State-of-the-Art and Challenges of Pressure-Tolerant Power Electronics and a Review of Related Research at NCSU

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August 13, 2025

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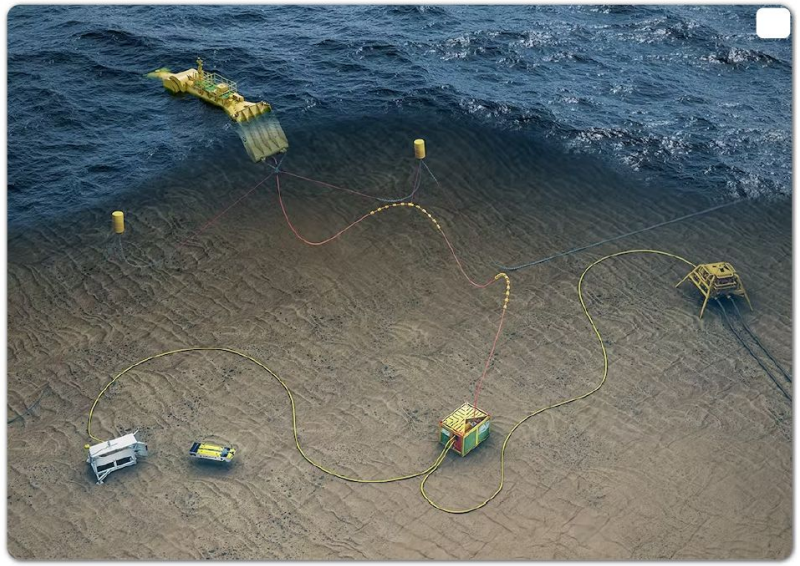
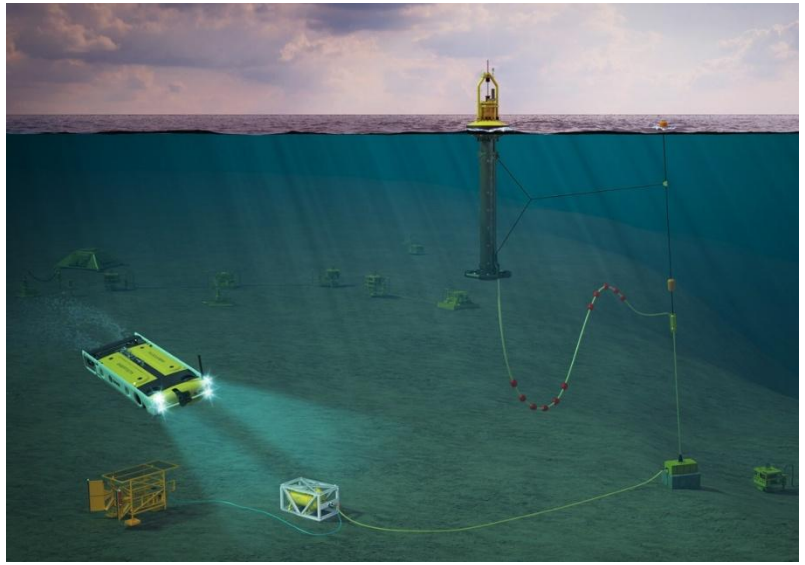
- State of the art of pressure tolerant power electronics (PTPE)
- Developmental challenges of PTPE for subsea application
- Research on PTPE at NCSU

Motivation

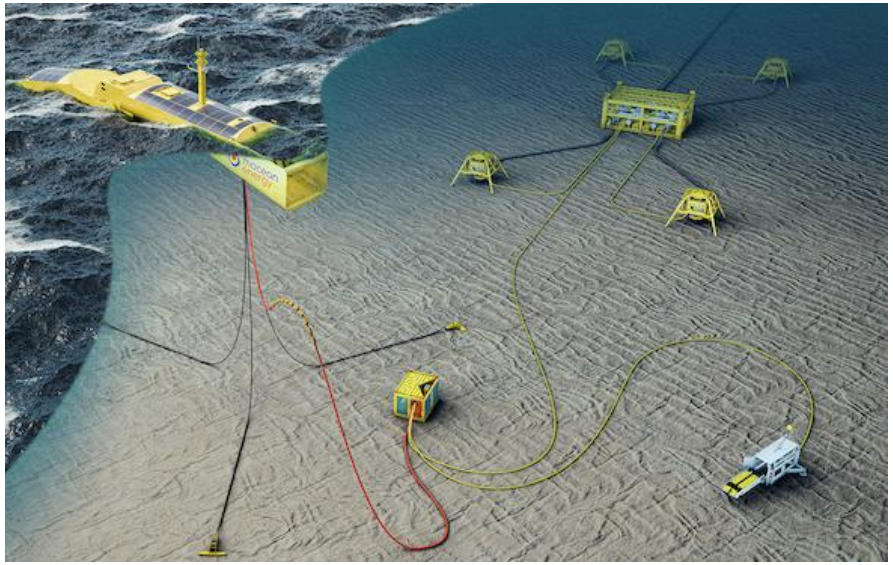
- Sustainable microgrid is required for offshore marine energy generation and loads
- Power umbilical is not suitable for deep offshore applications
- Offshore power converters are required for power regulations



Artistic view of marine energy generation for a subsea power system [1]



