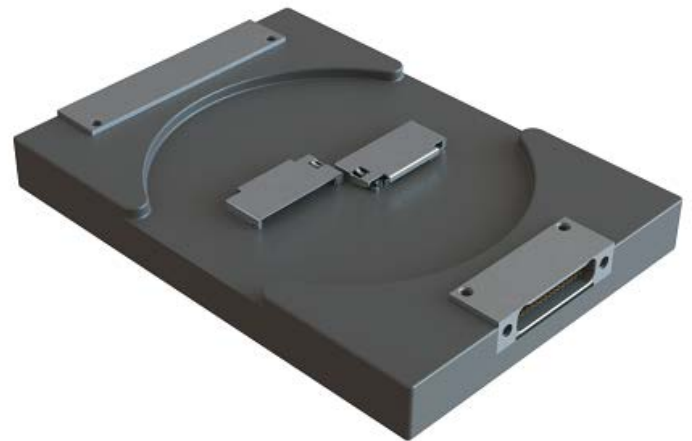


MD7-PRO DIGITAL SHM SYSTEM

Off-the-shelf in-service monitoring techniques utilize a dense web of analog sensors connected by individual wires routed to centralized acquisition and processing units. This traditional approach carries a significant weight penalty, can be complex to instrument and is susceptible to EMI. MDC has developed the MD7-Pro System, a digital Structural Health Monitoring (SHM) solution, where each element is networked on a serial data and power bus. Benefits of this distributed approach include higher fidelity data through digitizing at the measurement point, reduced computational burden through local signal processing and feature reduction, and overall minimal mass through the consolidation of cables and connectors.

ACCUMULATION NODE

The Accumulation Node serves as front-end interface to the SHM network. Measuring 55 x 40 x 5 mm with a mass of 20 g, it accepts 28VDC to distribute power for up to 100 daisy-chained Acquisition nodes, along with relaying commands, facilitating synchronization, and storage of the resulting data. It can be programmed to run autonomously, communicate over Ethernet, or accommodate flexible provisions for other wired and wireless protocol. In addition, the Accumulation Node offers 16 digital inputs and boasts 64-GB of static memory. A powerful FPGA with an ARM core processor can be programmed to execute embedded diagnostic algorithms or prognostic and health management (PHM) logic.

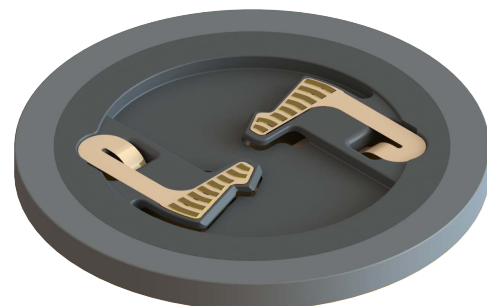


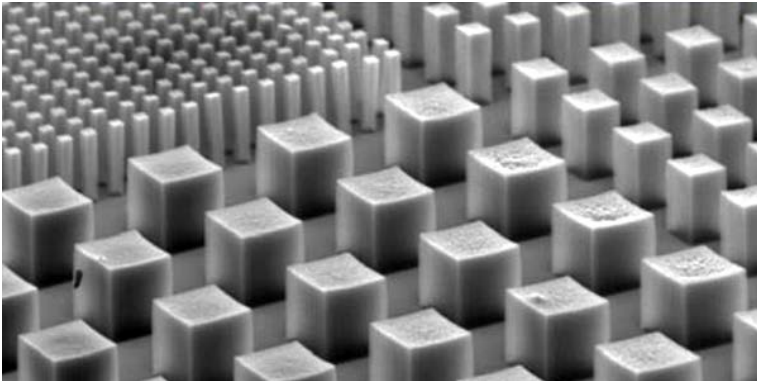
ACQUISITION NODE

The MD7-Pro system can be efficiently expanded by daisy-chaining Acquisition Nodes. Measuring 50 x 40 x 5 mm with a mass of 15 g, they are a direct replacement for traditional instrumentation such as oscilloscopes and function generators, enabling distributed data acquisition and signal processing. Each Acquisition Node provides a 20 Vpp 20 MSample/sec arbitrary function generator, 6 independent 12-bit channels of up to 50 MSamples/sec with programmable gain up to 500, plus 8 multiplexed 16-bit channels at 1 MSamples/sec with 2 Gbit of DDR3 memory. A triaxial accelerometer and temperature sensor are also integrated into each device.

