

# Design and Development of a Fluid Immersion Cooled, SiC MOSFET, 37.5 kW, Bi-Directional Motor Converter

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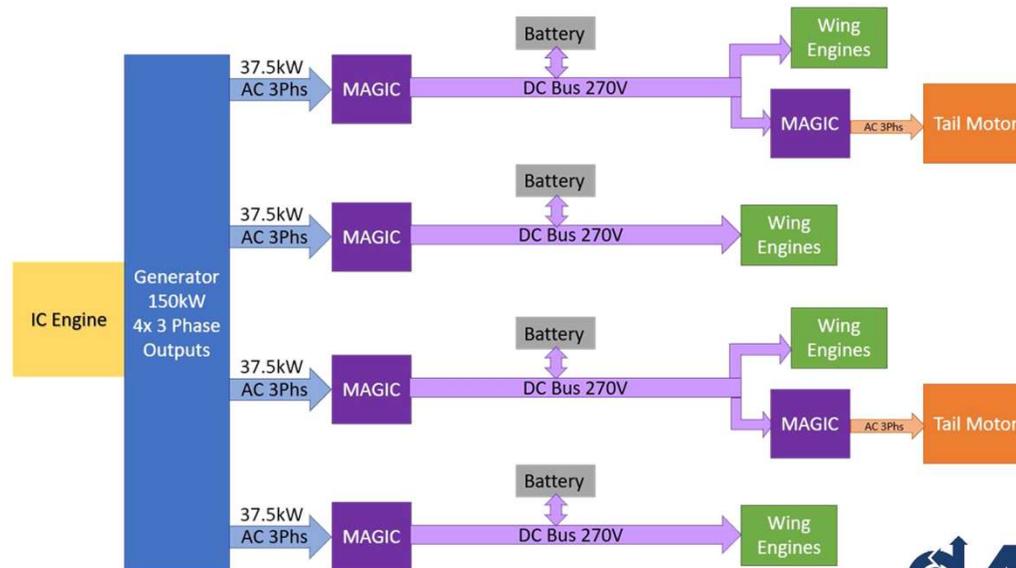
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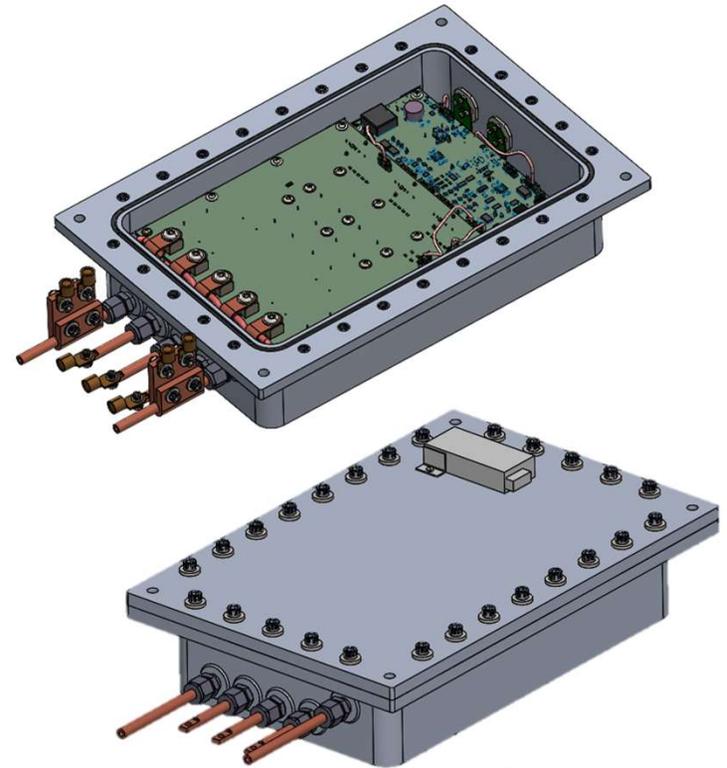
# 25% Scale SUSAN Aircraft Concept

- Sub-sonic Single Aft eNgine (SUSAN)
- Motor And Generator Intelligent Converter (MAGIC)
- Concept power architecture of 25% scale aircraft