Integrated subsea loads for marine exploration, monitoring, and surveillance [2]

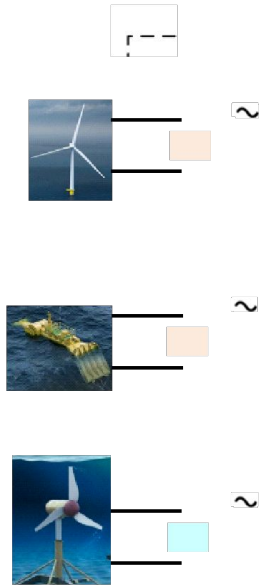


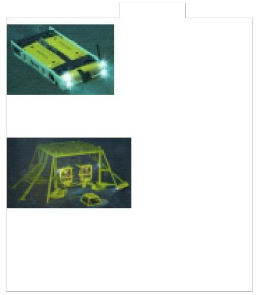
An offshore islanded microgrid [3]

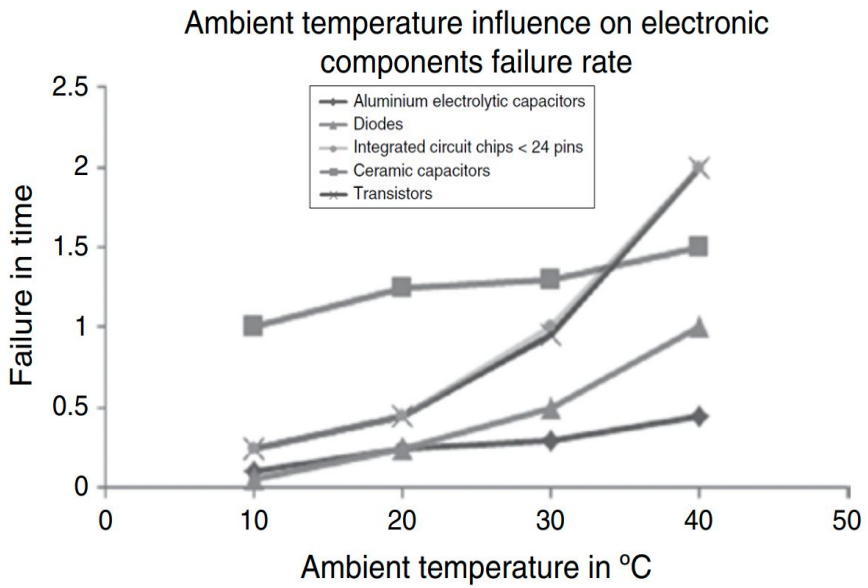
1. https://www.offshore-mag.com
2. https://www.offshorewind.biz/
3. https://waves-energy.co/blog/

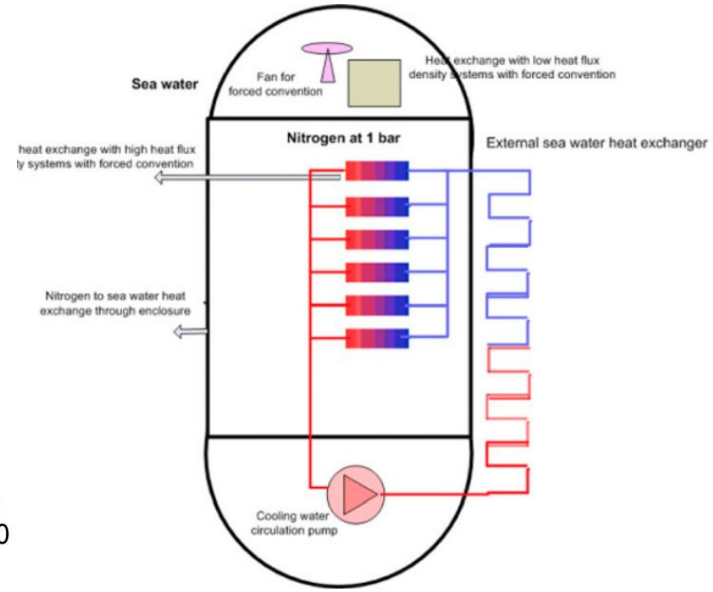
Motivation

- Power converter becomes a building block of the microgrid
- Failure rate of electronic components increases based on the ambient temperature
- Incorporation of thick metallic cylinders requires a sophisticated heat exchange mechanism





