

# RELIABILITY TEST AND IN-SITU FAILURE ANALYSIS OF WIDE BANDGAP POWER ELECTRONICS

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# POWER ELECTRONICS

## At the center of energy transition



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### Requirements

- Higher power
- Reliability
- Thermal management
- Compactness
- Integration

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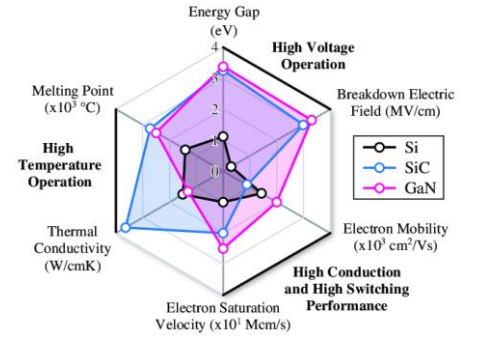
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## At the center of energy transition



Si IGBT/ Si MOSFET

SiC MOSFET/ GaN HEMT



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# ELECTRONIC MATERIALS CHAR. GROUP

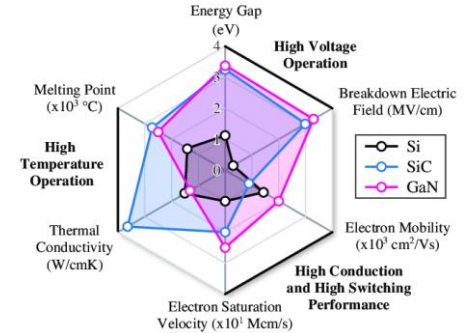
## Our research objectives

Reliability testing and failure analysis of WBG power electronics & beyond

Si IGBT/ Si MOSFET

SiC MOSFET/ GaN HEMT

Electronic Materials Char. Group



## Requirements

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# NEW OPPORTUNITIES

Argonne is addressing major industry challenges

**Benchmark  
next-generation  
power electronics  
against existing  
technology**

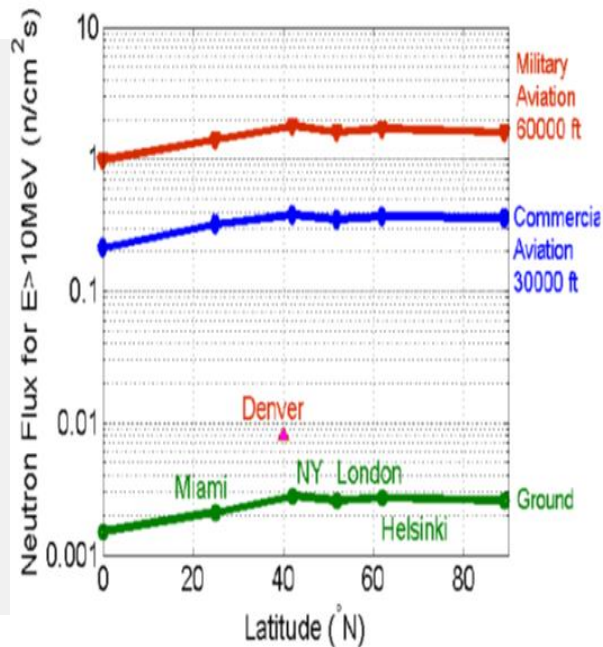
**Perform mission-  
specific reliability  
testing and  
disruptive in-situ  
physics-of-failure  
analysis**