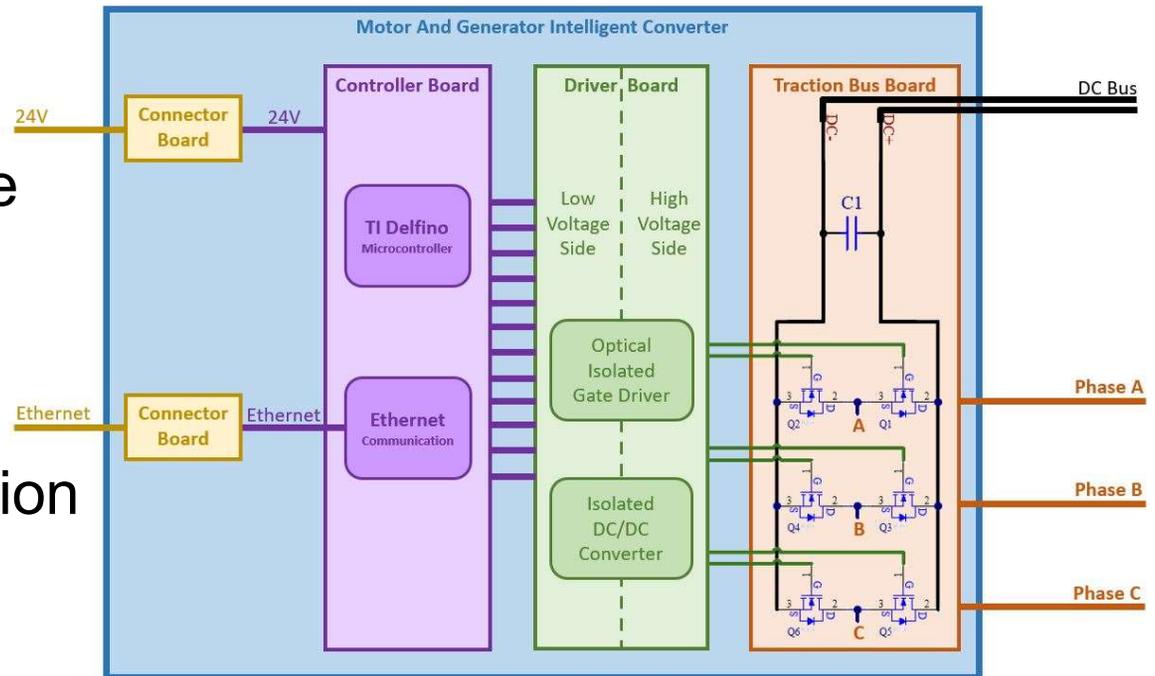
# MAGIC Key Objectives

- 37.5 kW AC
- 270 V DC
- Bi-directional power conversion
  - DC to AC, and AC to DC
- SiC MOSFETs
- Immersion cooling via PAO
  - Utilize combination DC + fluid lines
    - HiACT project (High-Power Advanced Cable Technology)
  - Pressurized to 50 PSIG



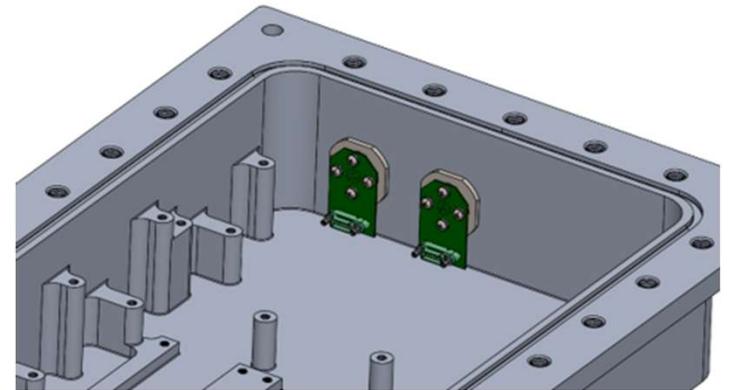
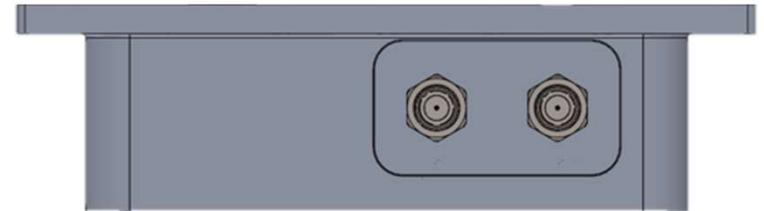
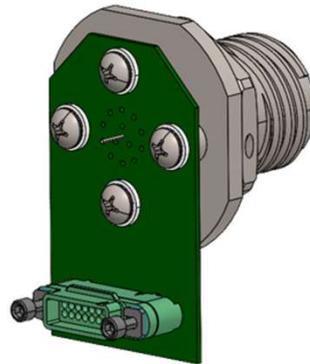
# Electrical Design

