



Auxiliary Power Units



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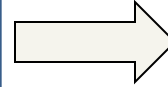
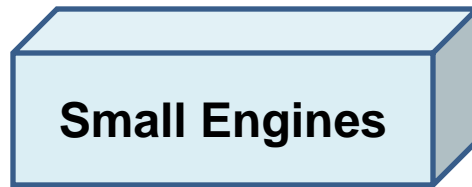
Kevin Centek
Non-Primary Systems Team Leader

Report Documentation Page

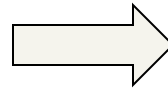
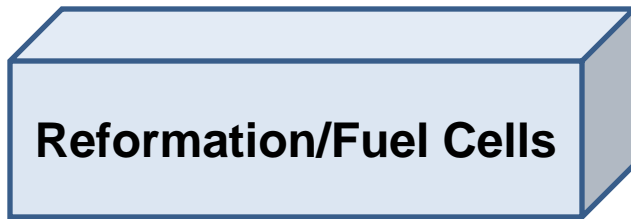
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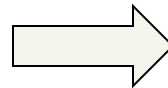
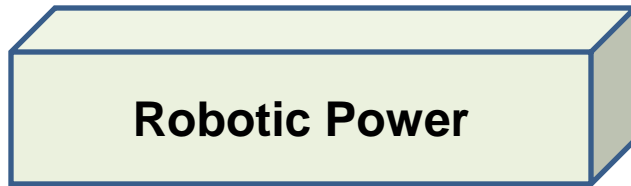
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- Achieve increased power density for existing vehicle APU space claims
- Optimize injectors for heavy fuels
- Minimize acoustic signature



- Achieve increased power density for existing vehicle APU space claims
- Optimize system integration and controls



- Achieve increased range (vs. current batteries) with small engine and fuel cell-based power sources
- Minimize acoustic signature of small engine-based robotic platforms
- Increase fuel cell reliability and shock and vibration performance

Mission Goals for each Focus Area:

- High Power Density Engine APU that can provide up to 45 kWe auxiliary power to meet increasing onboard vehicle power demands without reducing mobility.
- Silent Watch (undetectable at 50m) through the use of a fuel cell based APU that power mission equipment with main engine off while the vehicle is stationary with reduced acoustic and thermal signature.
- Small UGV power through small engine and fuel cell based solutions that can extend the mission duration and range of UGVs, reducing risk to soldiers.

9kW JP-8 Rotary APU:

Integrated, Demonstrated, Tested

Project Purpose & Goal:

- Develop, integrate, test and demonstrate a 9kW rotary engine APU in Abrams M1A2 SEP V1 tank
- Ruggedize design to meet vibration requirements of tank
- Optimize component placement for ease of maintenance
- Produce 6 units for testing at various government test facilities

Program Status:

- Completed 200+ hours (2000 miles) of in-vehicle operational conditions at Yuma
- Completed two 100 hour high temperature (125F) tests at TARDEC Propulsion Lab
- Completed M1A2 SEP V1 Integration Test of 300+ tank commands
- Delivered performance specification to PM HBCT, which may be used for open competition
- Delivered test report of all testing completed

Challenges:

- Consumes oil: 1 qt. every 12hrs.
- Requires constant use of glow plug
- Maintenance required every 75hrs
- Minimal noise mitigation work done



Schedule

	FY06	FY07	FY08	FY09	FY10	FY11
Generation 1 – Proof of Concept	■					
Generation 2 – Test Prototype		■				
Generation 3 - 9 kW APU			■			
- TARDEC Testing				■		
- Aberdeen Proving Grounds Tests				■		
- Yuma Proving Grounds Test				■		

Project Purpose & Goals:

- Design, model, build & deliver Rotary Diesel APU
- Utilize lessons learned from previous Rotary APU work
- Produce APU for Abrams space claim
- Increase power by utilizing modern rotary engine technology
- Minimize dependence on glowplug
- Decrease oil consumption

Technology Description:

