SiC Based Power Conversion/Conditioning System for a High Power/Low Duty Cycle Weapon System

Presenter:
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Background: Platform Integration
Challenges of High Power Systems

• **Weapon System Power & Loads:** Future Advanced Sensors and Weapons Systems, including Directed Energy Weapons (DEW) require significant amounts of electrical power (pulse and stochastic loads) to operate, and increased thermal management.

• **Platform Limitations:** Military platforms cannot support these dynamic loads. These weapon systems cannot interface directly to the vehicle’s electrical power system due to these fluctuating combat loads, and the need to buffer and maintain stable electric power on the vehicle.

• **Platform Interfaces:** The power conversion & energy storage interface systems should be developed in parallel with the DEW System development.
Problem Statement

Project Description / Technical Challenges

• Solve technical challenges associated with developing and demonstrating a high density, high efficiency power conversion and conditioning device for high power, low duty cycle, rotary wing aircraft-based applications.
  • Robustly provide requisite pulse power to the weapon system,
  • Buffer aircraft electrical distribution system from impact of loads. e.g. MIL-STD-704F: AIRCRAFT ELECTRIC POWER CHARACTERISTICS
  • Meet Space, Weight, Power and Cost (SWaP-C) as well as Thermal Management Systems (TMS) constraints.
Who’s Problem – Who Benefits?

- **Navy/USAF/USA/DARPA/MDA/DoD Primes Problem:**
  - Power Conversion & Conditioning System (PCCS) interface integration between Laser Weapon Systems (LWS)/High Power Electromagnetic (HPEM) weapons and platforms must be addressed in parallel with weapon system development.

- **Warfighter Benefits – Game Changer!**
  (same arguments as for LWS/HPEM development):
  - Enable defensive and offensive non-kinetic attack options
  - Provide operational flexibility
Baseline Laser Technology

• Prototype LWS Developments (chemical to electrical)
  – Long history of chemical laser Development (~1960’s start)
  – Recent application of commercial (electric) fiber lasers
  – Continuing development of Free Electron Laser (FEL)
  – Demonstrations use temporary electrical sources and available COTS power conversion hardware

• No fielded Program of Record (POR) systems to date
  – No immediate program requirement for robust, integrated PCCS hardware interface designed to Military requirements, and meeting SWaP-C constraints.
NAVAIR SBIR (N122-114)  
Requirements

Develop an advanced Power Conversion/Conditioning System (PCCS) that will buffer the Aircraft’s generation and distribution system from the effects of high power level pulse loads such as Lasers.

- Pulsed power duty cycle: 10 to 25%
- Pulsed power duration: ≥30s
- Pulsed power level: 100 to 150kW per module
- Input voltage: 115Vac 400Hz 3Φ or 270Vdc
- Output Voltage: 270 to 500Vdc nominal
  ±1 to ±5% tolerance
  6V ripple maximum
- Support parallel operation of modules to provide higher power levels.
- Module can consist of sub modules of lower power level.
RCT Solution
Representative Duty Cycle

- SiC based PCCS with constant source power input and Energy Storage Device (ESD) to store power with Charge and Discharge naturally resulting from Source/Load Power Imbalance

\[
\begin{align*}
P_{\text{INPUT}} & = 25\text{ kW} \\
& \text{Continuous} \\
P_{\text{OUTPUT}} & = 100\text{ kW} \\
& 25\% \text{ Duty Ratio} \\
& 30\text{ Seconds} \quad 120\text{ Seconds} \\
& 90\text{ Seconds}
\end{align*}
\]
RCT Solution - Details

• SiC MOSFET Based PCCS
• LIC Module as the ESD Building Block

Characteristics:
• Input Power: 33.3kW Maximum
• Pulse Power Capability: 100kW Average, 200kW Peak
## Performance Features

<table>
<thead>
<tr>
<th>Features</th>
<th>Advantages</th>
<th>Benefits</th>
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<tr>
<td>Modular</td>
<td>Supports parallel operation of modules</td>
<td>Provides for higher power levels</td>
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<td>Module can consist of sub modules of lower power level.</td>
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<td>High Efficiency</td>
<td>Efficient use of platform power</td>
<td>Reduced platform fuel consumption/increase weapon cost effectiveness</td>
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<td>High Power Density</td>
<td>High Power to volume/weight ratio</td>
<td>Takes up less space/weight for a given power level. Space, Weight and Power (SWaP) are critical for all military applications</td>
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Generic Duty Cycle Simulation

- ESD Internal DC Bus Voltage
- 270Vdc Output Bus Voltage
- AC Input Voltage
- AC/DC Input Converter Current
- DC/DC Output Buck Converter Current
- Power Drawn by the Pulsed Load
- Power Delivered by the AC Distribution System

400Hz, 120/200Vac Input Case: Constant Power Pulse, Multiple Pulsed Load Cycles

Distribution Statement A - Approved for public release; distribution is unlimited, as submitted under NAVAIR Public Release Authorization 2017-299
Comparison - Other Options

1. Dedicated Fuel Cell Power System
   - Currently being studied by AFRL (Kirtland) still requires a PCCS
   - FC start and response time to load pulses needs to be addressed.