- Silicon Carbide (SiC) MOSFET modules
- Optically isolated gate drivers
  - Low coupling capacitance
- Ethernet communication
- TI Delfino microcontroller
- Code generation



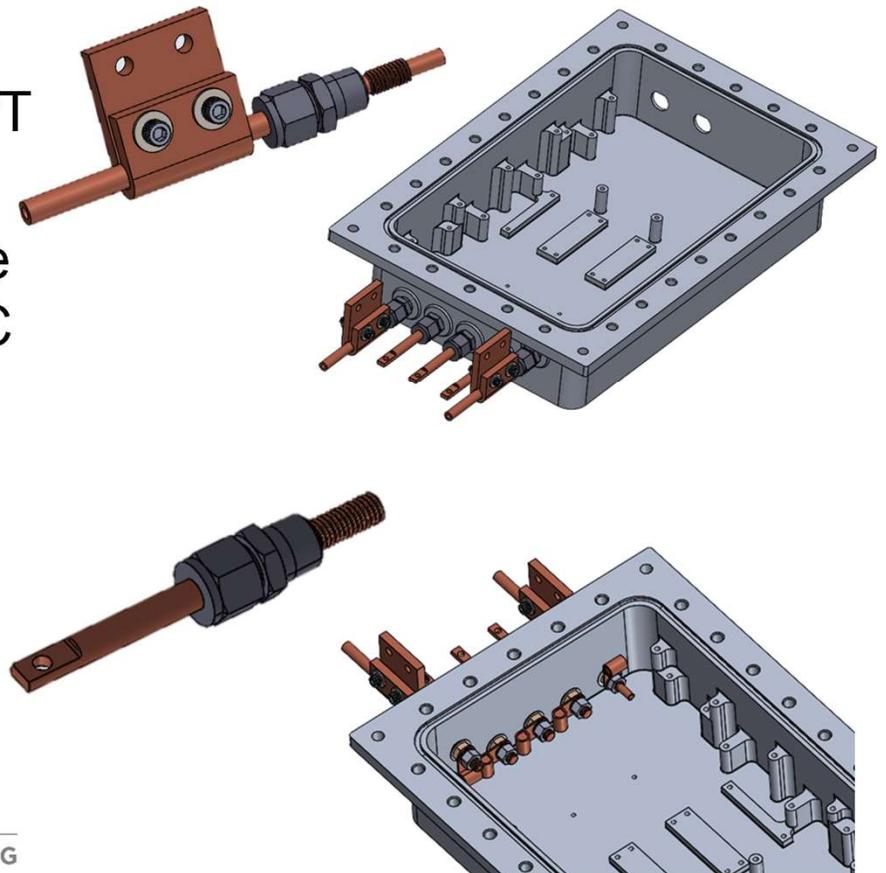
# Low Power External Connectors

- Glass sealed hermetic connectors for avionics power and comms
- Viton o-ring for PAO compatibility



