The University of Texas at Austin
Center for Electromechanics

2016 ADVISORY PANEL
POWER ELECTRONICS

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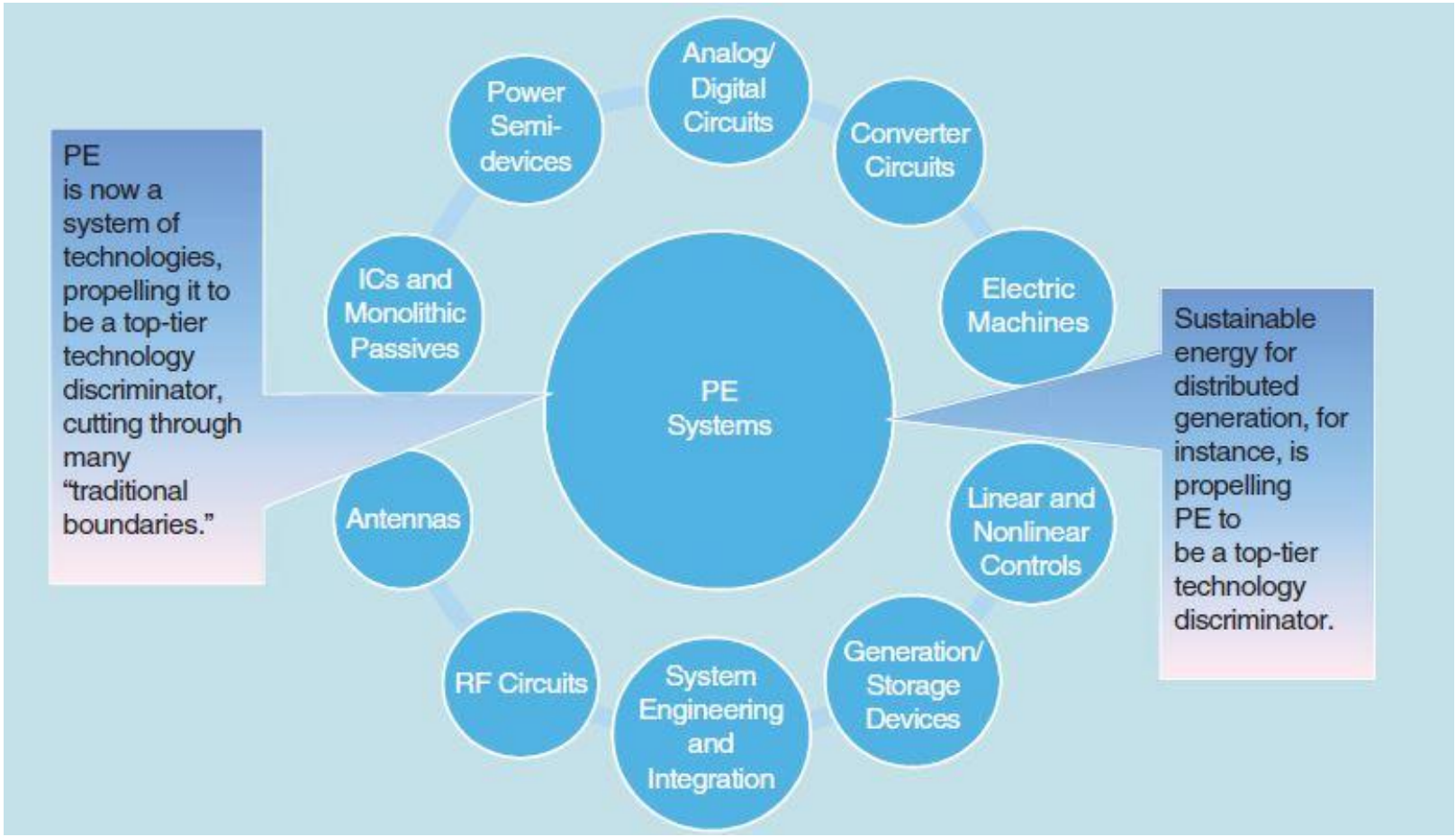
Center for Electromechanics
The University of Texas at Austin
5/10/2016

The evolving role of PE



Don Tan, IEEE Power Electronics Magazine, June 2015

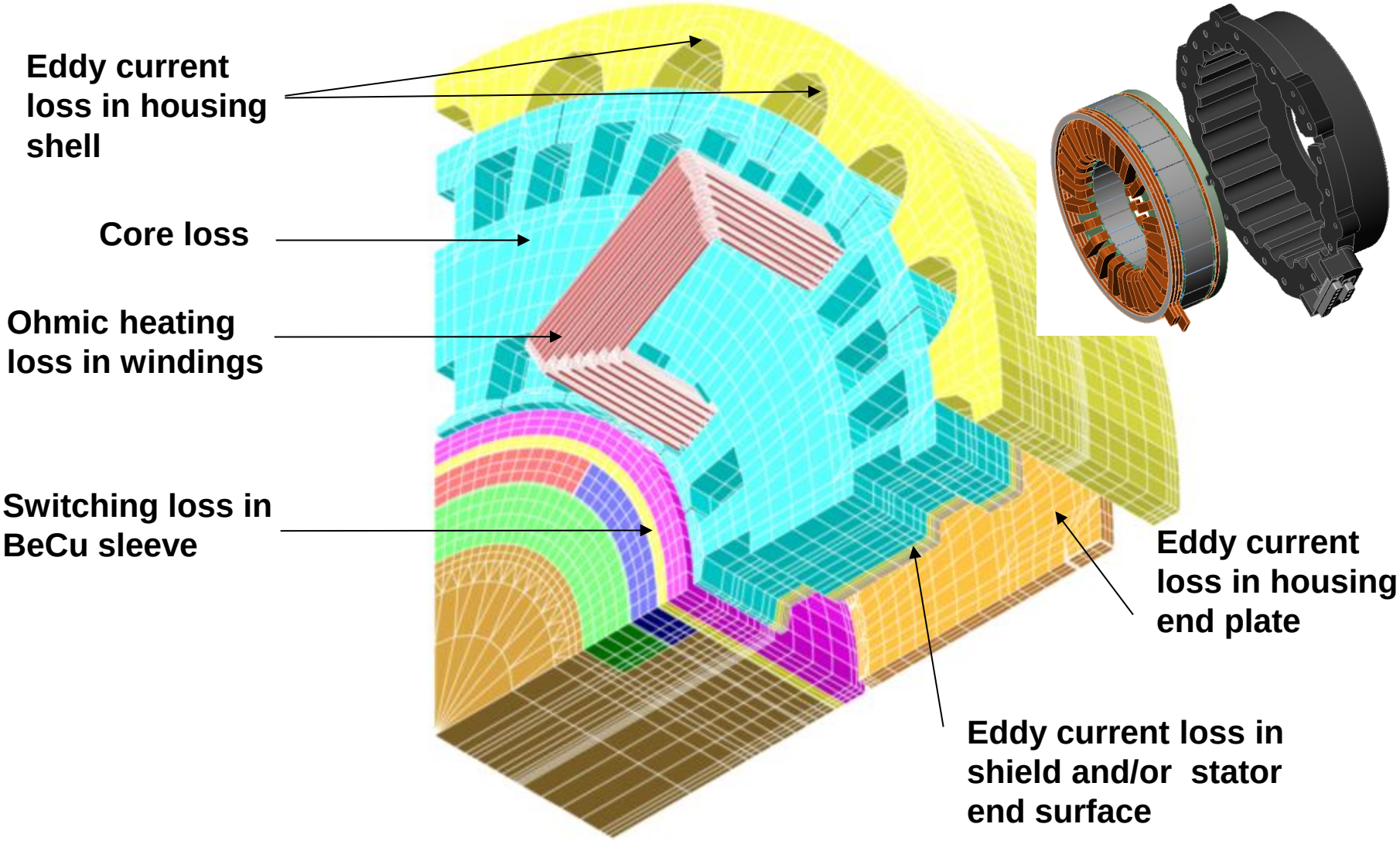
Challenges in Power Electronics

- Increased power densities
- Higher efficiencies (> 98 %)
- High reliability in extreme environments
- Lower electromagnetic emissions
- Modular turn-key systems
- High levels of integration
  - Controls combined with power stage (traditional case)
  - Controls and power stage combined with load (intelligent motors, appliances, etc.)
- Lower lifetime costs

