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

Presenter:
Dennis Mahoney VP, Business Dev.
1306 Concourse Drive, Suite 310, Linthicum, MD 21090
2201 Cooperative Way, Herndon, VA 20171

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.**

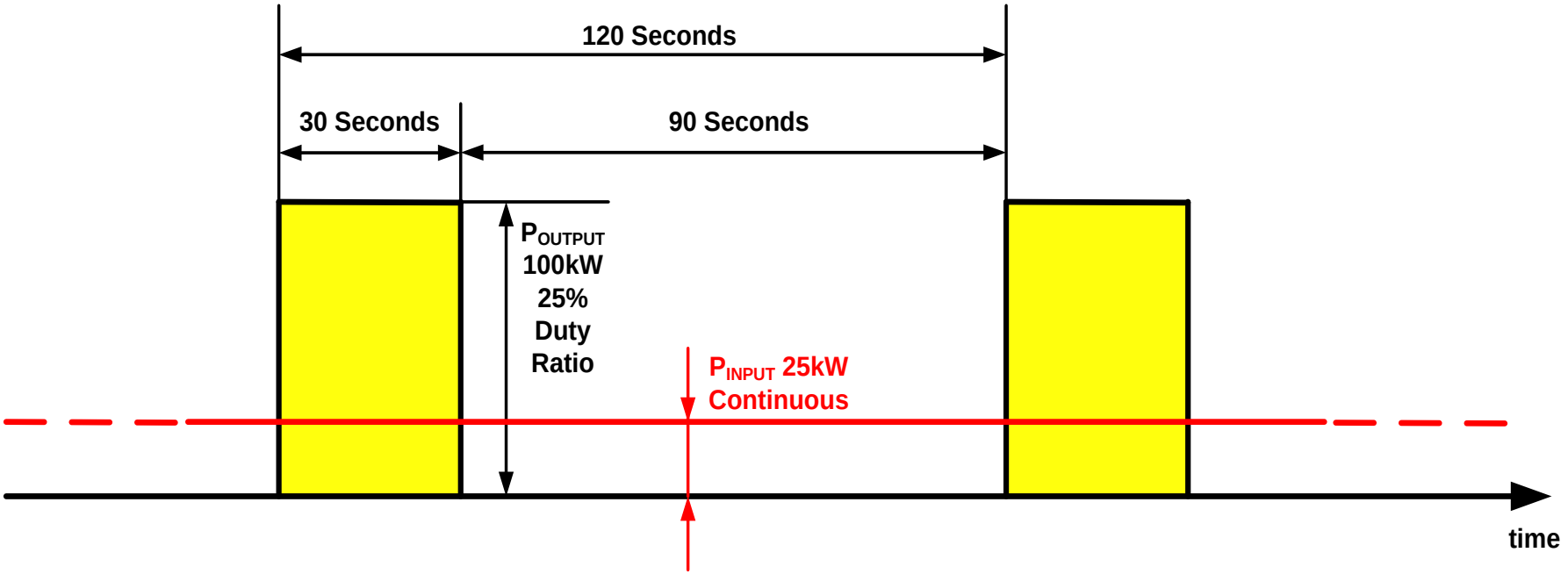
NAVAIR SBIR (N122-114) Requirements