STRUCTURAL SONAR ARRAY

Traditional SHM methods require dense sensor meshes to precisely resolve damage position. Thus, MDC has patented the Structural Sonar Array, a PZT beamforming package to facilitate both passive acoustic emission and active guided wave scans. From a single node position, a probability of damage map can be generated in response stiffness changes detected by a guided wave scan, or due to the passively captured acoustic response from an impact event. Results from multiple nodes can be combined synchronously and/or asynchronously to enhance resolution.



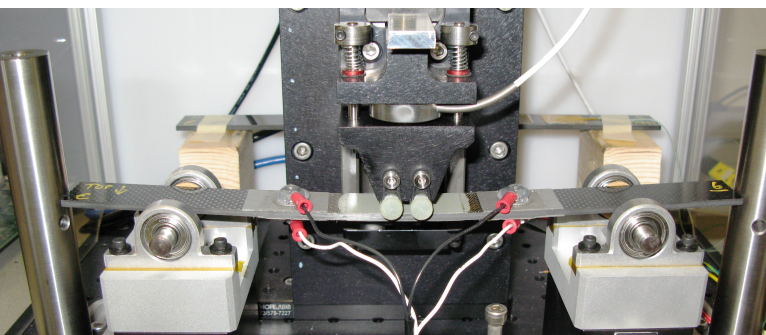


NANO ENGINEERED FUNCTIONALITY

Carbon nanotubes (CNT) have demonstrated the ability to provide multi-functional capabilities to host materials due to their electrical and thermal properties, such as lightweight replacements for wire, ESD/EMI/lightning-strike protection and heat sinks. Most work at MDC has focused on tailoring optimized resistivity profiles. By varying sheet resistance between 5 and 500 Ohm/sq, they can provide an efficient means for generating heat. Similarly, they can be used as an embedded sensor network for monitoring structural health & usage. While MDC does not produce CNT, we have established reliable modeling and integration processes to incorporate COTS CNT into robust nano-engineers components.

ICE PROTECTION SYSTEMS

Ice Protection Systems (IPS) anti-ice to prevent the formation of ice and/or deice to remove ice build-up from aerosurfaces. Current thermo-electric methods have proven unreliable, lacking durability and causing manufacturing issues for composites. MDC has demonstrated that CNT can be integrated with both composite and metallic aerosurfaces as an effective means for ice protection. They can provide equivalent performance as metallic heaters at a fraction of weight (1%), and have the potential for significant power savings. MDC has performed ice-tunnel testing across the FAA recommended icing envelope, and integrated their CNT-IPS design into a 3-meter full-scale UAV wing section.

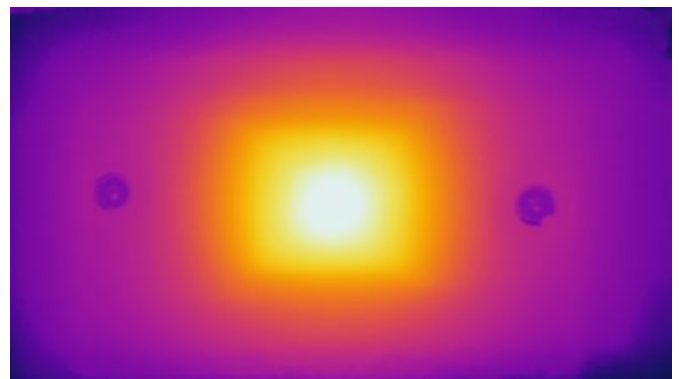


HEALTH & USAGE MONITORING

Due to piezoresistivity, CNT provide an effective means for usage monitoring. Individual CNT represent sensing elements, exhibiting a resistance value that varies with strain state. Once integrated into a component and loaded, the CNT can be calibrated to match traditional foil strain gauge results, while sustaining higher strain (12,000 $\mu\epsilon$) and temperature levels (550 °C). Furthermore, the dynamic response of CNT allow them to not only measure static strains, but capture stress waves due to an impact event. Finally, as damage can be represented as a permanence in local residual strain, the CNT network can be used to assess the health of a component.