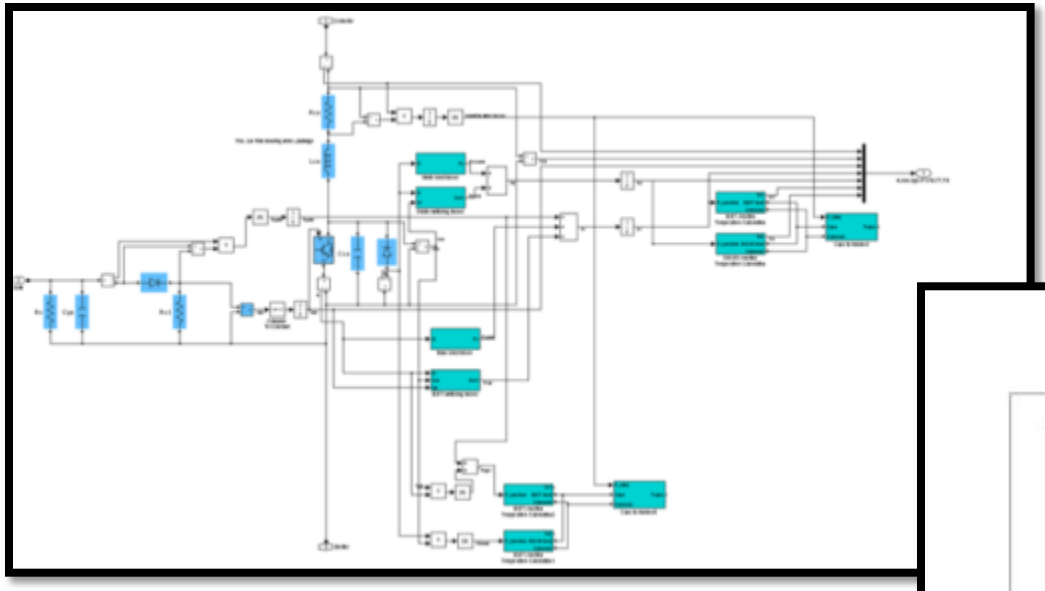
Power Density Challenge

- System size reduction makes cooling more difficult
- Increased power outputs result in increased losses
- Temperature rise limited by power device, magnetic, capacitor, internal temperatures
- Strong interactions between packaging, thermal performance, and reliability means all aspects of power electronics design must be addressed concurrently
- An integrated approach is essential in the design and manufacture of future power electronic systems