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**

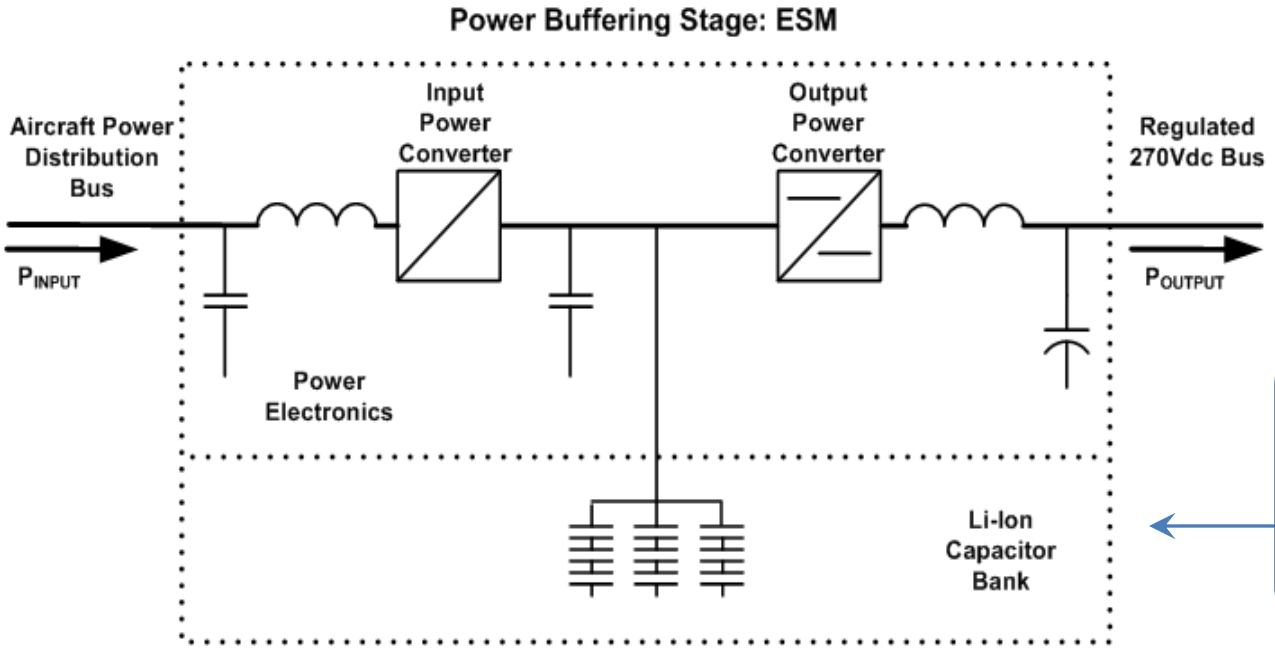


RCT Solution - Details

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

Characteristics:

- Input Power: 33.3kW Maximum
- Pulse Power Capability: 100kW Average, 200kW Peak

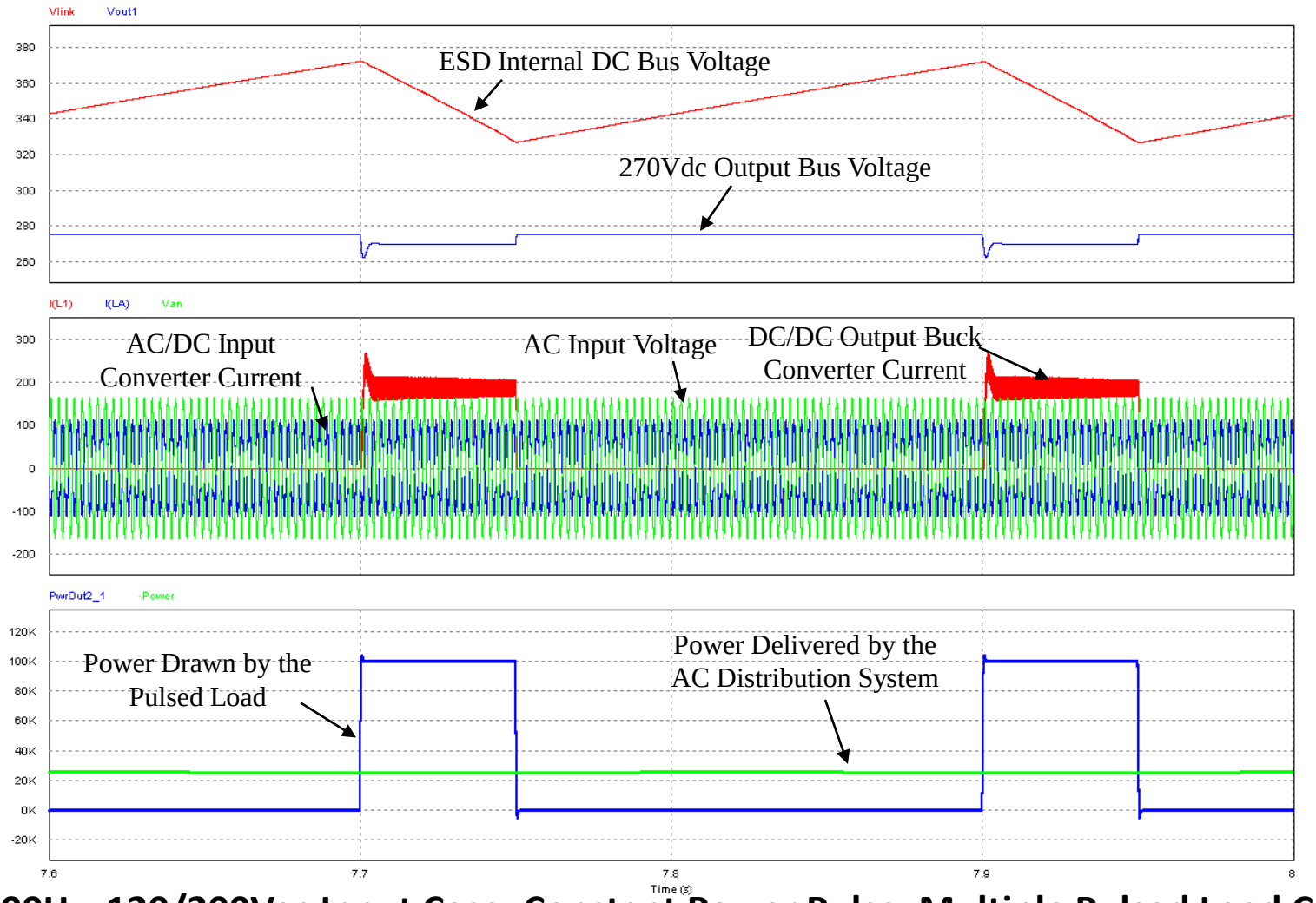


Lithium - Ion Capacitor (LIC)