OUT-OF-OVEN CURING

Autoclaves heat convectively, meaning they heat air through a blower, which in-turn heats the surface of the composite. Since they contain a fixed volume of air, the cost to produce the heat remains fixed regardless of the size of part being cured, yielding much waste. MDC has demonstrated the use of CNT to conductively cure composites out-of-oven. Conductive curing costs scales with part surface area rather than autoclave volume, thus providing a path for reducing composite acquisition costs by up to 50%, while providing uniform properties with degree-of-cure feedback.



Revolutionary Power Generation



Airborne Systems



Mobile & Portable Power



Vehicle Technologies



Building & Grid Technologies

Bleed-Air Turbo Alternator

- Converts bleed-air to electrical power
- Lightweight • Low cost
- Simple integration • High reliability

Modular Power Unit

- Scalable MPU, 5-250kW ground or flight power
- Lightweight • Low cost • Fuel flexible
- Supports aircraft electrification initiatives

Primary eAPU

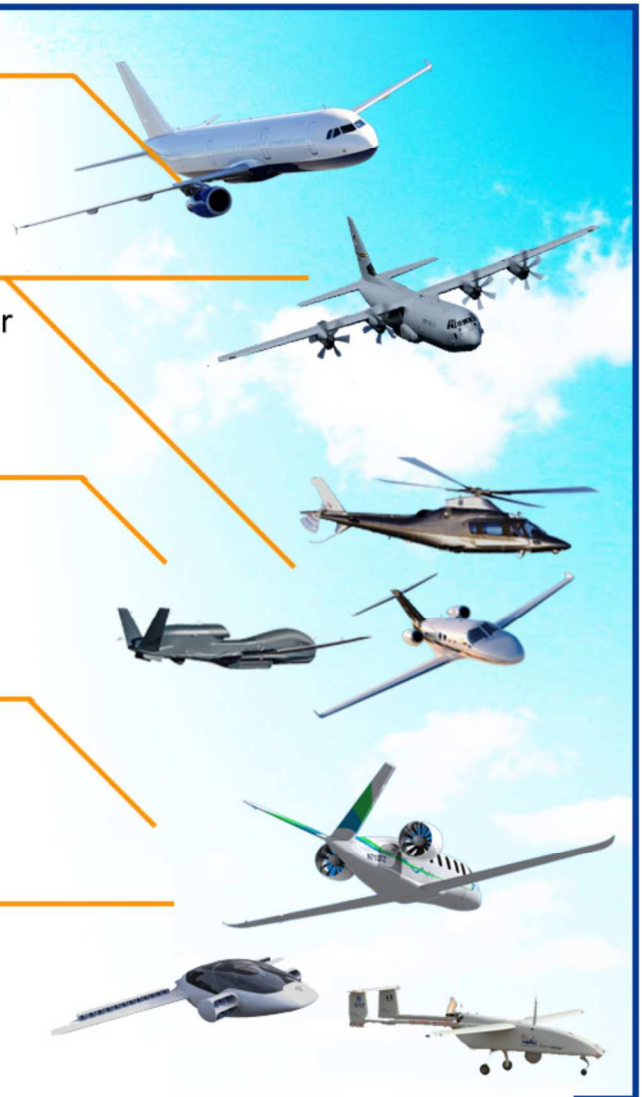
- Lightweight, Low cost alternative to state-of-the-art APUs (up to 250kW)
- Technology scalable for range of aircraft

Range Extender

- Enabler for electric propulsion era
- Low Emissions • Quiet • Compact
- Lower cost and maintenance than batteries

Backup Charging System

- Stow-away charging unit for ground operation
- Power density up to 4kW/kg
- Improves mission capability