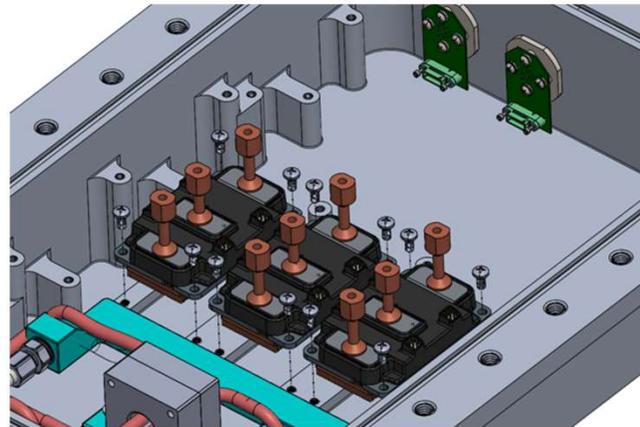
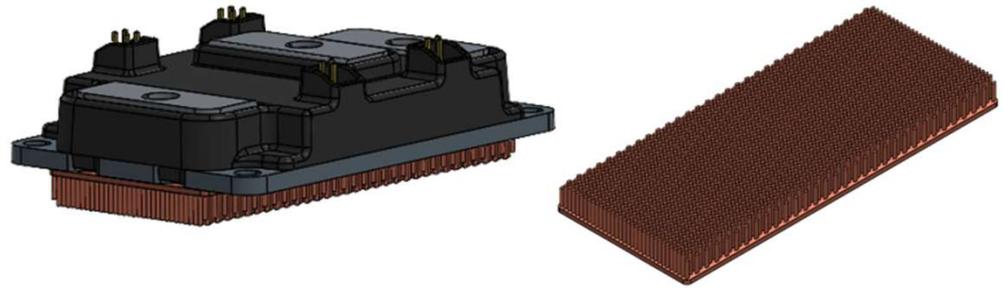
# High Power External Connectors

- **Combination DC + Fluid lines**
  - Copper tube through a plastic NPT tube fitting
  - Copper clamp on tube outside the box & threaded tube inside for DC
  - Adapted from HiACT project
- **AC lines**
  - Copper rod through plastic NPT tube fitting
  - Hole on rod outside the box & threaded tube inside



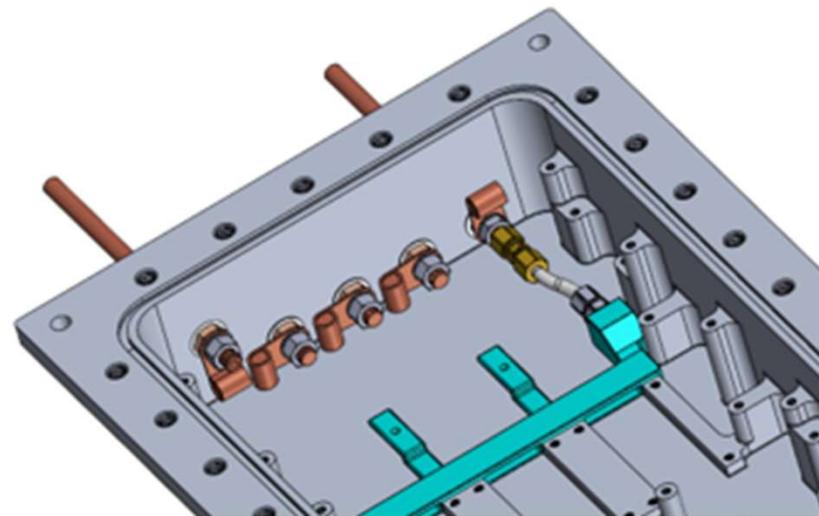
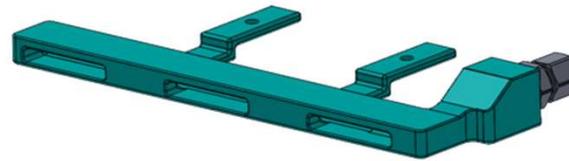
# MOSFETs

- 3 SiC MOSFET modules, 2 switches in each
- Copper pin fin heat sinks on each FET to increase surface area for more effective cooling
- FETs sit on rails