**Develop simulation  
models to improve  
the speed and  
lower the costs of  
these analyses**

# NEED FOR MISSION SPECIFIC RELIABILITY TEST

## Aerospace environment

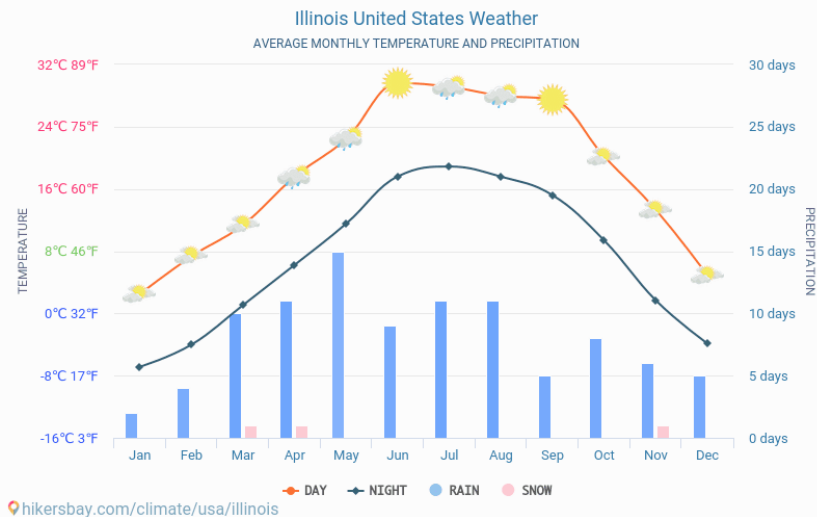
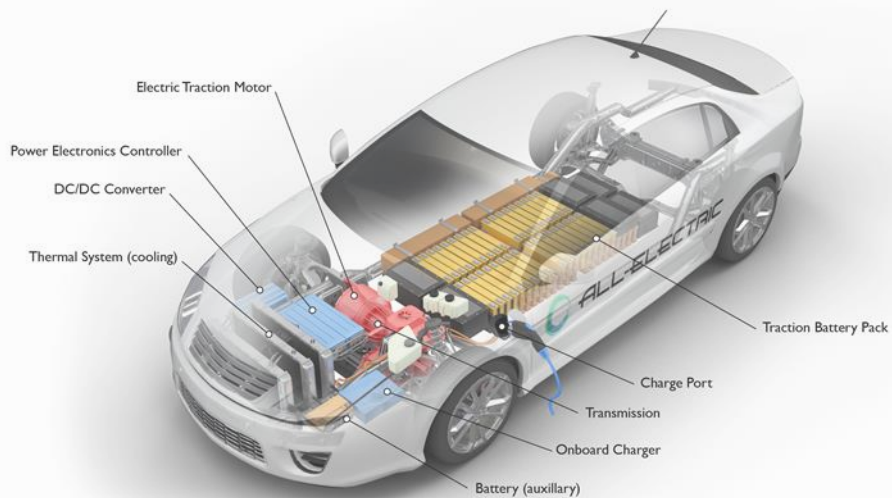
- Terrestrial neutron radiation everywhere
- Neutron flux increase with altitude and latitude