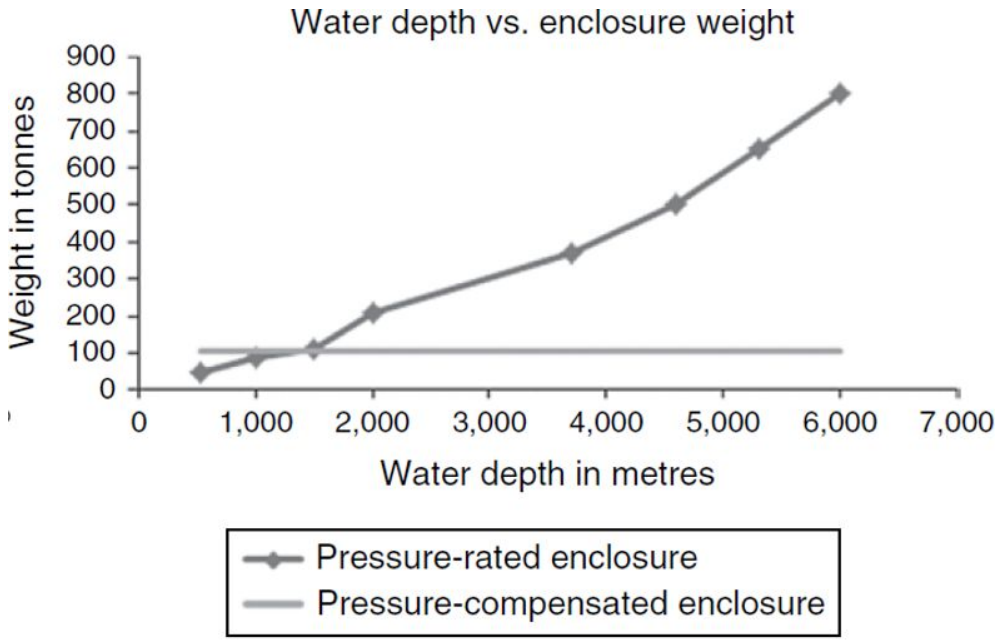


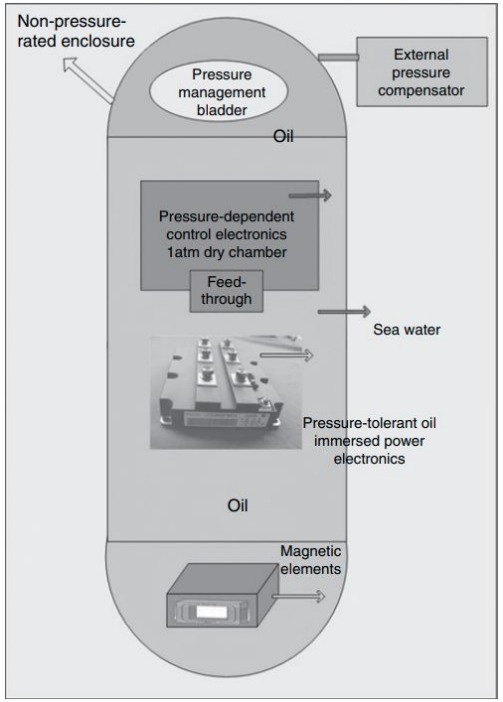


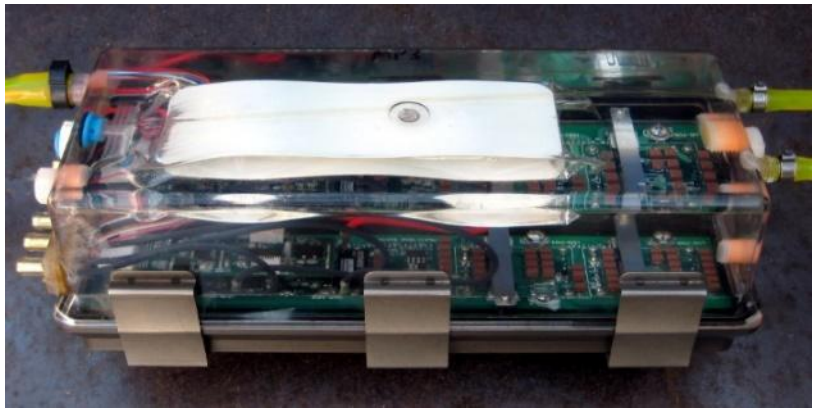
1. Evaluation of Wireless Communication Networks on Secondary Control in Underwater Microgrid 2020 IEEE Energy Conversion Congress and Exposition (ECCE), Detroit, MI, USA
2. A review of thermal and humidity management needs and feasible solutions for next generation subsea electric systems

Motivation

- Significant weight of cylinder is added at higher water depths
- Pressure-compensated enclosure is independent of water depth





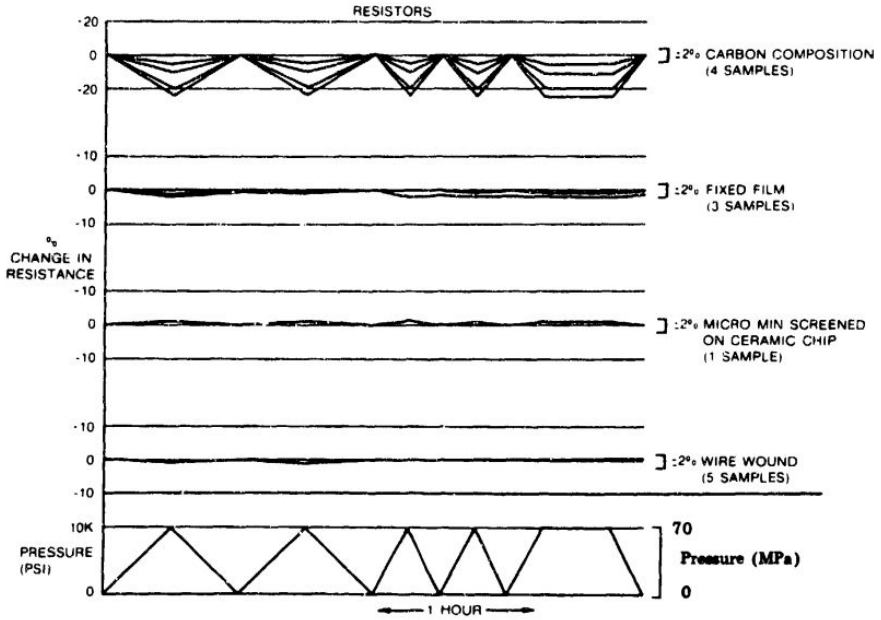


We need pressure-tolerant power electronics (PTPE)!!!!!!!