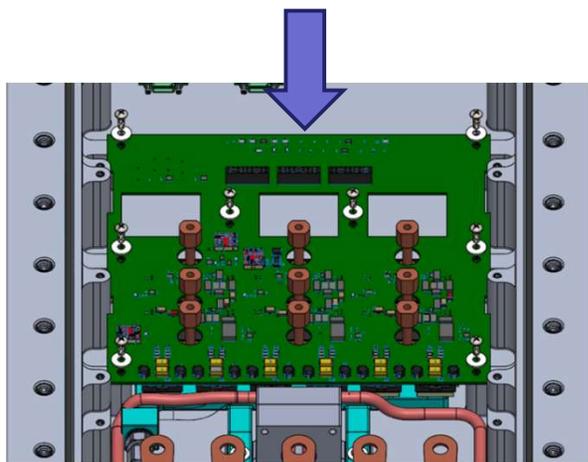
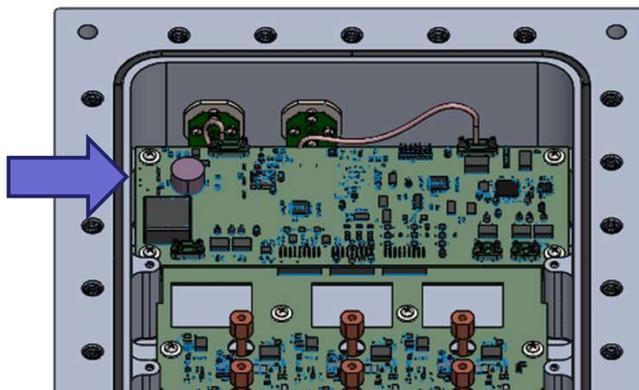
# Manifold

- 3D printed manifold to direct fluid underneath MOSFETs
- Fluid enters through vertically higher tube and exits through lower tube
- Manifold attached to fluid output of box to pull fluid underneath the MOSFETs