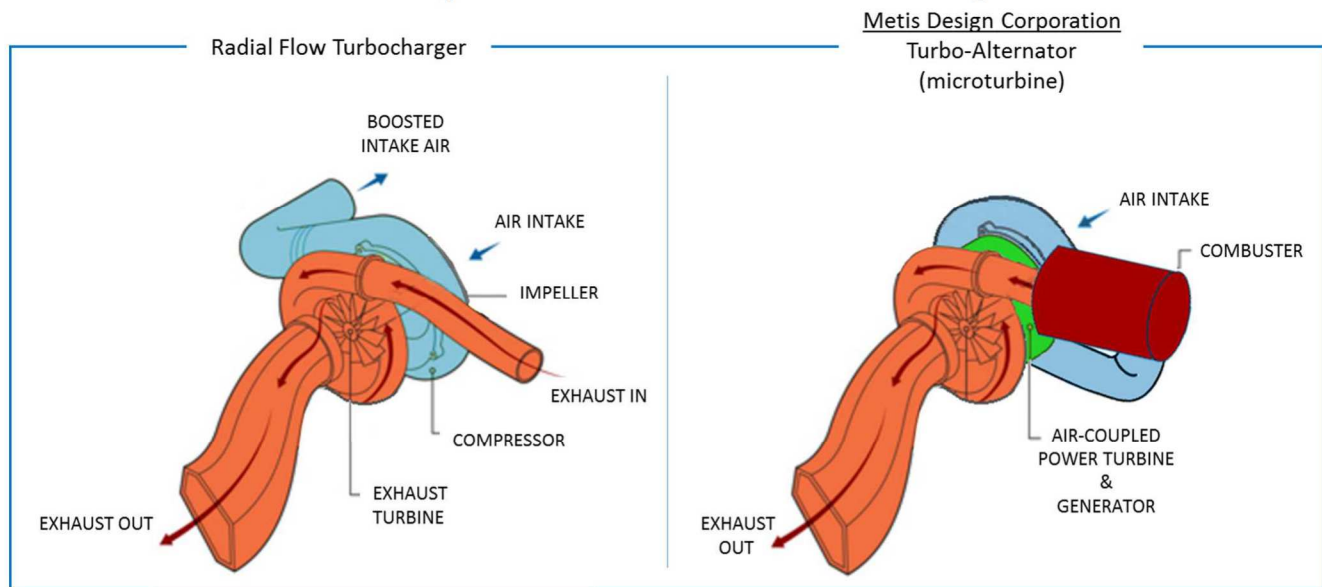




ADVANCED MICROTURBINE TECHNOLOGY

Innovation Summary

Metis Design has multiple patents covering a novel microturbine design that incorporates an air-coupled coaxial impeller (high-speed spool) and power turbine (low-speed spool) within the housing of a modified common radial flow turbocharger. This 'down-geared' power turbine enables the integration of a coreless axial-flux generator directly into the turbocharger housing, which is more compact and lower cost than any state-of-the-art generator configurations. The illustration highlights the commonalities of this revolutionary microturbine to a traditional turbocharger.



Technology Highlights

Reduced Size & Weight

- Air-Coupled technology eliminates additional envelop required for direct-drive designs
- Removes significant weight & volume associated with geared turbines

Lower Manufacturing Costs

- Innovative low-cost generator design
- Many mature parts and processes
- Reduced bill of materials

Emissions & Reliability

- Lower environmental impact and noise emissions than reciprocating engines
- Longer MTBF & total life than reciprocating engines

Hardware Development

Maturity

- Turbomachinery validation tests complete
- Low-risk design iteration ongoing
- eAPU laboratory validation planned for 2017

Prototype Specifications

- Design Power: 40kW
- Weight: < 13 kg (29 lbs)
- Volume: < 0.1 m³ (4 ft³)
- Fuel Type: LP

Scaled Technology Plan

- Output Range: 1-250 kW
- Specific Power: 0.75 - 4 kW/kg
- System Lifetime: > 25,000 hours
- Fuel Types: Diesel, Gas, Heavy Fuels, LP, CNG



Contact: rory@metisdesign.com

Current Solicitation

Metis Design Corporation is currently engaging with end-users and potential industry partners to ensure alignment between the current technology roadmap and market demands. Additionally, the Metis team is pursuing funding opportunities that will supplement ongoing NASA and ARPA-e government-funded programs and accelerate market readiness.