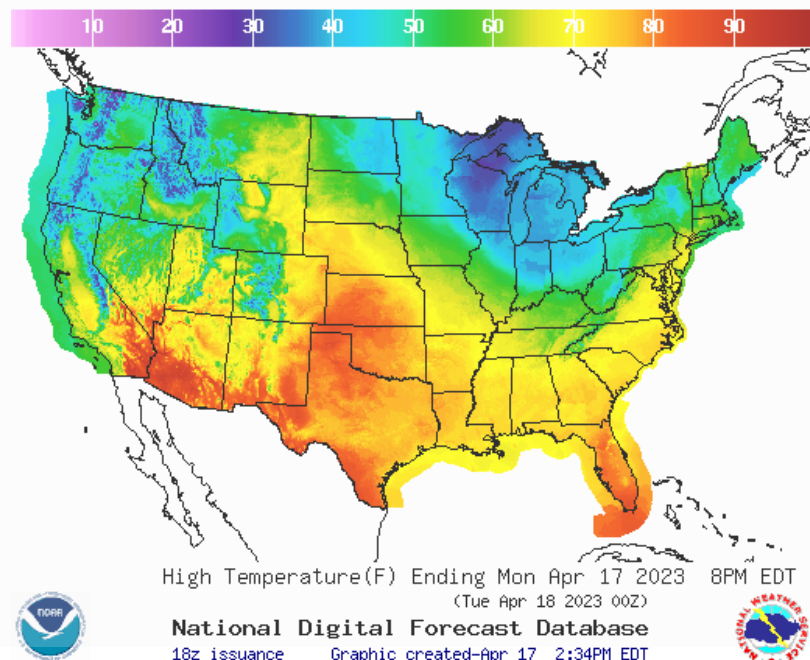
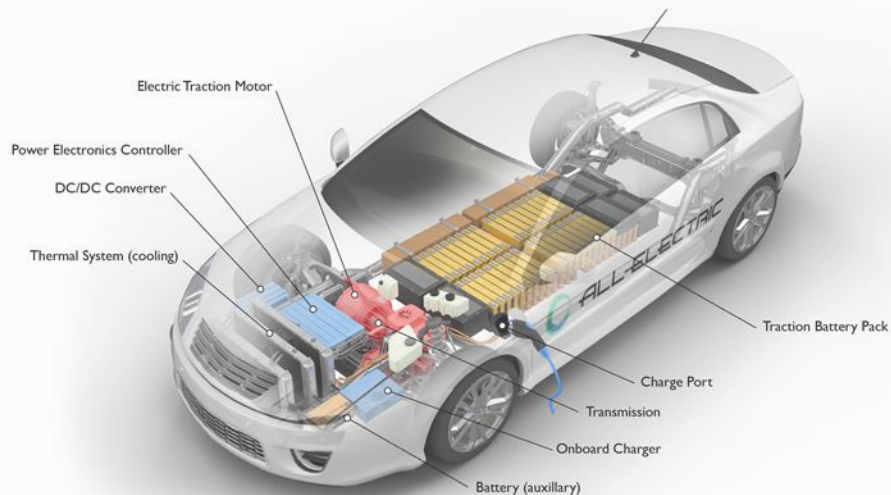
# NEED FOR MISSION SPECIFIC RELIABILITY TEST

## EV environment profile



# NEED FOR MISSION SPECIFIC RELIABILITY TEST

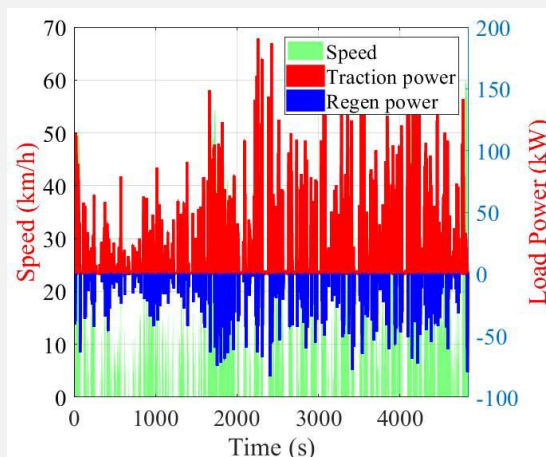
## EV environmental profile



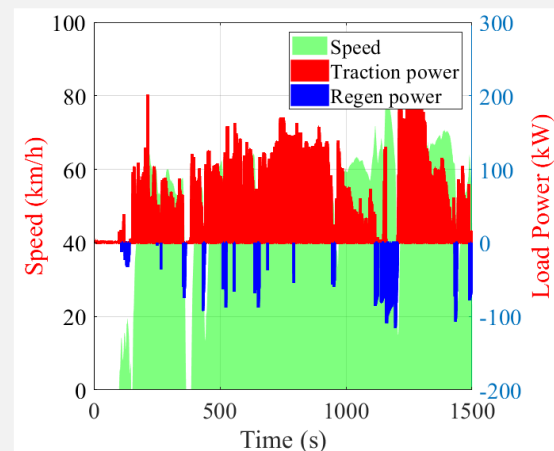
# NEED FOR DISRUPTIVE FAILURE ASSESSMENT

## EV system profiles

- Different stress conditions for power electronics based on location and time
- Lack of field level data
  - Rapid growth of EV industry
  - Power electronics transition to meet high power demand