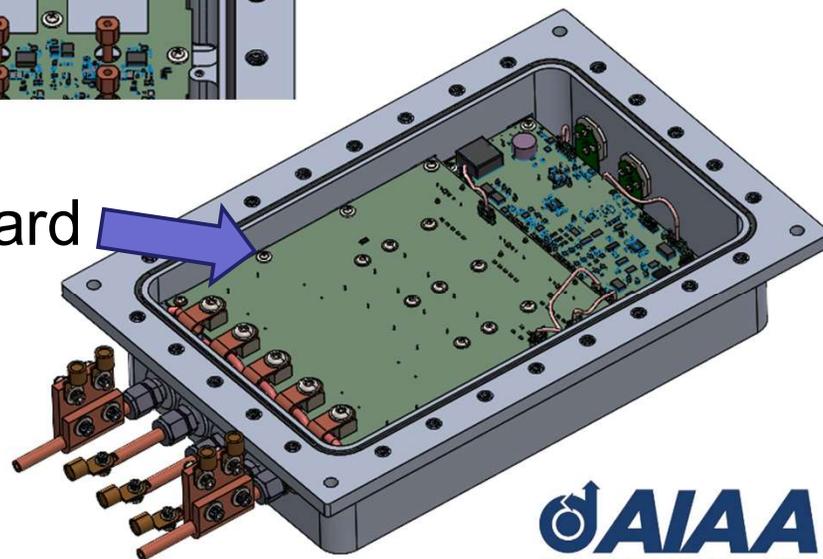


# Circuit Boards

Controller Board  
Driver Board



Traction Board



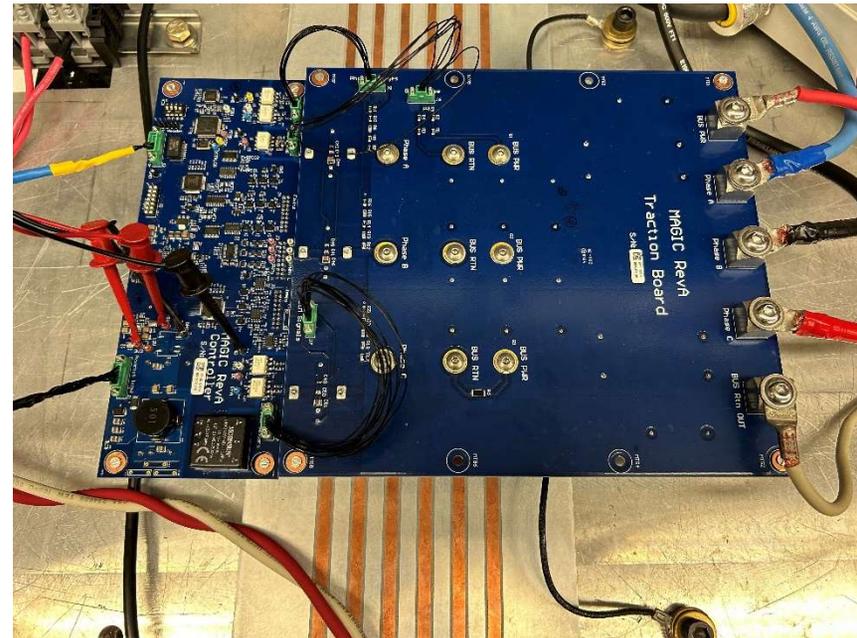
# Software and GUI

- In-house developed GUI
- Controls capable of bi-directional converter operation
- Code generation for rapid prototyping



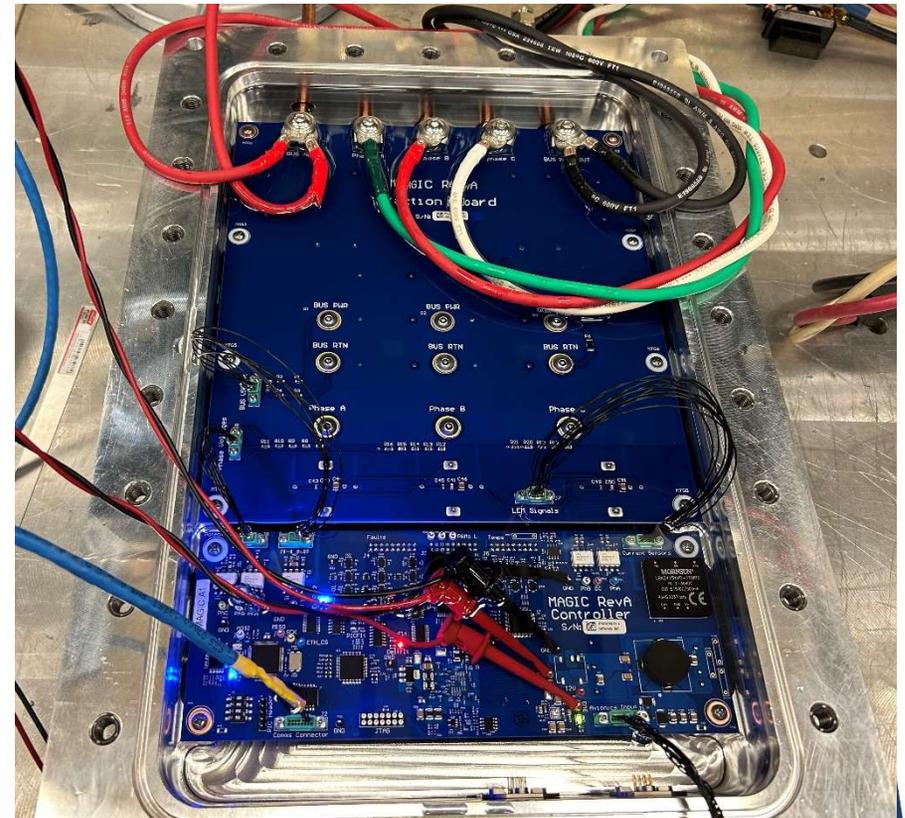
# Cold Plate Testing

- Lab testing with cold plate build of inverter
- Achieved full DC bus voltage of 270 V and AC current of 140 Arms
- Spun COTS motor with dynamometer to produce 10 kW