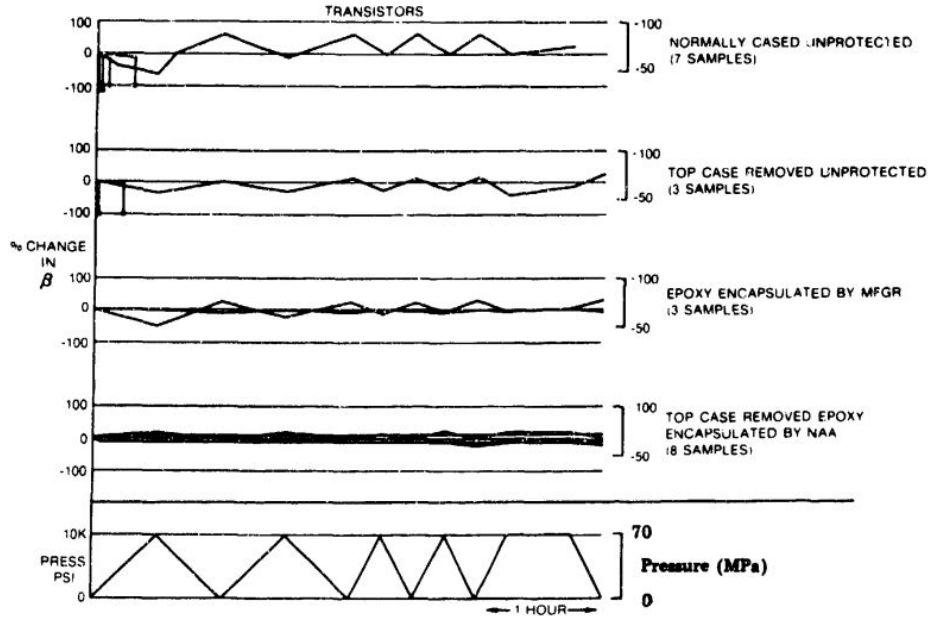
1. Evaluation of Wireless Communication Networks on Secondary Control in Underwater Microgrid 2020 IEEE Energy Conversion Congress and Exposition (ECCE), Detroit, MI, USA
2. A review of thermal and humidity management needs and feasible solutions for next generation subsea electric systems
3. Designing pressure-tolerant electronic systems, Nic Bingham

PTPE State of the Art

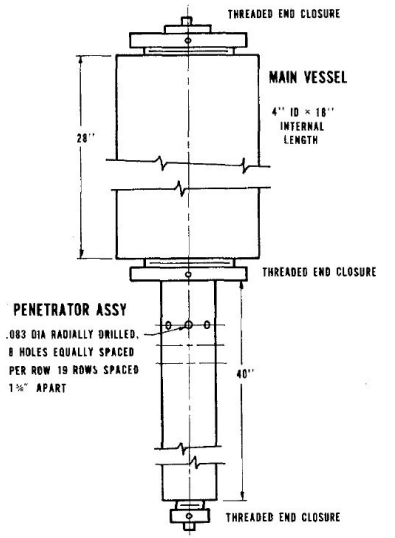
- First wave of PTPE research in the 1970s by Barnes and Gennari
  - Outdated technological components
  - Lack of live pressure testing