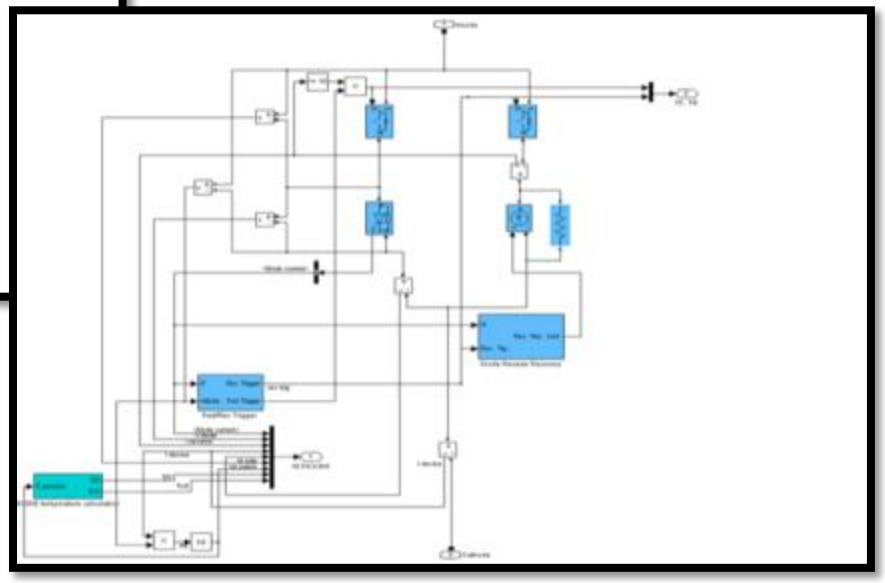
Complete Motor Design and Prototype



Detailed Electrical Simulations

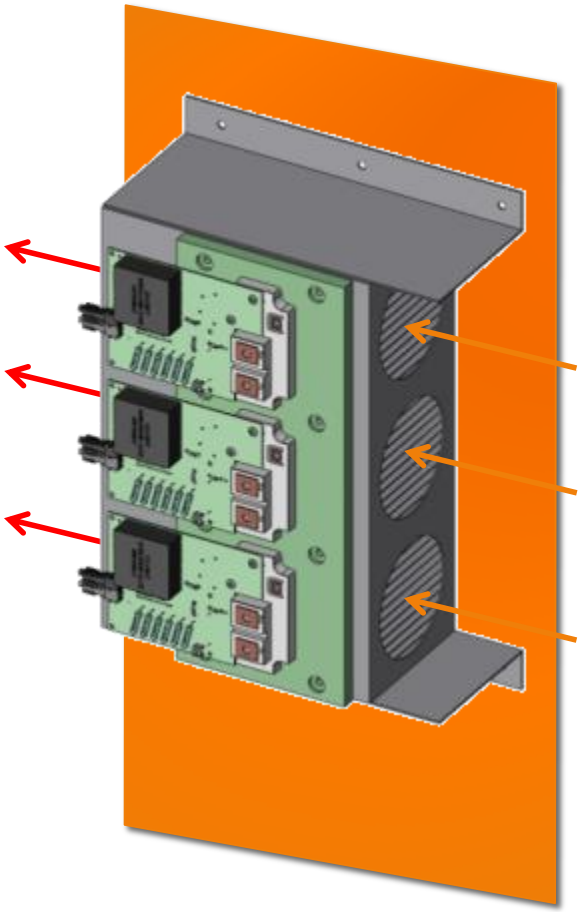


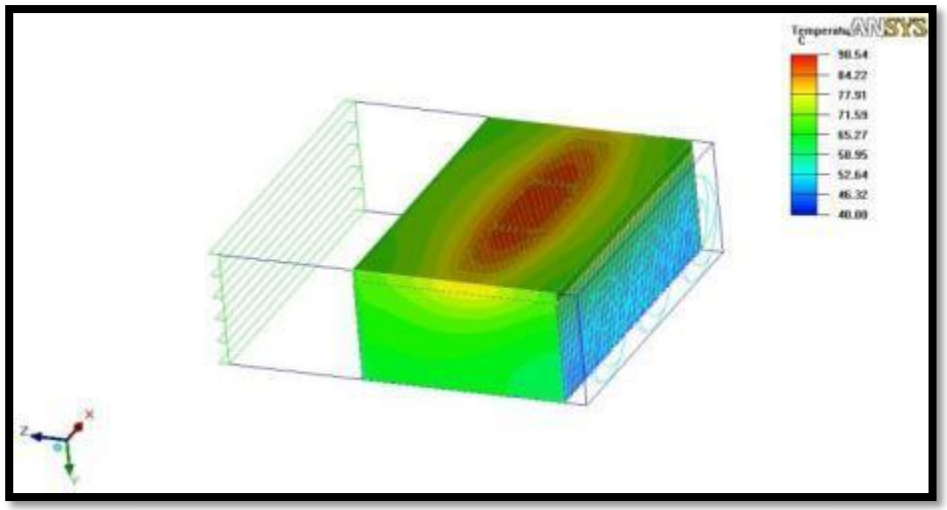
IGBT Model

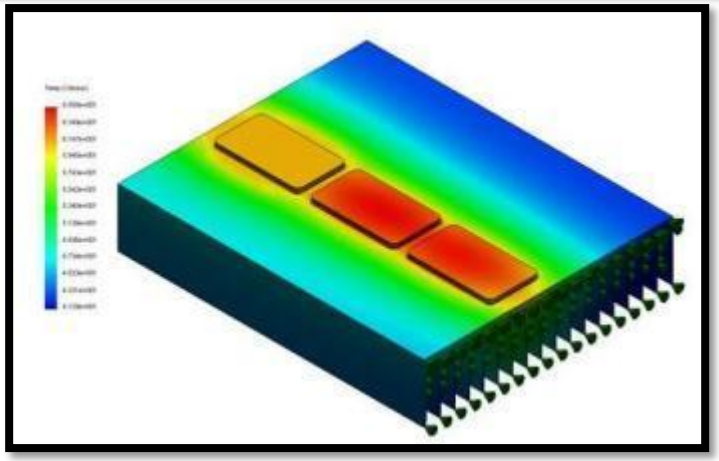


Diode Model

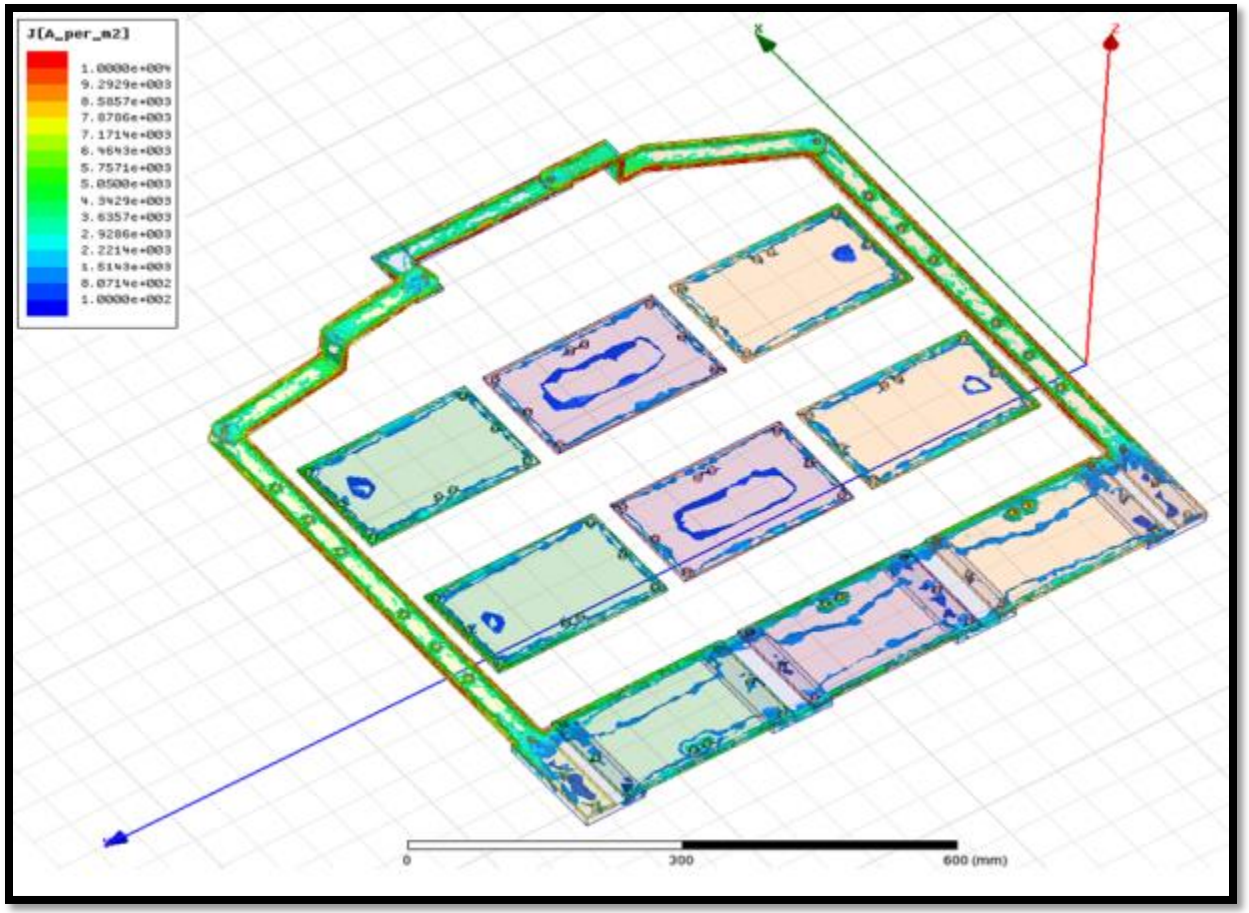
Thermal Analysis





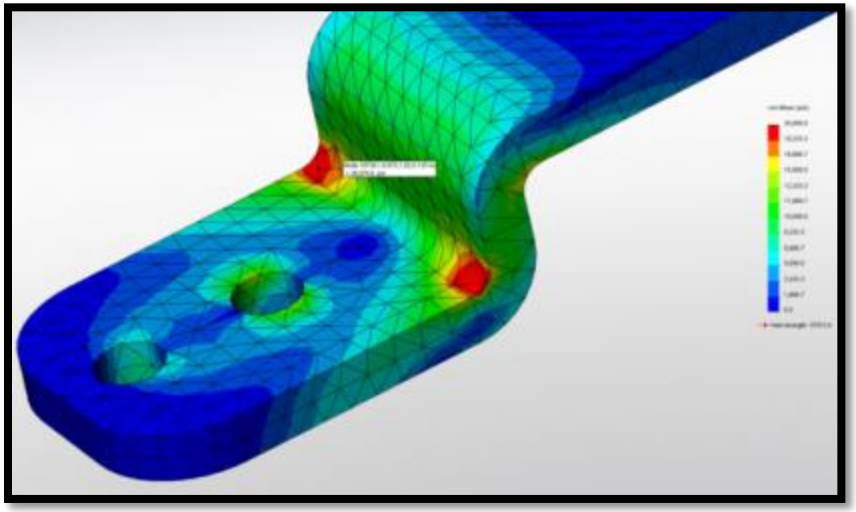


