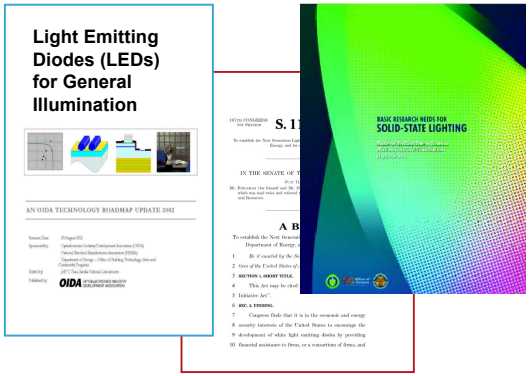
Ultra Wide-Bandgap Grand Challenge at Sandia

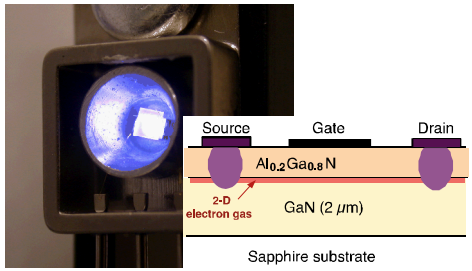
Sandia National Laboratories

SAND2015-10539PE

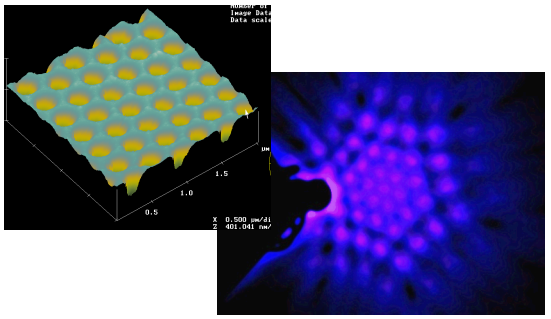
1999-2006: Comprehensive US Technology Roadmaps



2003-2007: high power amplifiers, UV emitters

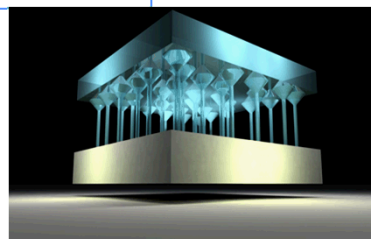


2000-2004: SSL Grand Challenge LDRD



2009-2014: DOE EFRC for SSL Science

SSLS EFRC
SOLID-STATE LIGHTING SCIENCE
ENERGY FRONTIER RESEARCH CENTER

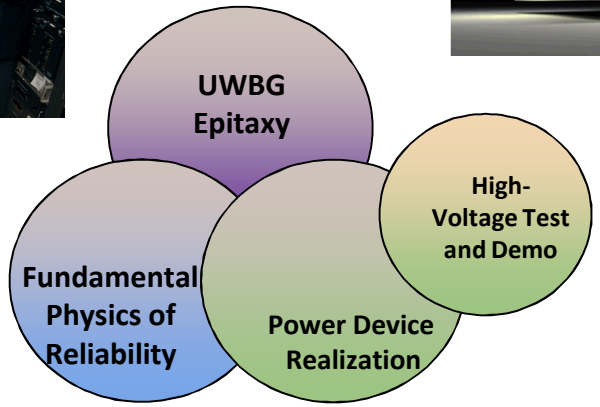


2006-2008: DOE /EERE National Center for SSL

2003-2012: DOE-Funded Collaborations with industry

R&D 100

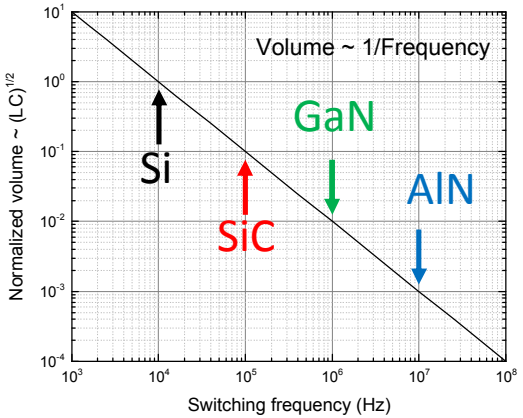
UWBG
ULTRAWIDE BANDGAP
POWER ELECTRONICS