Results of resistor tests



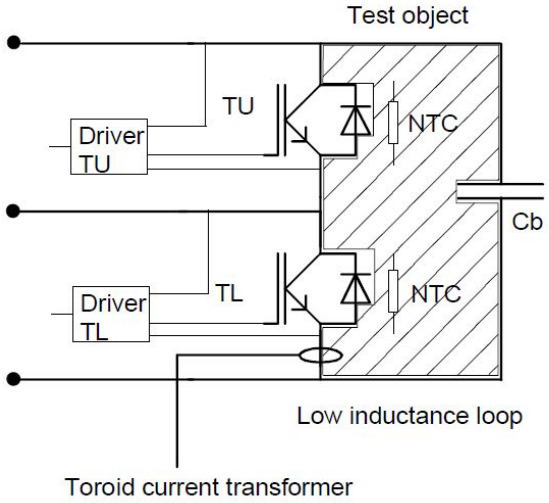
Results of transistor test

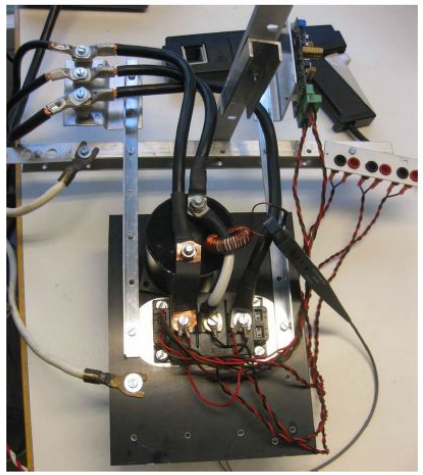


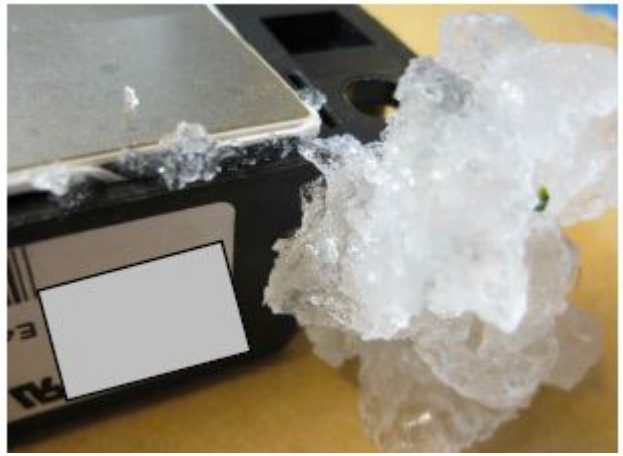
1. A REVIEW OF PRESSURE-TOLERANT ELECTRONICS, HOWARD E. BAYINES AND JaBmis J. G•ENNARI

PTPE State of the Art

- Second wave of PTPE research in the 2000s by Hernes and Pittini for offshore oil and gas exploration.
  - Identified the bus capacitor, switching component, and gate driver as the central part of the converter
  - Off-the-shelf packaged switching components failed at high pressure due to voids



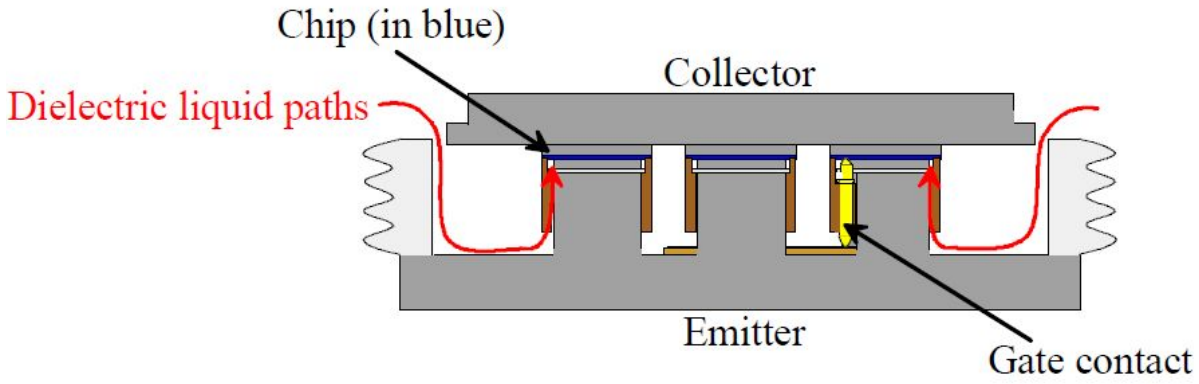


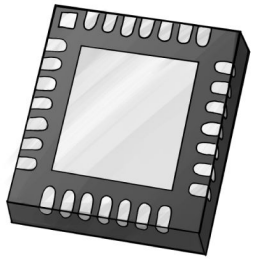


1. Pressure Tolerant Power Electronics: IGBT Gate Driver for Operation in High Pressure Hydrostatic Environment, Pittini, Riccardo; Hernes, Magnar ; Ljøkelsøy, Kjell

PTPE State of the Art

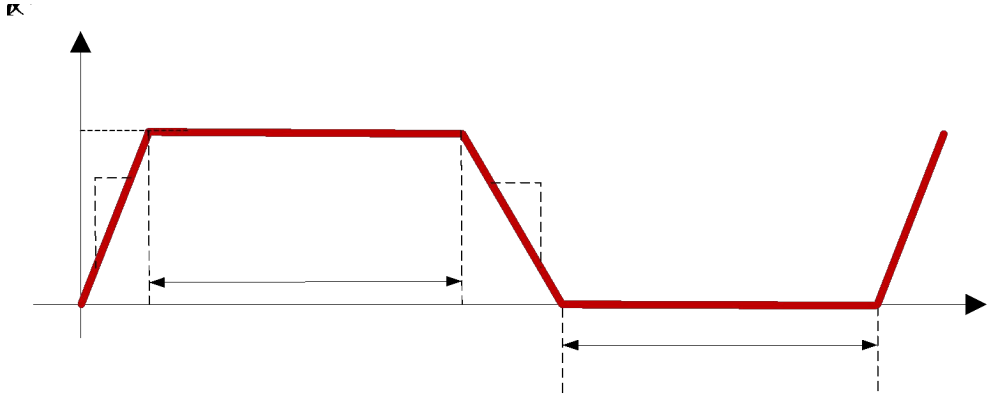
- Third wave of Modification of electronic components allows a void-less configuration and improves mechanical and structural performance
  - Tightly packed electronic components with leaded packaging offer extra room for pressure compliance