Magnetic Analysis

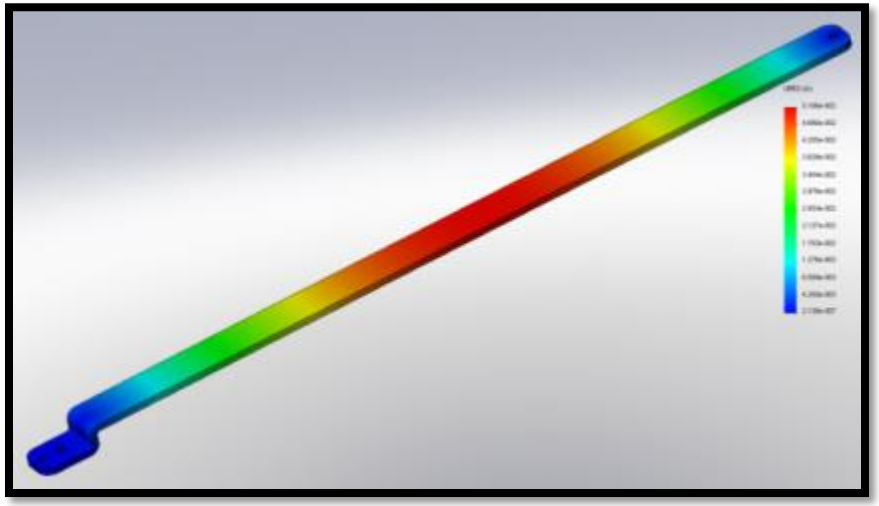


Compute stray inductances

Stress Analysis of Bus Bar



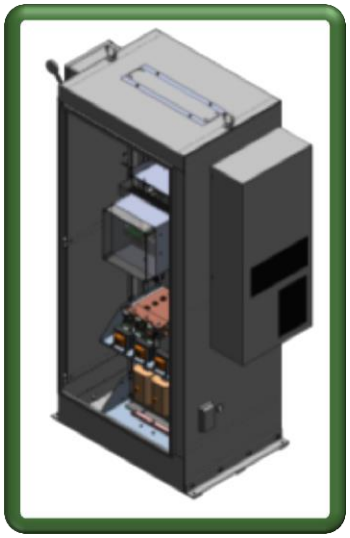
Stress concentrations result in 26 ksi VM stress



Deflection due to load

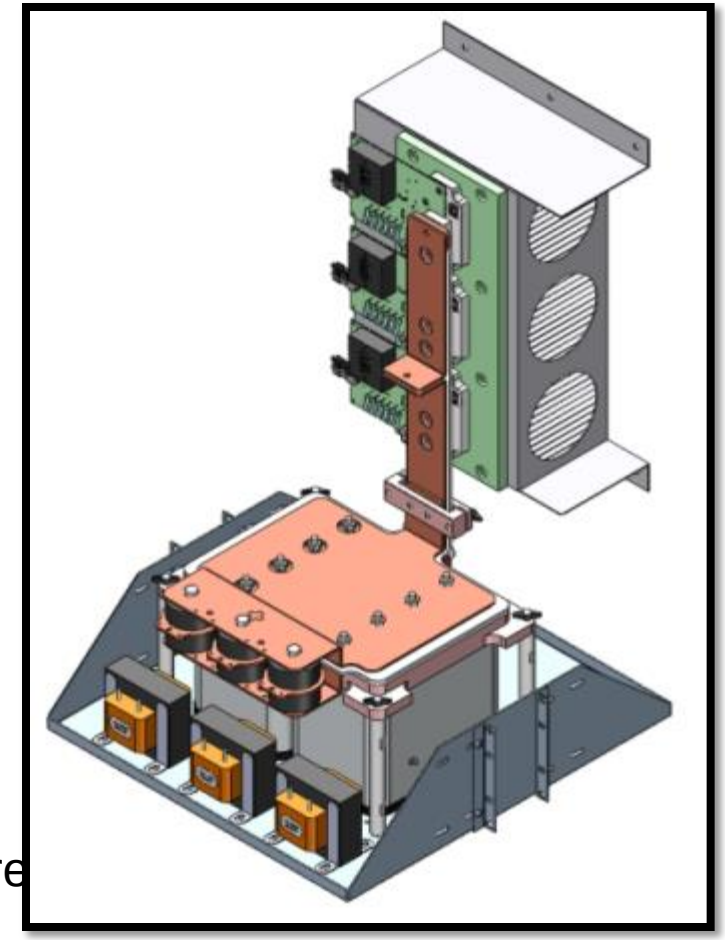
Solid Modeling

- Optimize electrical performance
- Optimize thermal management
- Optimize ergonomics