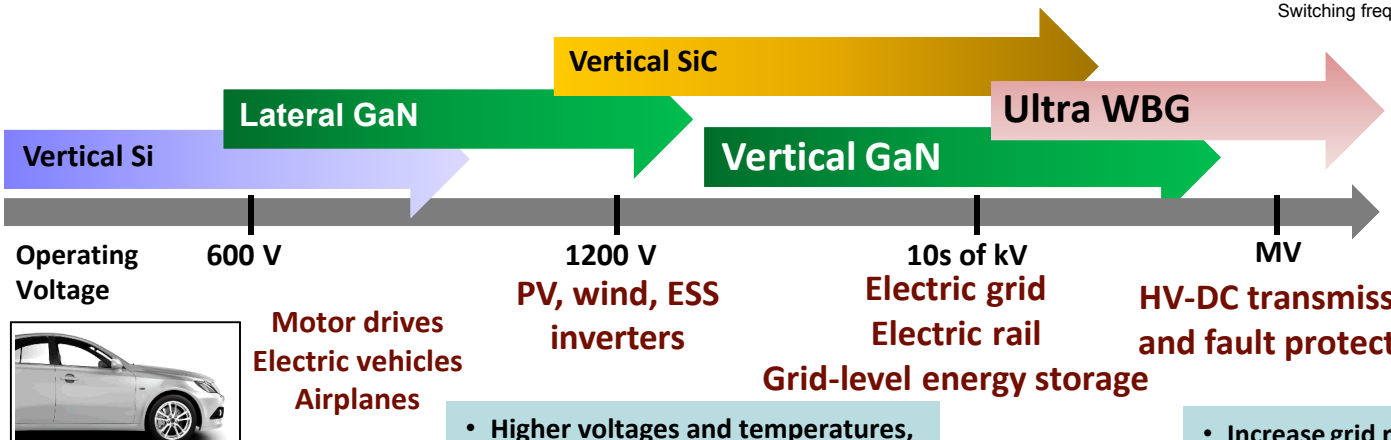


- 60+ years as DOE/NNSA mission lead in electronics
- 30+ years of compound semiconductor research
- 20+ years of wide band gap materials & device R&D

Wide Bandgap SWaP

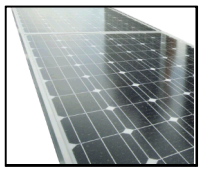
- Current power electronics are limited by the properties of Silicon devices
- New system capabilities are enabled by:
  - Higher switching frequency (enables better SWaP)
  - Lower power loss
  - Higher temperature operation
  - Greater breakdown voltage





- Higher voltages and temperatures, lower resistive losses
- High Reliability

- Reduce or eliminate passive components (capacitors, inductors)
- Spectral purity extends motor lifetime
- Operate at higher temperatures without liquid cooling

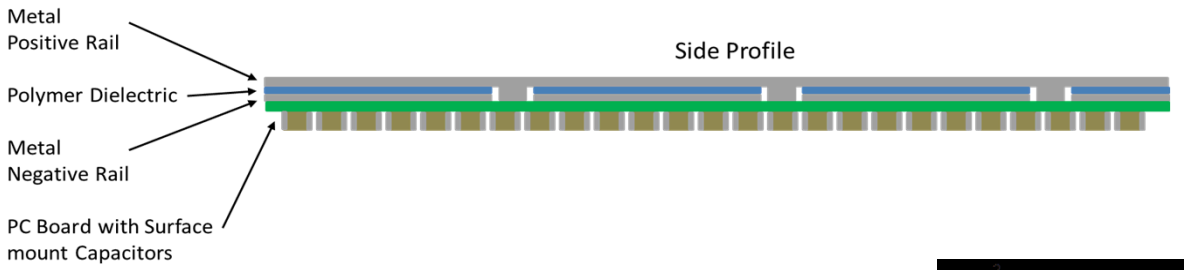


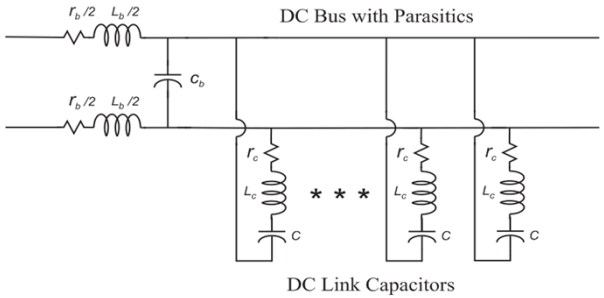
- AC subsystems to 13.8 kV

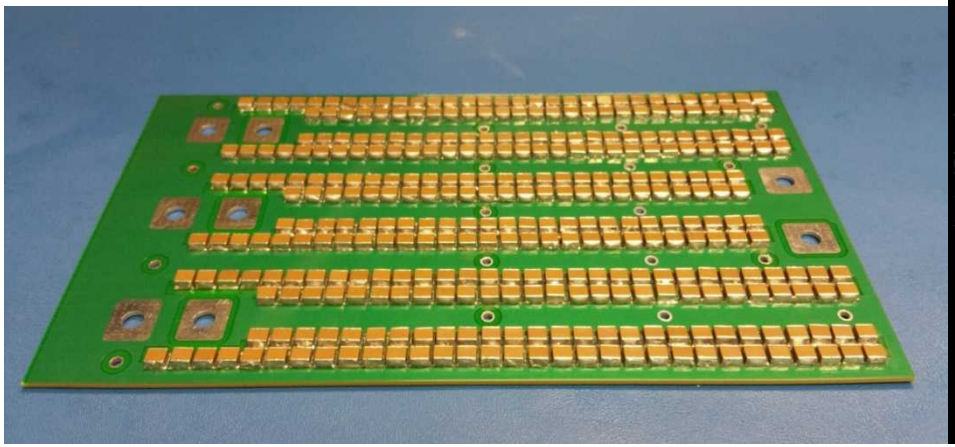
- Increase grid resiliency
  - Synthetic Inertia and ancillary functions
- Less resistive energy loss
- Replace expensive IGBT / Thyristor stacks
  - Direct Connection to MV network
  - FACTs and power smoothing