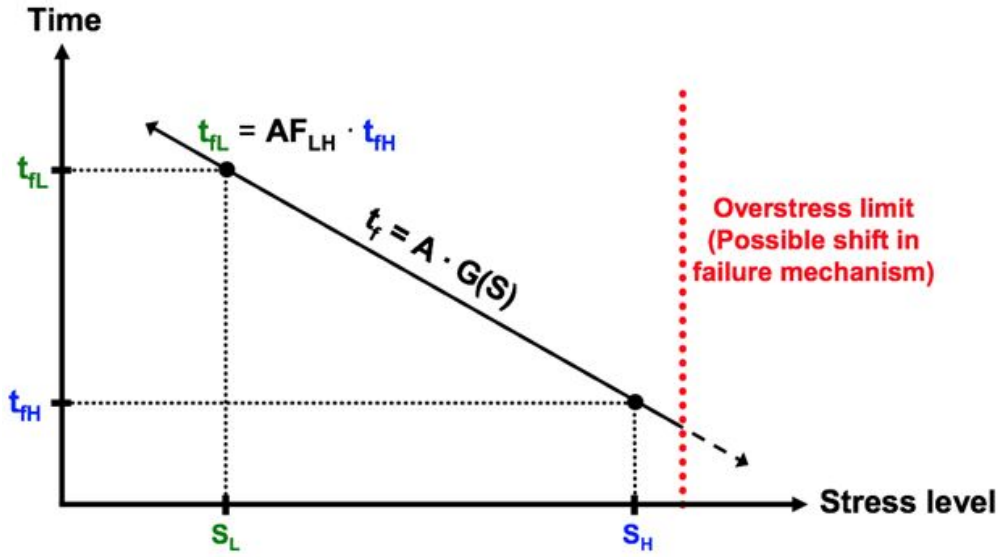


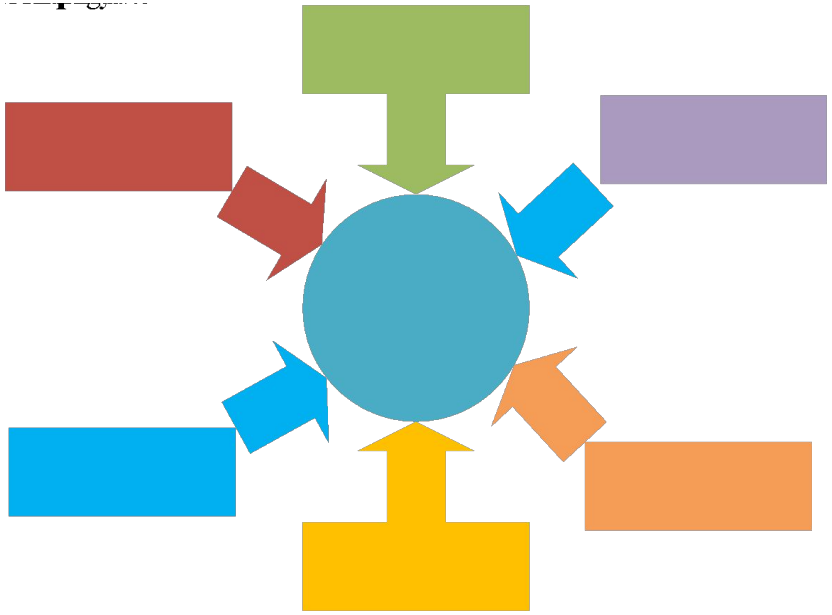


Challenges of PTPE for Subsea Applications

- Lack of unified testing methodology
  - Pressure profiles
  - Multi-Stressor Integration
  - Component level and system level alignment
  - Long-term impacts testing
    - Lack of accelerated life test (ALT) models based on pressure