Performance Features

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

Generic Duty Cycle Simulation



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

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

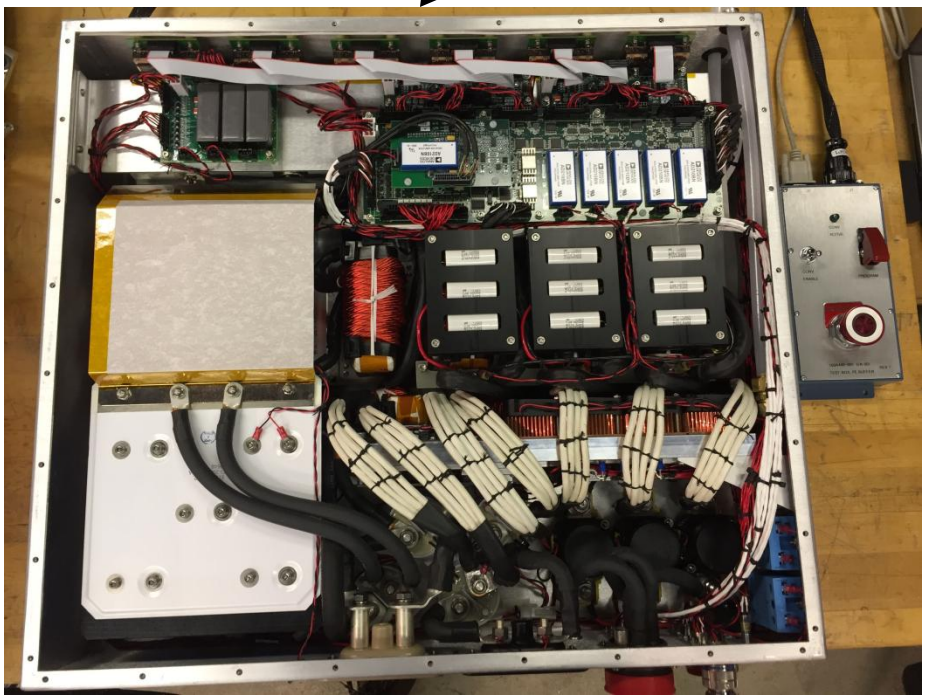
Current State of Development

- **Design Complete**
- **Manufacturing Complete**
- **Factory Testing in Progress**

Contract Number: N68335-14-C-0275 Ending on: August 31, 2017					
Milestone	**Risk Level**	**Measure of Success**	**Ending TRL**	**Date**	**Status**
Preliminary Design Review (PDR)	Low	Completed PDR	2	Nov-14	✓
Critical Design Review (CDR)	Med	NAVAIR approved CDR	3	Apr-15	✓
PCCS Prototype Manufacturing	Med	Complete Manufacturing	3	Nov-16	✓
PCCS Prototype Testing	Med	Successfully Complete Factory Testing	4	May-17	50%

Current State of Development

PCCS Power Electronics



Energy Storage Device

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
  - US Navy/US Air Force/US Army/NASA
  - 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

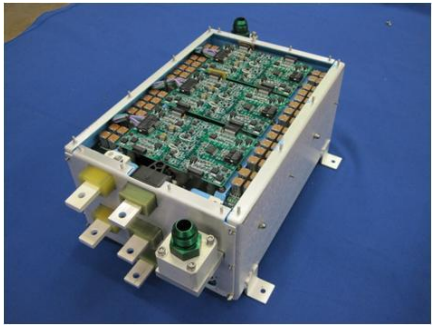
Leading developer of advanced, high power/high power density electronics & motors/drives for demanding applications in the defense/aerospace sector

- **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

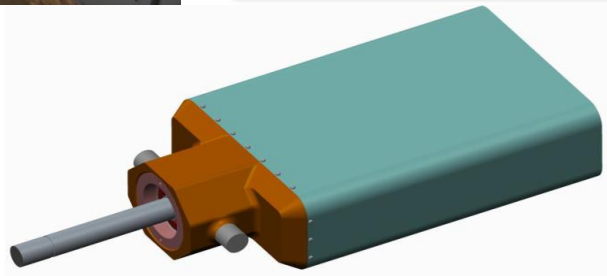
Energy Storage Module
800kW (ONR)
2018 Navy SDTS Laser Demo

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



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

High Temp EM Actuator & Electronics (AFRL)
10,500 lb_f; 4” slew, 1 sec slew rate



Contacts

Dennis P. Mahoney, PE
VP, Business Development
(w): (410) 694-8044
(c): (508) 735-8920
dmahoney@rct-systems.com

Steve Cobb
President
(w): (410) 694-8051
(c): (508) 320-8063
scobb@rct-systems.com

RCT Systems, Inc.
Power Systems Division
1306 Concourse Drive, Ste 310
Linthicum, MD 21090

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