Load profile of an EV in extra-urban region



Load profile of an EV in an urban region

IEEE Journal Of Emerging And Selected Topics In Power Electronics, Vol. 10, No. 5, October 2022

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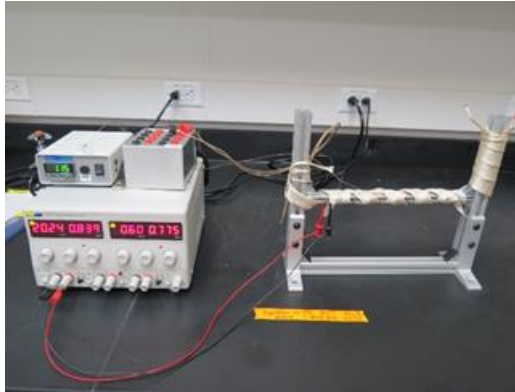
# BENCHMARKING NEXT-GEN POWER ELECTRONICS

## Reliability test

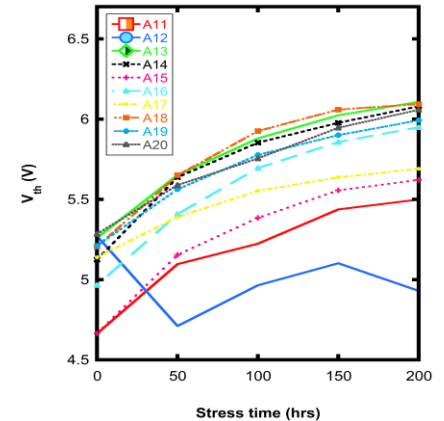
### SYSTEM

- In-situ thermal aging
- Bias temperature instability test

Ahmed et al., SN Appl. Sci. 1, 733, 2019.



10 channel reliability test platform



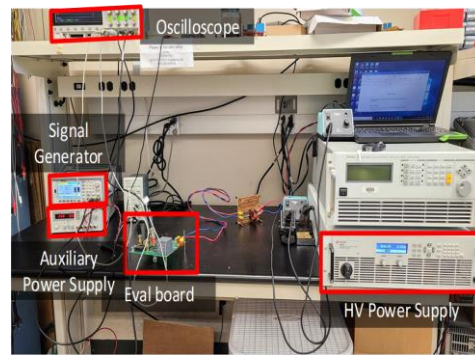
Device Performance Analysis

# BENCHMARKING NEXT-GEN POWER ELECTRONICS

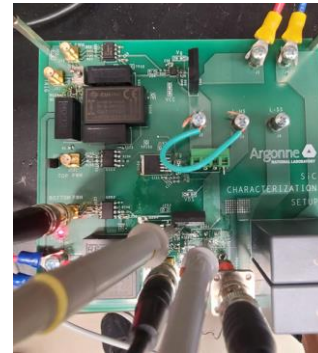
## Switching behavior

### Platform

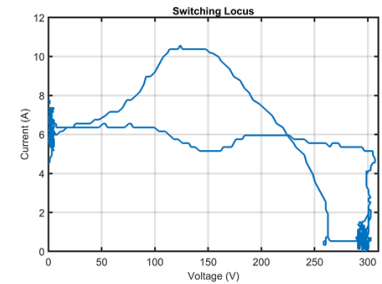
Hard/ soft-switching,  $dV/dt$ ,  $dI/dt$ , switching locus determination



Device property analysis



Argonne developed platform



Device property observation

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# MISSION SPECIFIC RAD-HARD TESTING