2. Dedicated Generator system for the weapon.
   - Would be big, heavy, probably involve another prime-mover

3. LARGE energy storage element - charged before the mission, and then used directly to fire the weapon.
   - Very large and heavy...number of shots would be limited by initial energy storage capacity.

4. Beef up existing aircraft generation & distribution system to handle the highest power requirement.
   - This would be oversized and overkill, big, heavy, inefficient systems.

5. Do nothing
   - Would cause significant disturbances on the aircraft distribution system, leading to unacceptable adverse affects on all aircraft loads.
   - Would increase failure rate of generator systems, leading to increased maintenance hours/cost associated with generator repair or replacement

Other Options – Heavier with Negative Aircraft Impact
Current State of Development

- Design Complete
- Manufacturing Complete
- Factory Testing in Progress

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<tr>
<th>Contract Number: N68335-14-C-0275 Ending on: August 31, 2017</th>
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<td><strong>Milestone</strong></td>
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<tr>
<td>Preliminary Design Review (PDR)</td>
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<tr>
<td>Critical Design Review (CDR)</td>
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<tr>
<td>PCCS Prototype Manufacturing</td>
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<tr>
<td>PCCS Prototype Testing</td>
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Transition to Fleet

• No Government Program of Record at this time
• USA/USAF/USN/SOCCOM/MDA development programs [e.g. AC-130J, Apache, High Energy Laser Mobile Test Truck (HELMTT), USAF SHiELD] are potential transition opportunities being pursued.
Partners Needed/Sought

• **RCT will sell/license technology to:**
  – Defense Primes/Integrators (Boeing, General Atomics, LMCO, NGC, Raytheon, etc.)
  – Defense Weapon Systems providers
  – Commercial customers

• **Expertise/capabilities we seek**
  – Defense/Aerospace production & system integration experience (qualification and support)
  – Contract manufacturing
Company’s Role

• RCT can design & manufacture
  – PCCS System – limited production capability

• Open to all types of arrangements
  – Licensing
  – Partnering
  – Targeted Business Sale
  – Seller/Buyer
Company Overview

Leading developer of advanced, high power/high power density electronics & motors/drives for demanding applications in the defense/aerospace sector

• Contract and IR&D
• Core Capabilities:
  – Power Electronics and Control Systems
  – Energy Conversion and Distribution
  – Packaging and Thermal Management
  – Electric Machines and Drives
  – Active Magnetic Systems
• Linthicum, MD
  – Near BWI Airport
• ISO 9001:2008 certified
Other Developments

**Energy Storage Module**
- **800kW (ONR)**
- 2018 Navy SDTS Laser Demo

**SiC Traction Motor Drive**
- **220kW (TARDEC)**
  - Power density: 25.1kW/liter
  - Weight: 11.34kg (25lb)

**150kW Cap Charger (ARL)**
- 0-10kV DC in 2 secs

**High Temp EM Actuator & Electronics (AFRL)**
- 10,500 lb;
- 4” slew, 1 sec slew rate
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Backup Slides
Business/Product Areas

Rotating Machinery Types

- Traction
- Servo
- Generator-only

**Products:** Motors, Motor/Gen; ISG; APUs; High Speed Machinery; Rim-Driven

**Types:** PM/Induction/Switched Reluctance, Hybrid

Systems – Serve as Prime for the following

**Products:** Micro Grids; Pulse Power; PHEVs; Energy Storage, AC Power Distribution Systems; Isolated & protected DC distribution; Vehicle/Ship/Aircraft/UUV, Minesweeping etc Power Subsystems; Propulsion systems.; Off-board power Distributed energy (PV, Wind, Tide, Current) Electro-Pneumatic Transducers (EPT)

Converters (DC output)

- Bi-Directional; Unidirectional; Isolated; Non-Isolated; Boost/Buck
- Battery/bus interface bi-directional;
- HV pulse capacitor rapid charging;
- Battery Chargers
- High current DC power
- SSCM

Inverters (AC output)

- Specialty Motor Drives
- Fuel Cell, PV, Battery to AC (1 & 3 phase)
- Bi-Directional AC conversion;
- Freq Converters;
- Utility interface
- SSIM