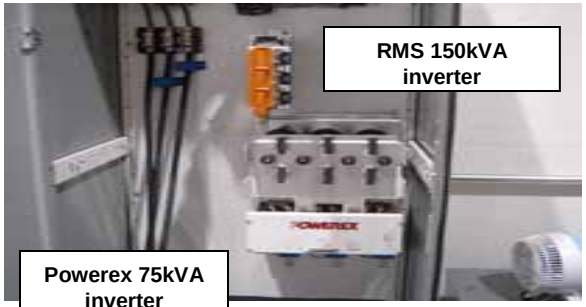
UMR FACTS & Energy Storage Project

StatCom Front Panel



Performance Comparison
StatCom vs. StatCom/BES

Rinehart Motion System Converter Project



System level solution using fluid-cooling techniques in a power hybrid assembly that includes all the components of the PCS

- Power Semiconductors
- Gate drive and Controller
- DC link capacitors
- Current and Voltage sensors

Result: Reduced size, lower cost

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Wide Band Gap Based Power Converters

- Design and development of an advanced power converter using WBG devices
- Demonstrate increase performance, cost reduction, better thermal management design and decrease footprint and compare to silicon based systems
  - STTR: Aegis Technology/University of Tennessee
  - SBIR: Arkansas Power Electronics
  - SBIR: Peregrine Power, LLC
  - SBIR: SatCon Technology Corporation

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Battery Projects

- Advanced Batteries for Energy Storage Applications
  - ZnBR
  - Li Ion
  - NiMH

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