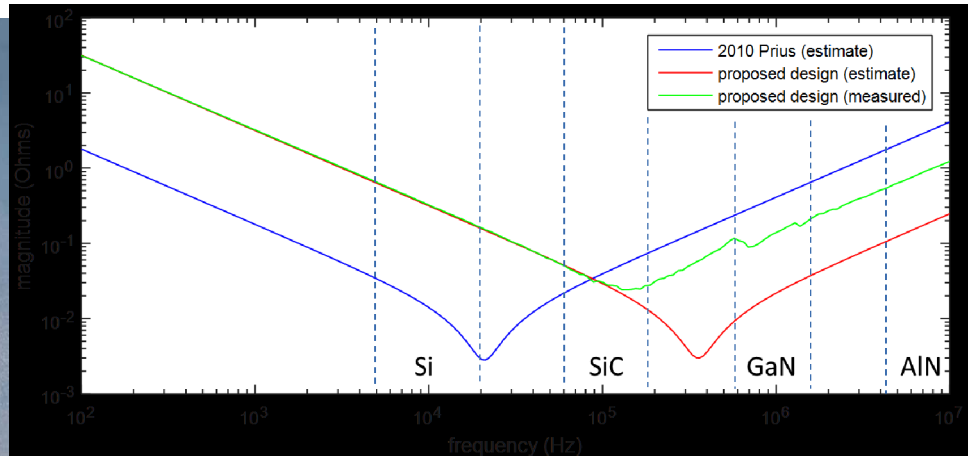
Wide Bandgap SWaP

- **High-Power inverter applications (i.e. PV inverters, electric vehicles, …) have a DC link with substantial smoothing capacitance**
  - **Conventional film capacitors → large ESL, low resonances (~10kHz), reliability issue**
- **PCB approach to replace bulky capacitors with SMB ceramic capacitors**
  - **low-ESL→ high resonance suitable for WBG devices**
  - **low-ESR → low loss**
  - **easy manufacturability → low cost and high reliability**



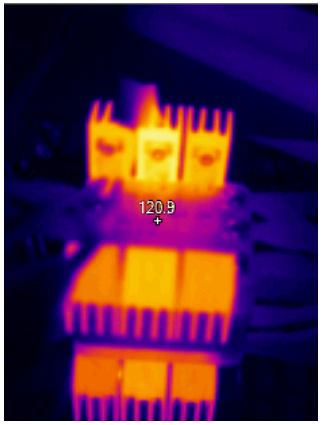


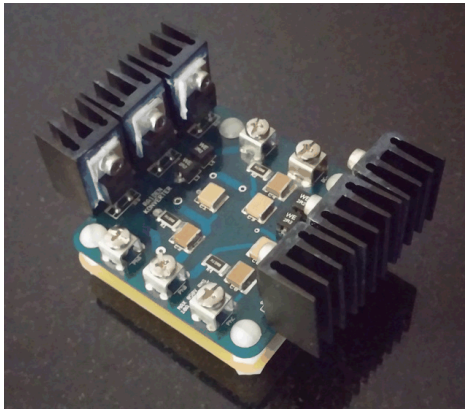




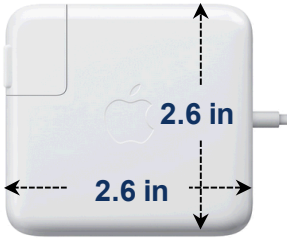
Wide Bandgap SWaP

- A 6-pulse rectifier built and tested
  - 3-Phase AC in, DC out
  - Passive → no controller
- 6 Avogy GaN diodes and EMI filter on a PCB
- Devices rated for 1200 V / 5 A
  - Practical for 800V_{AC} RMS / 900V_{DC}
- Converter tested using 10 kVA, 400 Hz PM generator
- Converter tested to:
  - 43 W/in^3 at 300 V→ 150 W/in^3 (theoretical) at full voltage
  - 4.25 kW/kg
  - 130^{o}C junction temperature (est)





6 W/in^3



MacBook Air (45W)

20.6 W/in^3

Current SOA with GaN WBG
Avogy Zolt (70W)

Sandia rectifier
550 W, 12.8 in^3
43 W/in^3 (demonstrated)