- Rotary engine, continuous glowplug ignition
- 17kW electrical output
- Improved fuel economy
- 350 lbs
- Fits in Abrams space
- Reduced cooling burden
- Lower fuel consumption (kg/kW)

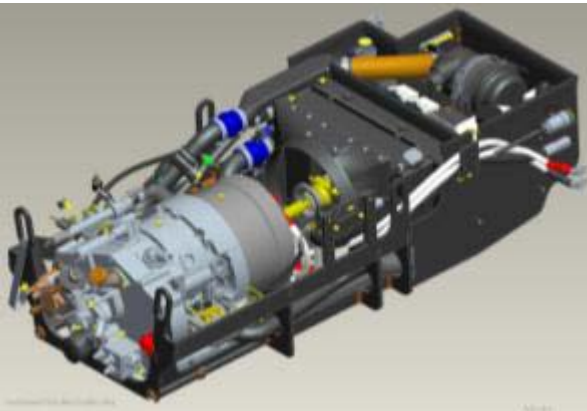
Challenges

- Consumes oil, but at lower rate than previous generation
- Requires use of glowplug for combustion
- New engine design: limited evaluation done

Schedule

	FY09		FY10		FY11		
	Q1	Q3	Q1	Q3	Q1	Q3	
Component Design	█						
Component Fabrication	█	█					
Engine Assembly		█	◆				
Engine Performance Testing		█	█	█	◆		
Component Testing			█				
Engine Endurance Testing				█	█	◆	
APU Fabrication					█	█	
APU Testing						█	◆

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Reciprocating Piston APU: Current Program

Project Purpose & Goals:

- Produce APU for Abrams space claim
- Utilize COTS Direct Injection (DI) compression ignition engine
 - State of the art in reducing fuel consumption and optimizing fuel control
- Integrate muffler inside space claim

Technology Description:

- 10kW electrical output (360A)
- Single Cylinder 4-stroke Diesel engine
- Liquid Cooled
- In-cylinder fuel injection
- 420 lbs
- Fits in Abrams space (including muffler)
- True compression ignition

Challenges

- Consumes oil: 1 qt. every 24hrs. Reservoir needs refill every 40 hrs
- No ballistic protection in unit design
- Not a drop-in design
- Minimal noise mitigation work done



Schedule

	FY08	FY09	FY10	FY11	
Component Design	[Gantt bar spanning FY08]				
Component Testing	[Gantt bar spanning late FY08 to early FY09]				
Air Cooled Unit Fabrication	[Gantt bar spanning late FY08 to early FY10]				
Air Cooled Unit Testing	[Gantt bar spanning late FY09 to early FY10, ending with a yellow diamond]				
Liquid Cooled Unit Design	[Gantt bar spanning early FY09 to early FY10]				
Liquid Cooled Unit Fabrication	[Gantt bar spanning early FY09 to early FY11]				
Liquid Cooled Unit Testing	[Gantt bar spanning early FY10 to early FY11, ending with a yellow diamond]				
TARDEC Test & Evaluation	[Gantt bar spanning early FY11 to early FY12, ending with a yellow diamond]				

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Project Purpose & Goals:

- Build, test, mature & deliver Rotary Diesel Engine
- Utilize state of the art high pressure fuel system, direct injection, and turbocharger system
- Produce 25kW APU for Abrams in 3 yrs.
- Collaborate with AMRDEC UAV Shadow program to use same technology for multiple applications
- Minimize oil consumption, use oil for cooling to minimize logistical burden

Technology Description:

- 25kW shaft output , spark ignition
- Low noise & vibration design
- Extremely lightweight and power dense
- Fits in Abrams APU space
- Optimized fuel control and low fuel consumption
- Reduced logistic burden

Challenges

- New engine design: limited evaluation done
- Optimizing oil consumption, while providing enough lubrication for side seals
- Spark plug long term durability
- Use of multiple injectors have not been fully determined



Schedule

	FY11	FY12	FY13	FY14	FY15	FY16
Engine Build, Turbo Selection	■					
Engine Reliability Testing	■	■				
Engine Delivery & Demo		◆				
APU Build		■	■	■		
APU Delivery & Demo				◆		
APU Test & Evaluation (TRL 5)				■	◆	
APU Redesign & Optimization					■	