## Aerospace, outer-space and harsh applications

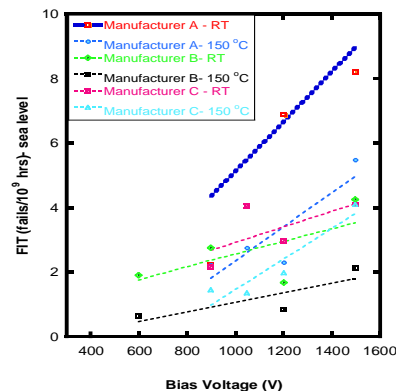
### SYSTEM

a 20-channel  
5kV platform for  
rad-hard  
environment  
test

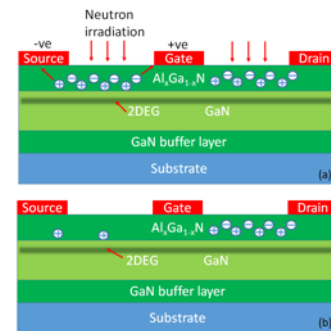
M. Ahmed et al., Proc. 2020 NSREC  
Data Workshop, paper no. 187, 2020.



High voltage testing capability



Device Performance Analysis



Physics-based modeling results



# MISSION SPECIFIC RELIABILITY TESTING

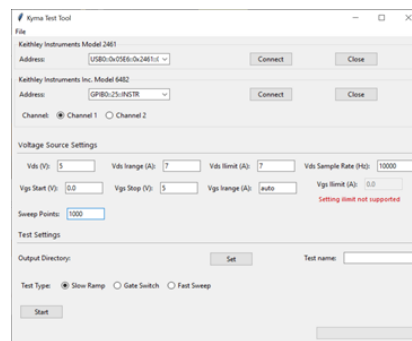
## Environmental specific parameters

### SYSTEM

In-situ thermal & humidity cycling of power device/ module with electrical bias



Environmental chamber



Stressing devices at a specific conditions



Physical degradation analysis

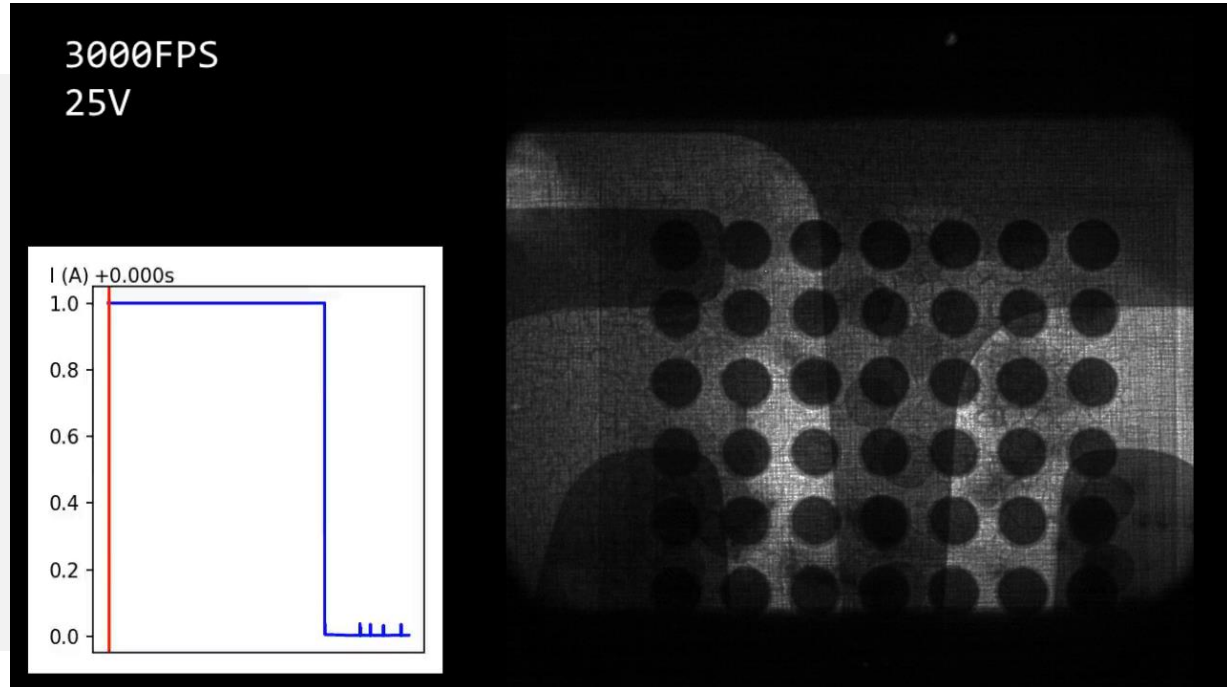
# FAILURE ANALYSIS OF NEXT-GENERATION WIDE BANDGAP GaN POWER DEVICE

When/ how/ where a device fail?