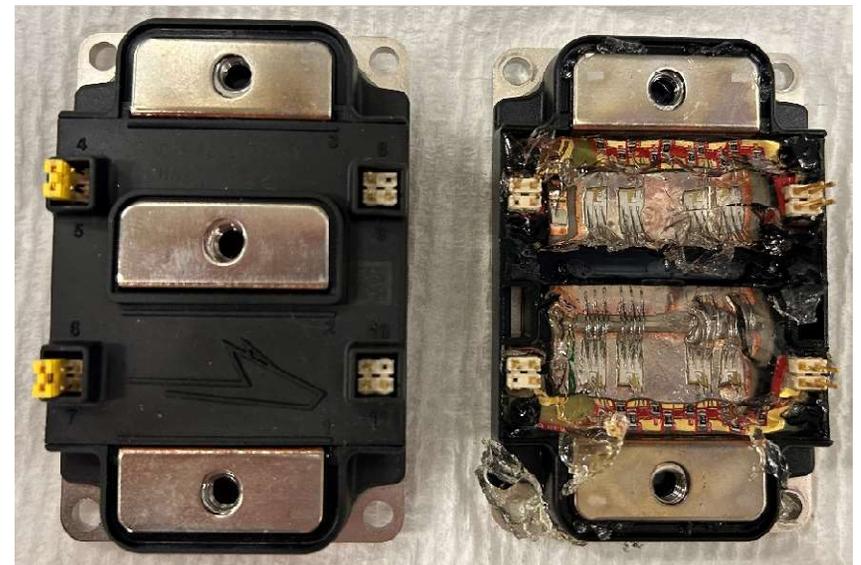
# Stagnant Fluid Immersion Testing

- Converter assembled in enclosure and PAO fluid added
  - Opticool-MIL 87252
- Remained in fluid for ~2 months
- Full DC voltage, AC current, and 10 kW operation again successful



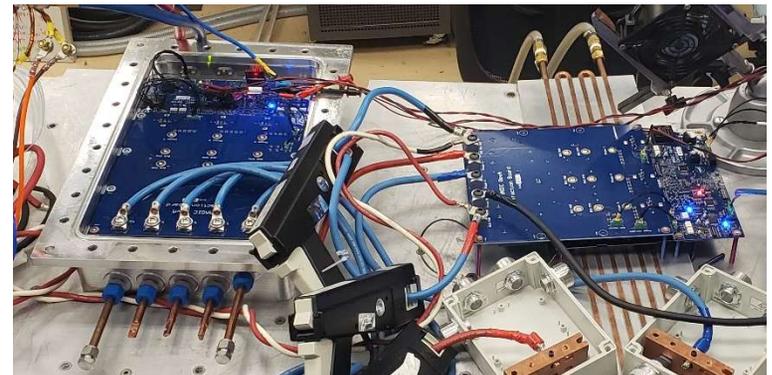
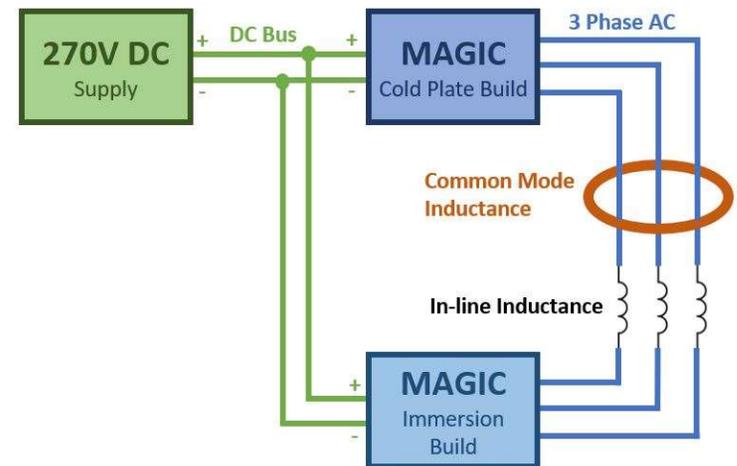
# PAO Incompatibility

- Upon draining the box, a clear goeey substance was seen coming from MOSFETs
- MOSFET modules are not completely sealed and contain silicon based potting material
  - Silicon is not compatible with PAO and therefore was breaking apart
- Determined were OK for short term use but not for long term or flight use



# Full Power Testing

- Pump-back testing was conducted to successfully achieve full power operation of 37.5 kW
  - Two MAGIC units connected together with a DC power supply to supply losses
  - Built up circulating current between units without needing power supply or load bank that can handle 37.5kW
- Needed to reduce common-mode current between converters
  - Added common-mode inductance



## Conclusions and Future Plans

- NASA GRC has developed a 37.5 kW, bi-directional, fluid immersion cooled motor converter.
- The design has flight heritage in both hardware and software.
- Future testing plans include fluid pumping testing to monitor component and fluid temperatures throughout the unit.

## Acknowledgments

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