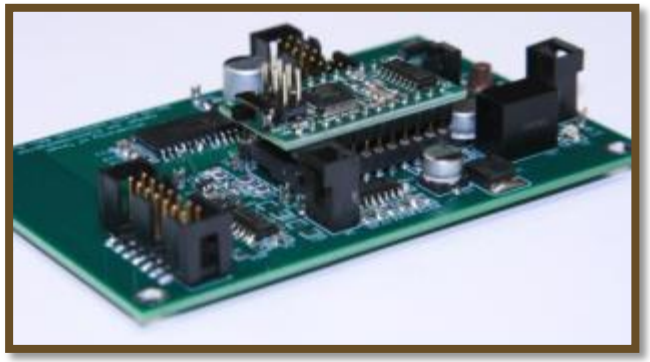
Solid Model Assembly

Real World Hardware

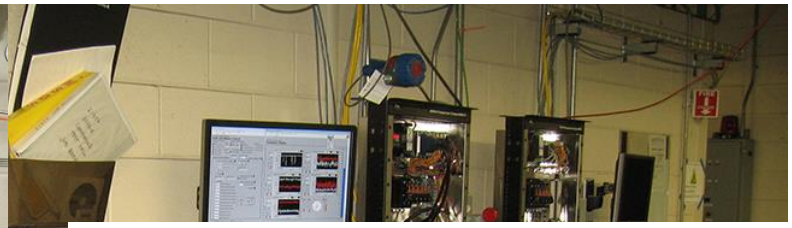


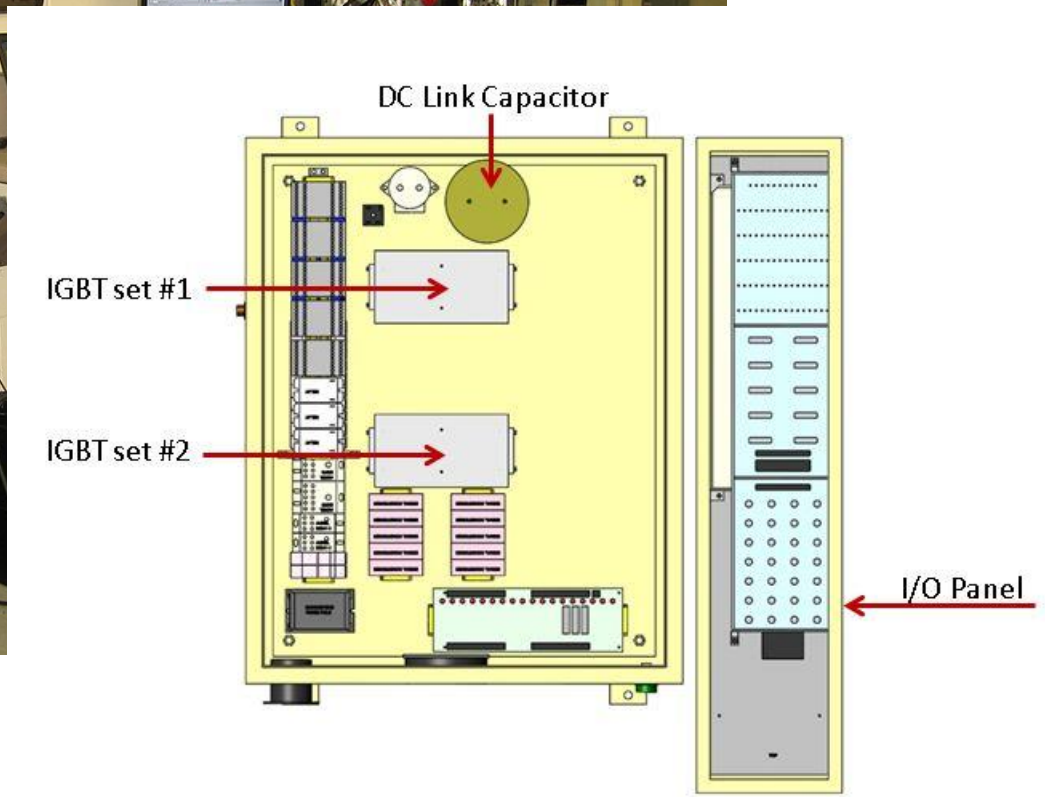
Embedded Controllers

- Customized to demand
- Circuit design, capture
- PCB layout, assembly
- SMT, TH soldering
- Software, controls
- Numerous licenses to partners

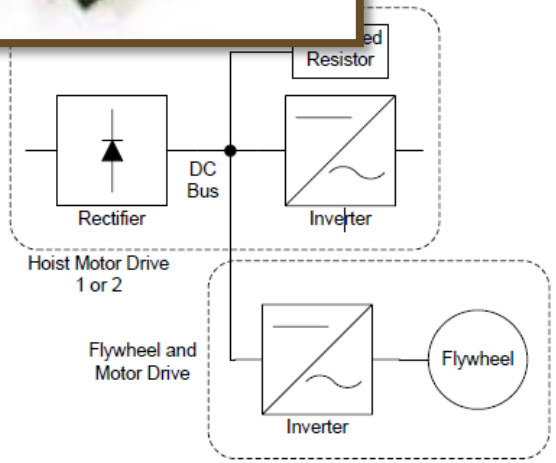


Linear Motor Compressor

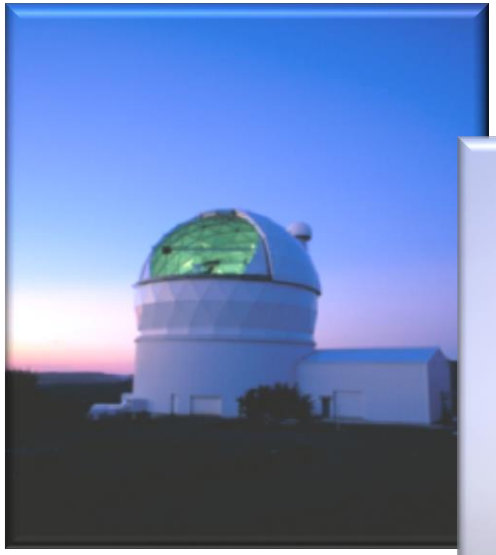


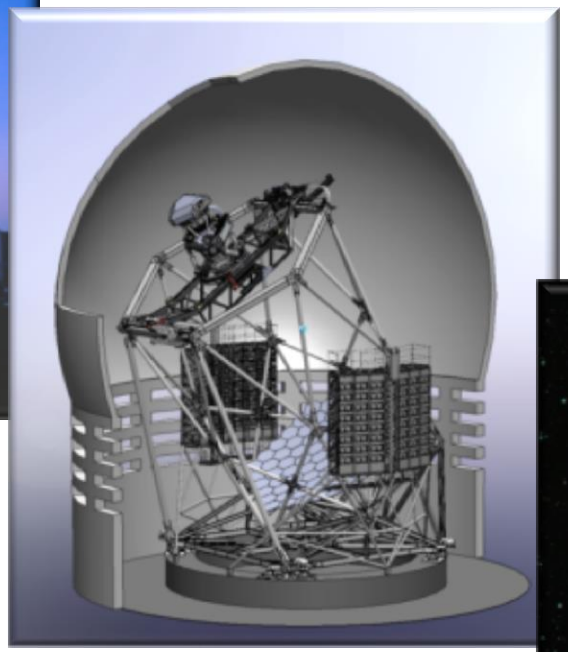


Hybrid Motor Design



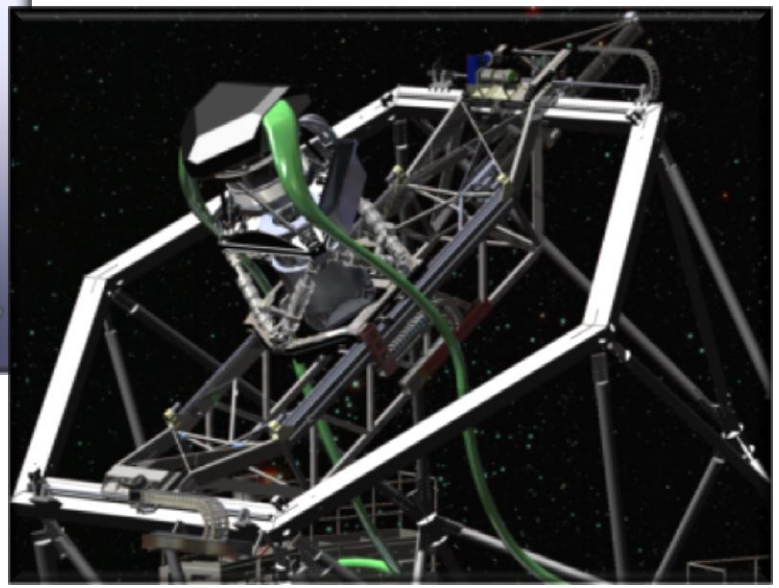
Large-Scale Electrified Motion





Scientists can't find 70% of the energy in the Universe.