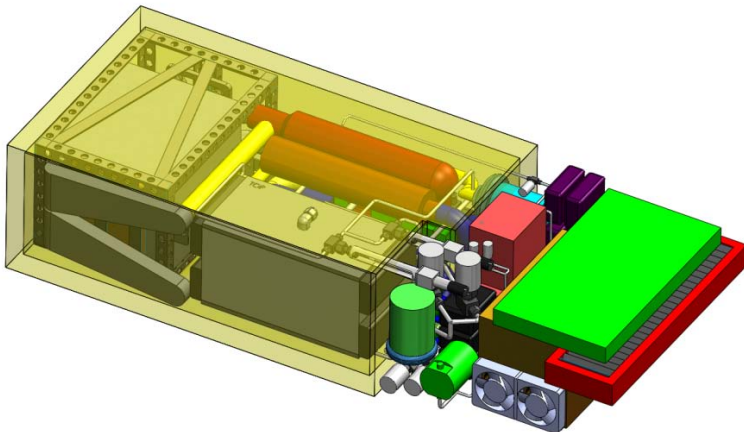
JP-8 Fuel Cell APU: Current Program

Project Purpose & Goals:

- Provide quiet, continuous, non-primary electrical power for extended engine-off operation with reduced acoustic and thermal signatures in a fuel cell based APU.
- Design and develop two APUs that deliver 5 kW (T), 10 kW (O) of vehicle electrical power
- Design systems to fit into the existing Abrams APU space claim

Challenges:

- Sulfur tolerant systems
- Immature technologies; Limited reliability data available
- High cost compared to conventional APUs



Technology Descriptions:

High Temperature PEM APU

- Regenerable Desulfurization System
- Steam Reformer
- Water Gas Shift Reactor

Solid Oxide Fuel Cell APU

- Regenerable Desulfurization System
- Autothermal Reformer
- Sulfur Tolerant Stack

Schedule

MILESTONES	FY10	FY11	FY12	FY13	FY14	FY15
System M&S	[Bar chart showing duration from FY10 Q1 to FY10 Q4]					
System Refinement	[Bar chart showing duration from FY10 Q3 to FY11 Q4]					
Prototype Development	[Bar chart showing duration from FY11 Q1 to FY12 Q4]					
Breadboard test	[Bar chart showing duration from FY12 Q3 to FY13 Q1]					
Field Hardening	[Bar chart showing duration from FY12 Q4 to FY14 Q1]					
Increase Power Density	[Bar chart showing duration from FY13 Q1 to FY14 Q4]					
Preliminary TTA	[Bar chart showing duration from FY13 Q3 to FY14 Q4]					
APU Demonstration	[Bar chart showing duration from FY15 Q1 to FY15 Q2]					

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Project Purpose & Goals:

- To integrate a 250 Watt Solid Oxide Fuel Cell system onto an existing Unmanned Ground Vehicle (UGV)
- Analyze current manufacturing process and perform a low rate initial production of 20 units
- Analyze production cost and unit variability
- Test 5 units at contractor facility for 2000 hours or failure

Technology Description:

- 250 Watt Solid Oxide Fuel Cell System
- Uses commercially available propane
- Fits into existing battery compartment
- Power system can be used as stand alone power source
- Increases mission duration over batteries

Challenges:

- Limited shock and vibration testing
- Meeting limited space constraints
- Manufacturability



Schedule

	FY10	FY11	FY12
250 Watt Sub-system analysis		■	
UGV SOFC system configuration		■	
Environmental testing shock/vib		■ ◆	
Design for Manufacture Study		■	
LRIP Mfg plan and execution			■
User/safety assessment			■
Delivery of SOFC power systems			◆

- Obtain 45kW in current or smaller space claim
- 2.5 gallon/hr for 25kW output
- Undetectable at 50 meters
- Mean time between failure 1140 hours