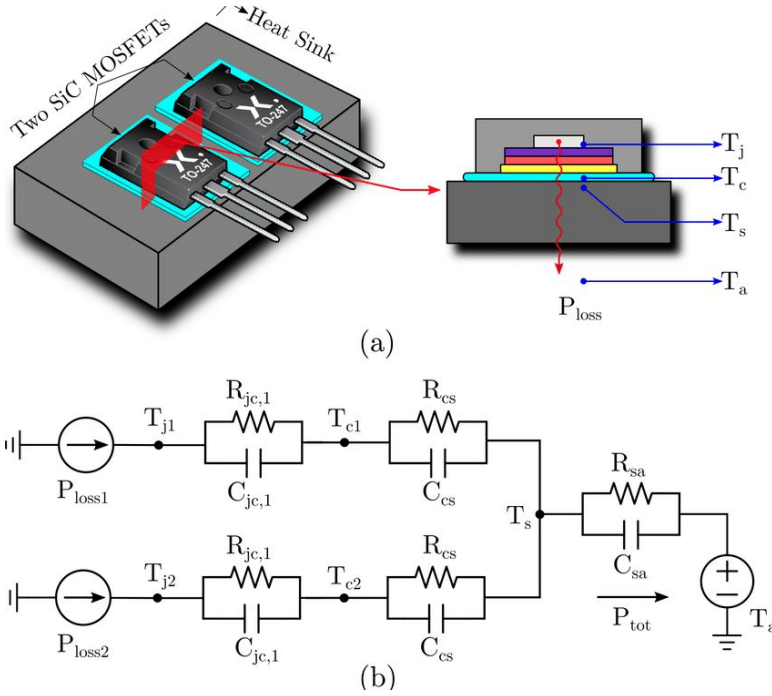






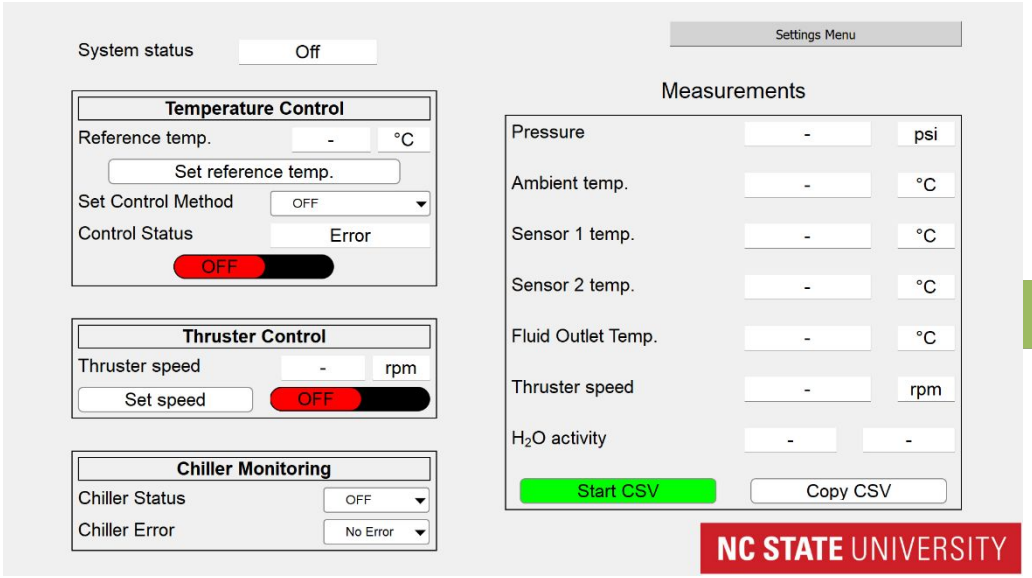
Challenges of PTPE for Subsea Applications

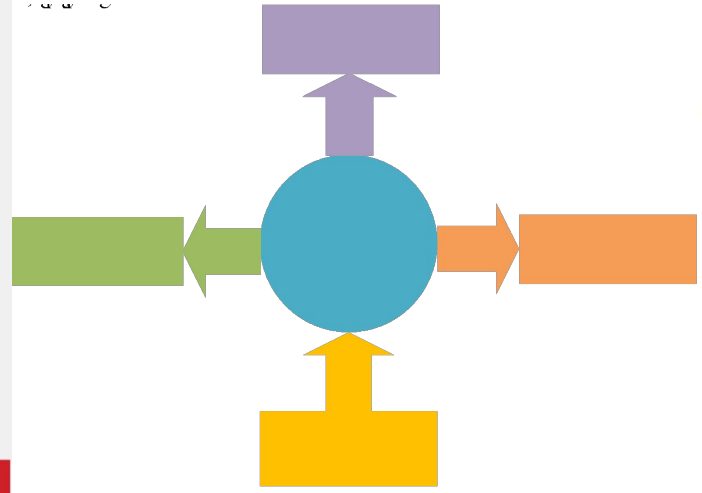
- Lack of pressure-related component models
  - Component pressure model
  - Sample sizing
  - Subsea temperature environment
- Modeling and simulation gap
  - Co-simulation of pressure-thermal-electrical simulation
- Device packaging and design
  - Voidless design challenge
  - Thermal management challenges
  - Insulation and dielectric strength challenges

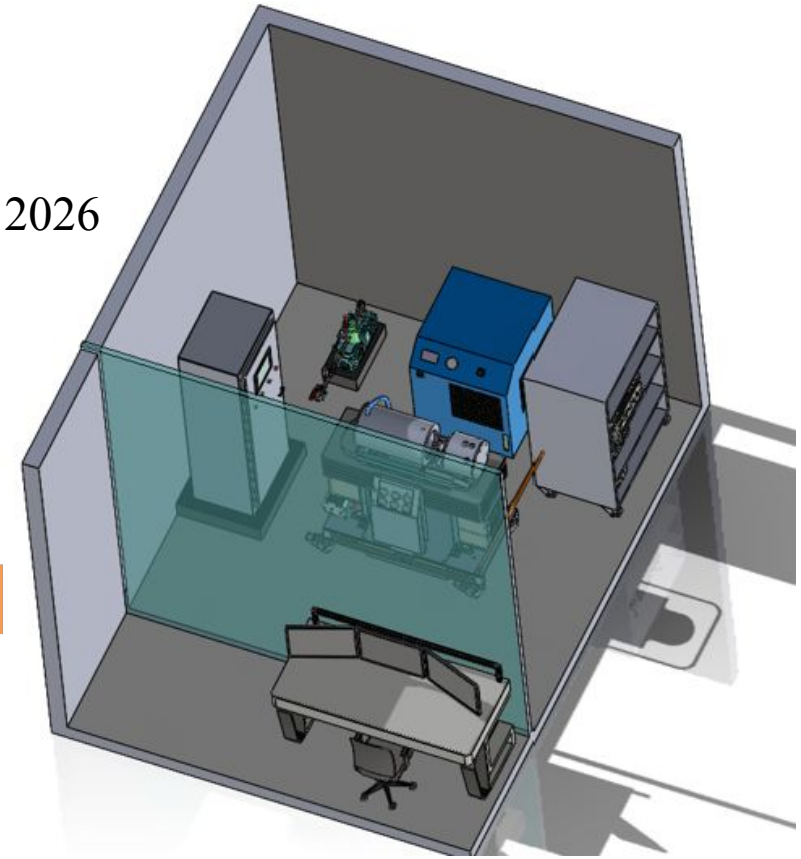


Research on PTPE at NCSU (NSF Supported)