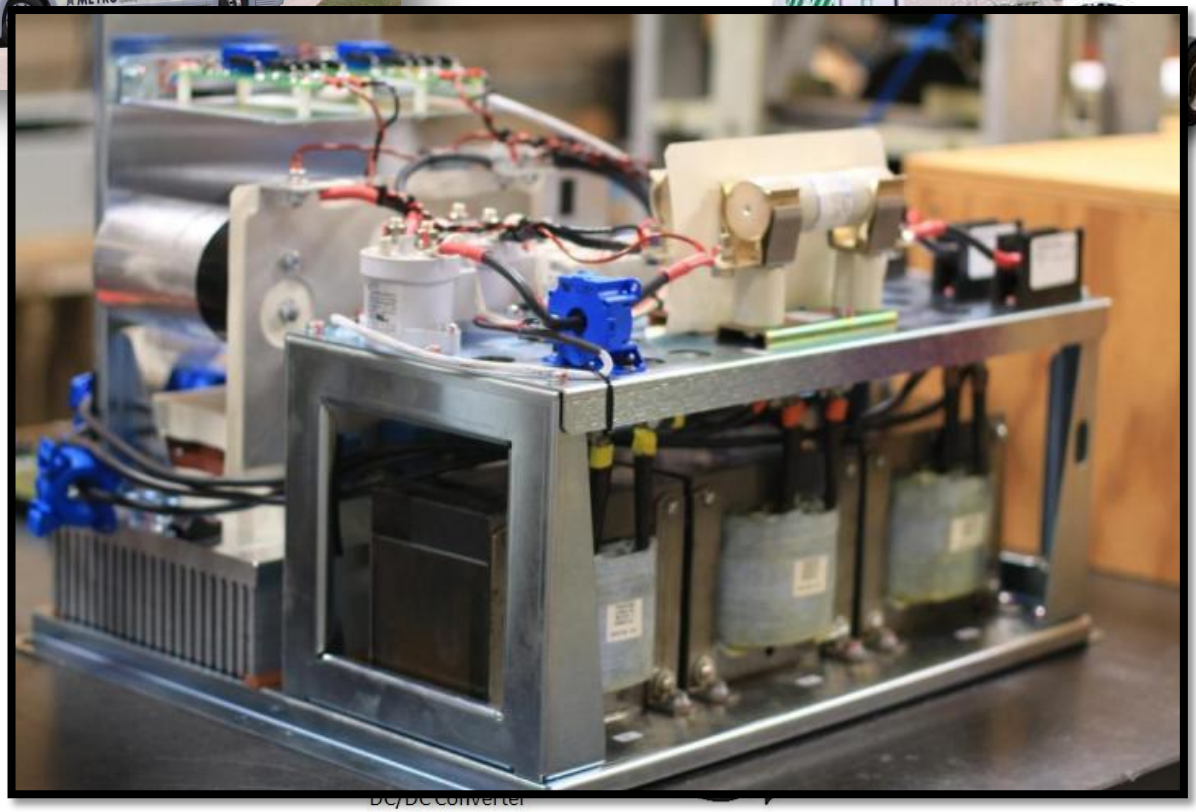
UT's Hobby Eberly Telescope is going to look for it.



13 controlled motors, 10 micron accuracy

CEM's 20 ton precision robot will do the work.

Alternative Fuel Vehicles



DC/DC converter

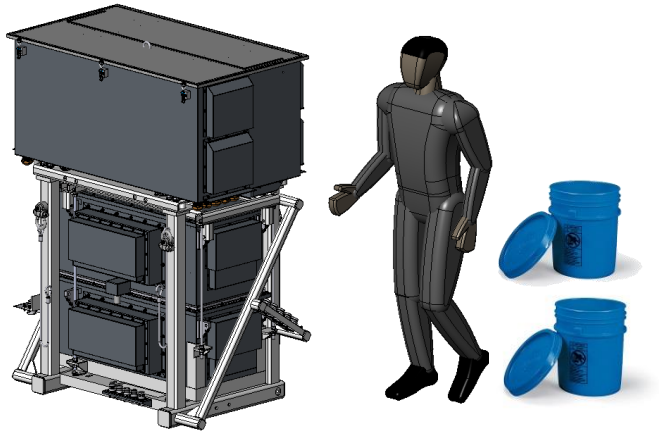
Active Suspension

Power Electronics are the enabling technology for Active Suspension

- Control system design driven by modeling and simulation
  - Developed in Matlab – Simulink
  - Deployed to dSpace AutoBox with auto code generation
- Demonstrated using air cooled COTS Power Electronics hardware
- Transition to production ready as demonstrated by hardware constructed in cooperation with corporate partner