## SYSTEM

Disruptive in-situ physics-of-failure analysis using Argonne's Advanced Photon Source

M. Ahmed *et. al.*, U.S. Patent No. 11493548



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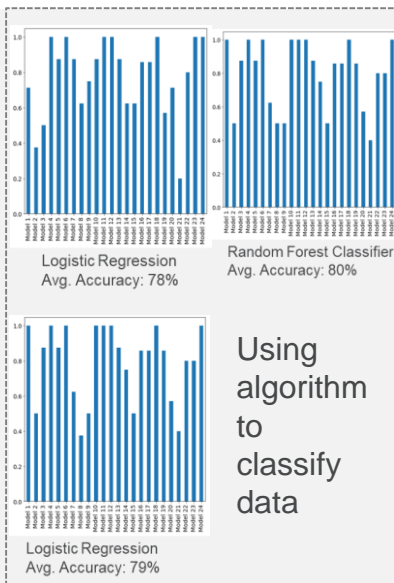
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# SIMULATION MODEL DEVELOPMENT

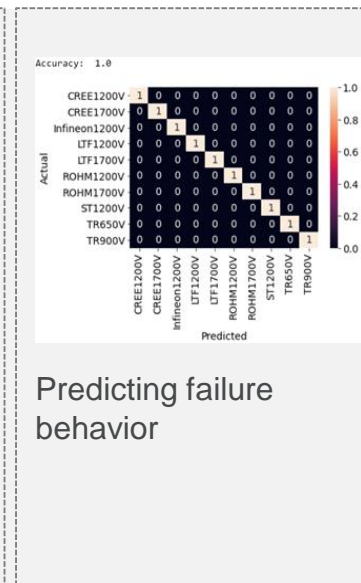
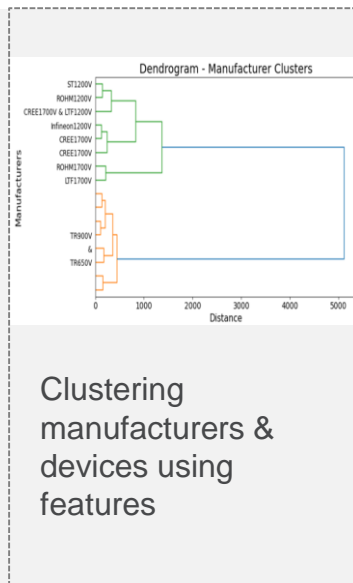
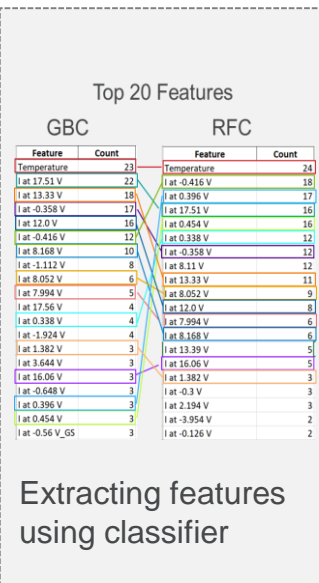
## Application specific

### PLATFORM Machine- learning based simulation model

<https://doi.org/10.48550/arXiv.2107.10292>



Using algorithm to classify data



# SUMMARY

- Mission-specific reliability testing and modeling of power electronics for electric grid, electric vehicles, & renewable energies
- Disruptive in-situ failure analysis of power electronics for advanced manufacturing
- Benchmarking WBG power devices for aerospace, outer space & other harsh environments
- Reliability and failure analysis of packaging and power interconnects for solid-state component development

# THANK YOU

## CONTACT

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