- NSF funded project – develop an automated test station for pressure tolerant electronics
  - Development of live pressure testing capability
  - Remote and autonomous operation in a fully-controllable environment
  - Pressure range: 1.4×10^{-3} to 10,000 psi
  - Ambient temperature range: -10ºC to +40ºC
  - Voltage and current range: 3 kV, 30 A
  - The station will be ready for energized pressure testing by the end of 2025/early 2026

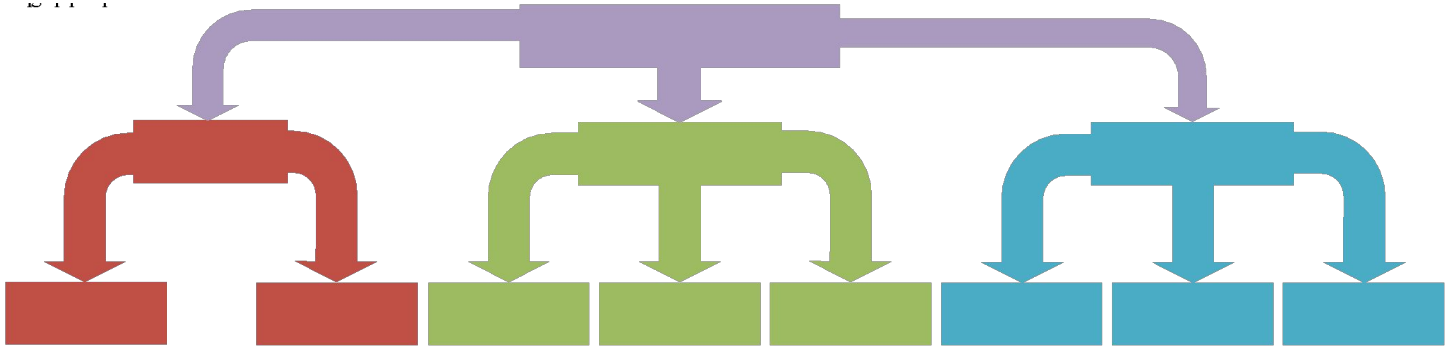


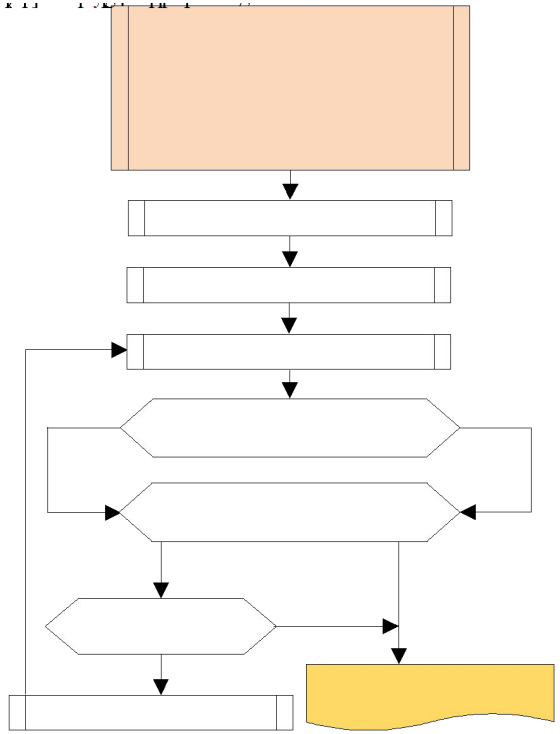


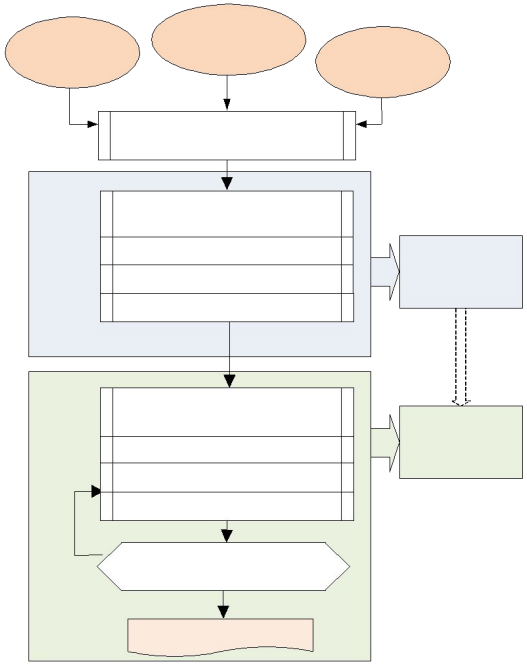


Research on PTPE at NCSU (NSF Supported)

- Power electronic device characterization
  - Benchmark testing
  - Passive pressure testing
  - Live pressure testing







But it is a long way to go!!!!!!


ANY
QUESTIONS?