Volume reduction from full cargo space to under-seat storage

Projected volume reduction for another project



Grid Controls

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AC bre

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5 MW

9501.0295

ıker

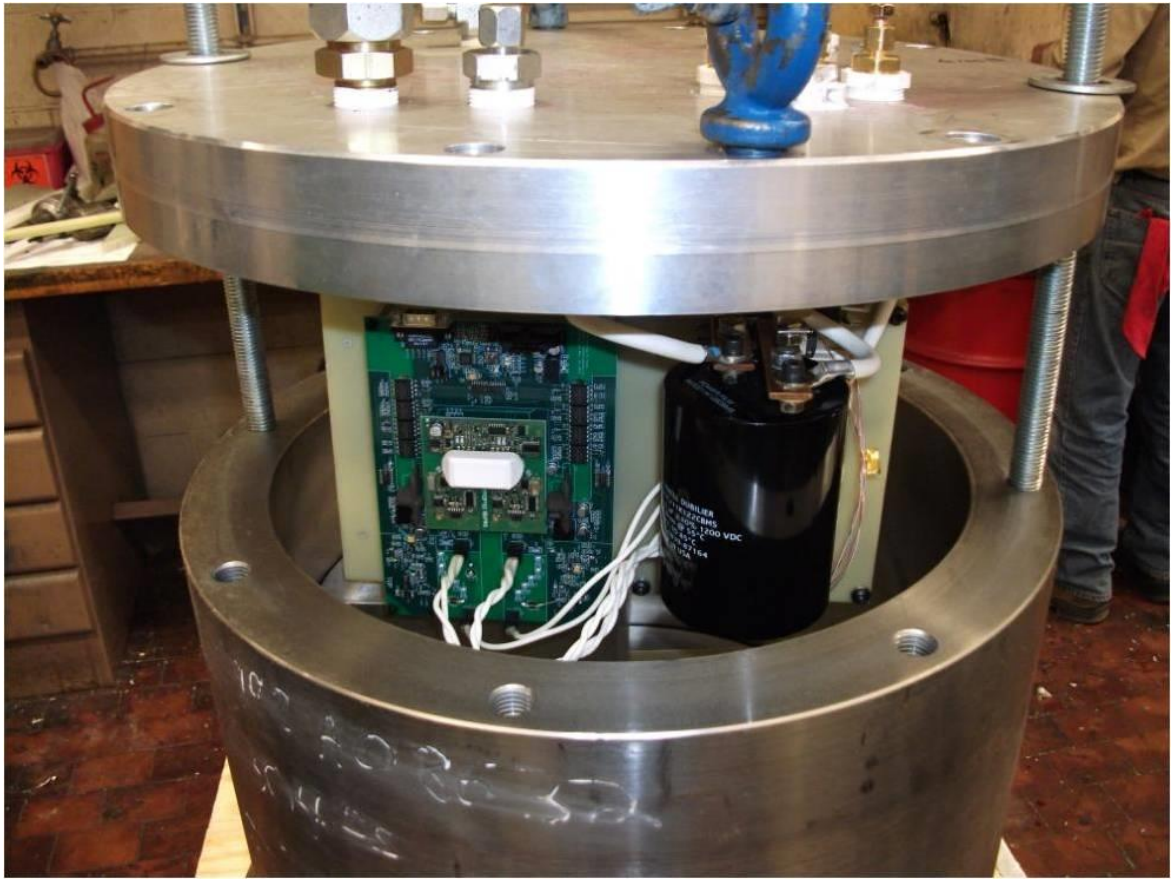
1.2 MVA
controlled

DC
disconnector

DC
onnector

Algae Lysing

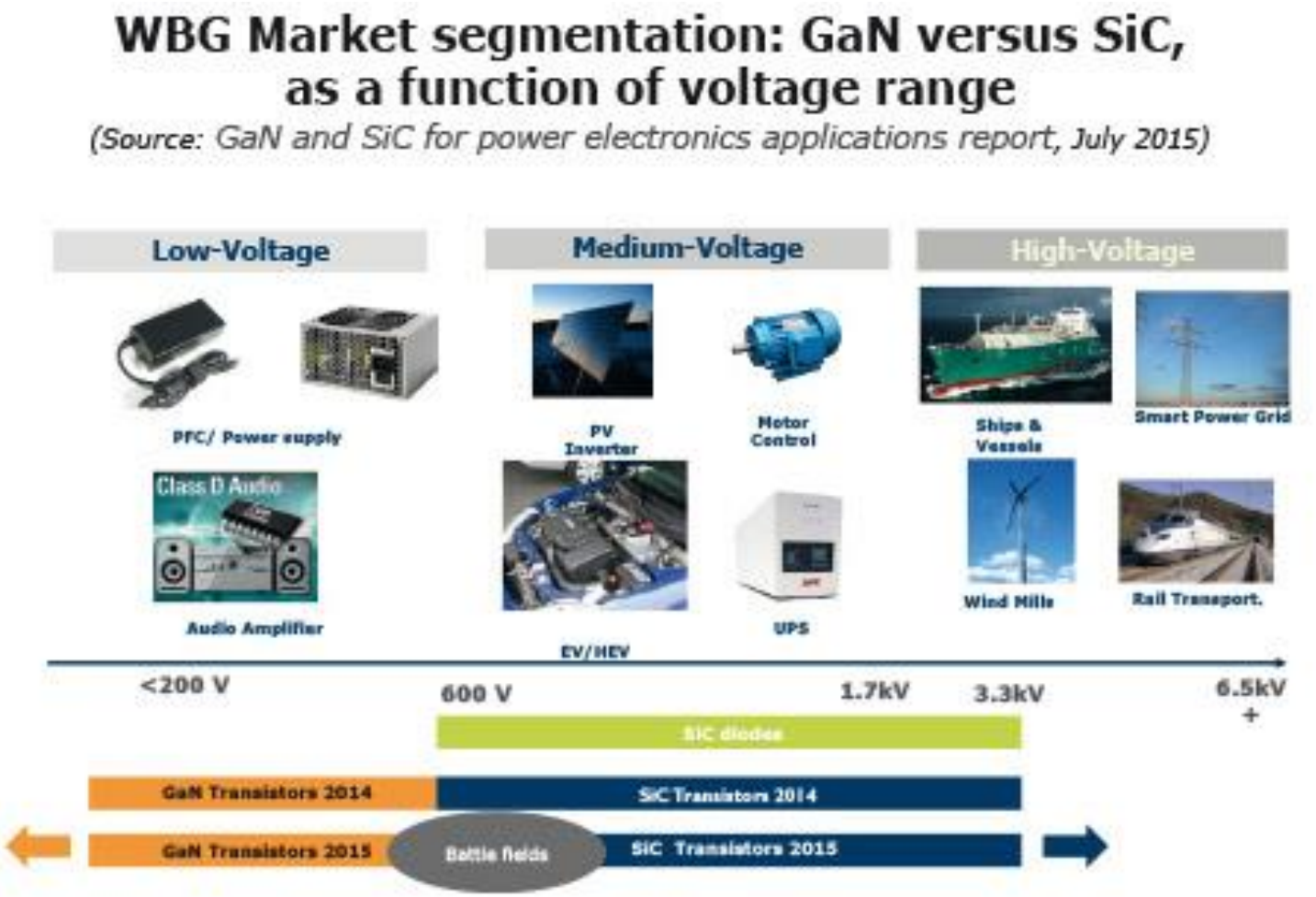
Subsea Oil & Gas



Pressure Tolerant Controller

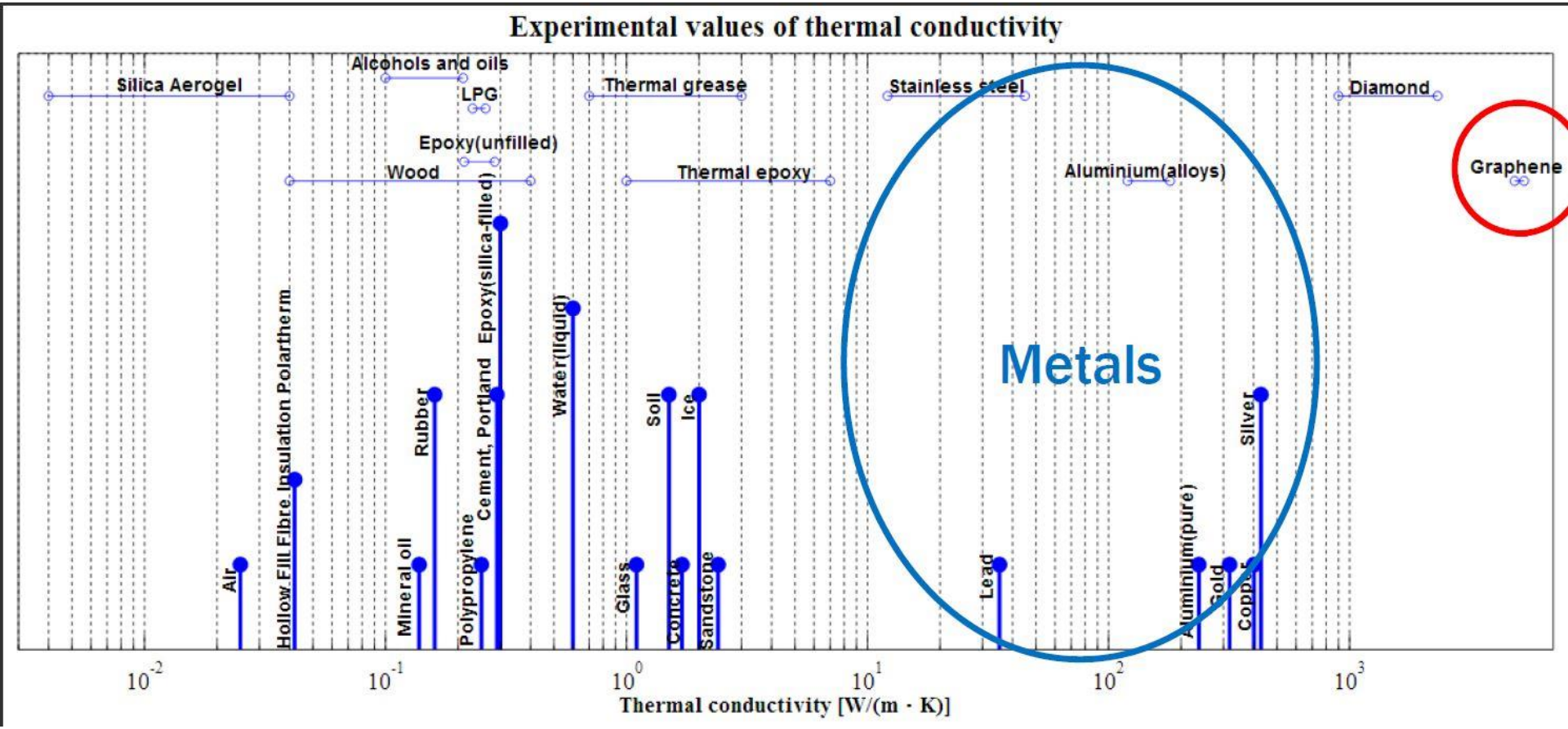
- Monitors 2 IGBT junction temperatures in real-time
- Tested to 4200 psi hydrostatic pressure
- 16-bit processor

Future of PE

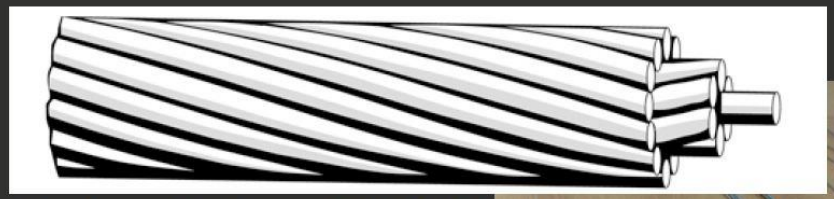


Ghosh et al, Natural Materials, 2009

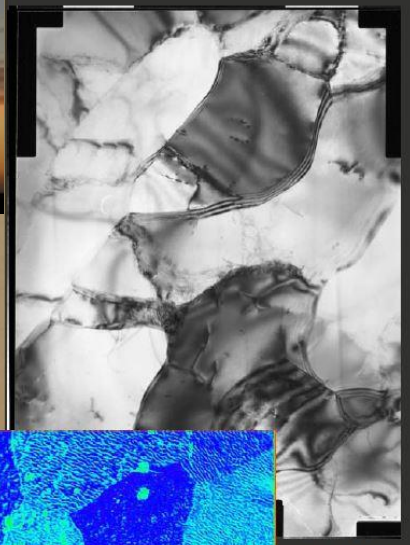
Future of PE


Experimental values of thermal conductivity
Silica Aerogel
Alcohols and oils
LPG
Thermal grease
Stainless steel
Diamond
Graphene
Epoxy(unfilled)
Wood
Thermal epoxy
Aluminium(alloys)
Metals
Air
Hollow Fill Fibre Insulation Polartherm
Mineral oil
Rubber
Polypropylene
Cement, Portland
Epoxy(silica-filled)
Water(liquid)
Glass
Soil
Concrete
Ice
Sandstone
Lead
Aluminium(pure)
Gold
Copper
Silver
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
Thermal conductivity [W/(m · K)]

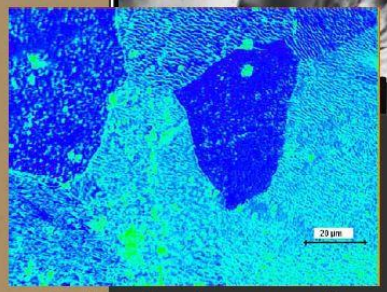
Future of PE



Replace steel core (8% IACS) with nanoaluminum (61% IACS)



TEM



Optical micrograph

Nanoaluminum cable wire strands

New Mexico Inst, Los Alamos

Future of PE

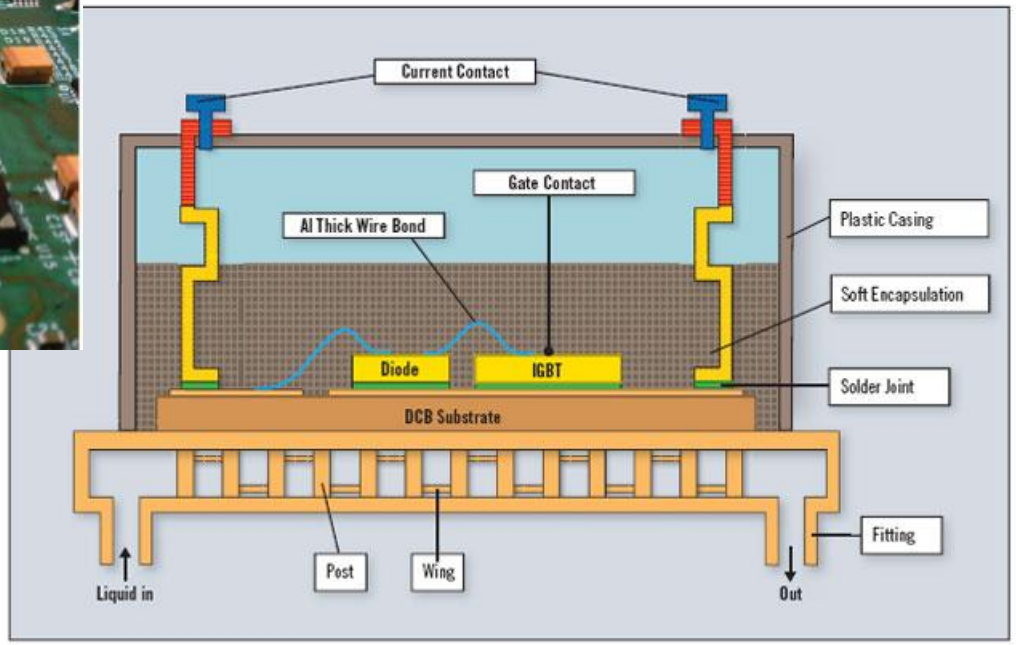
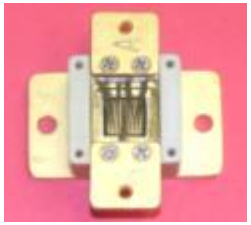
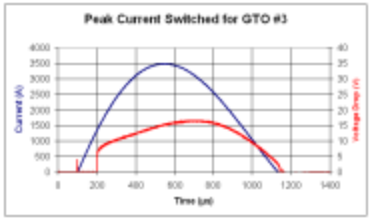


Fig. 6. Liquid-flow cooling inside the base plate with a direct integrated substrate.

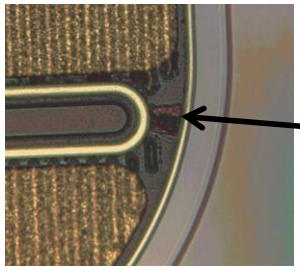
Powerelectronics.com, Georgia Inst of Technology

SiC SGTO Switch Development and Failure Investigation





ARL SGTO Pulse Test Results

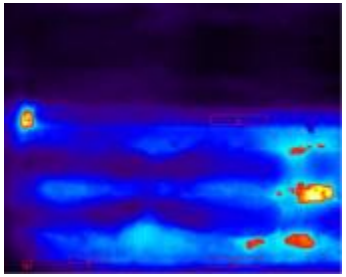


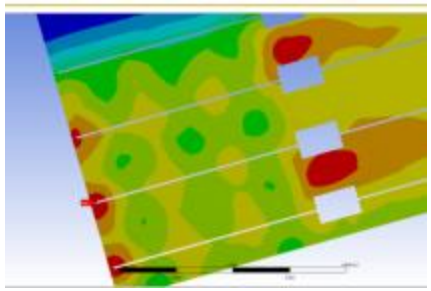
Polyimide Damage

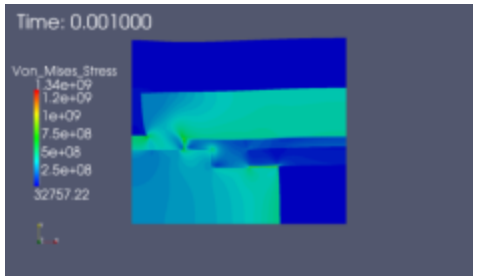
ANSYS Conduction Current Coupled Simulations

Thermal Imaging Experiments

EMAP3D Semiconductor Physics Simulations







SiC Device Design Improvements

CREE

ARL

Summary

- Future of power electronics
  - Applications demand smaller efficient solutions
  - Emerging technologies driving change
- CEM/ECE/ME Strengths
  - Technical skills: design, analysis, fabrication
  - Intellectual property: internal libraries/designs
  - Facilities: service power, supplies, tools
  - Personnel: professors, researchers, students
- Industry Involvement
  - Sponsor research focused on advancing power electronics design
  - Student internships