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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Army APU Needs

Abrams Tank has the greatest need for an APU

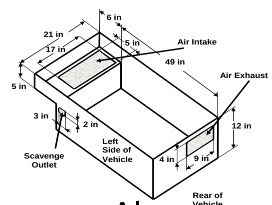
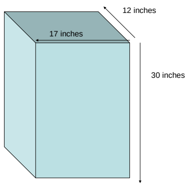
- A 2008 study* concluded an Abrams APU could save 74 gallons of JP-8 per tank per battlefield day, which calculates to saving 4,300 gallons per brigade per day
    - Time at idle, estimated to be as much as 83% of total operating time
    - Abrams tactical idle at 1250 rpm consumes 17gal/hr
    - Current APU solutions consume 1.5 gal/hr
- Study also showed benefit to Abrams main engine 10 year replacement costs by over $75,000 if the APU has over 500 hours mean-time between failure (due to reduced main engine idle time).
- Current band-aid solution does not meet requirements or power needs
    - 6 additional batteries integrated into the available space claim allow engine off operation
    - Vehicle has to idle to meet 8kW power requirement (baseline turret with OIF upgrades)

*AMSAA Study Lead: Mr. Robert M. Roche *In Response To:* RDECOM Tasker 2990: Per AMC Current Operations Update, 10 June 08;*Adapted from Brief to CG, RDECOM, 2 Apr 08*

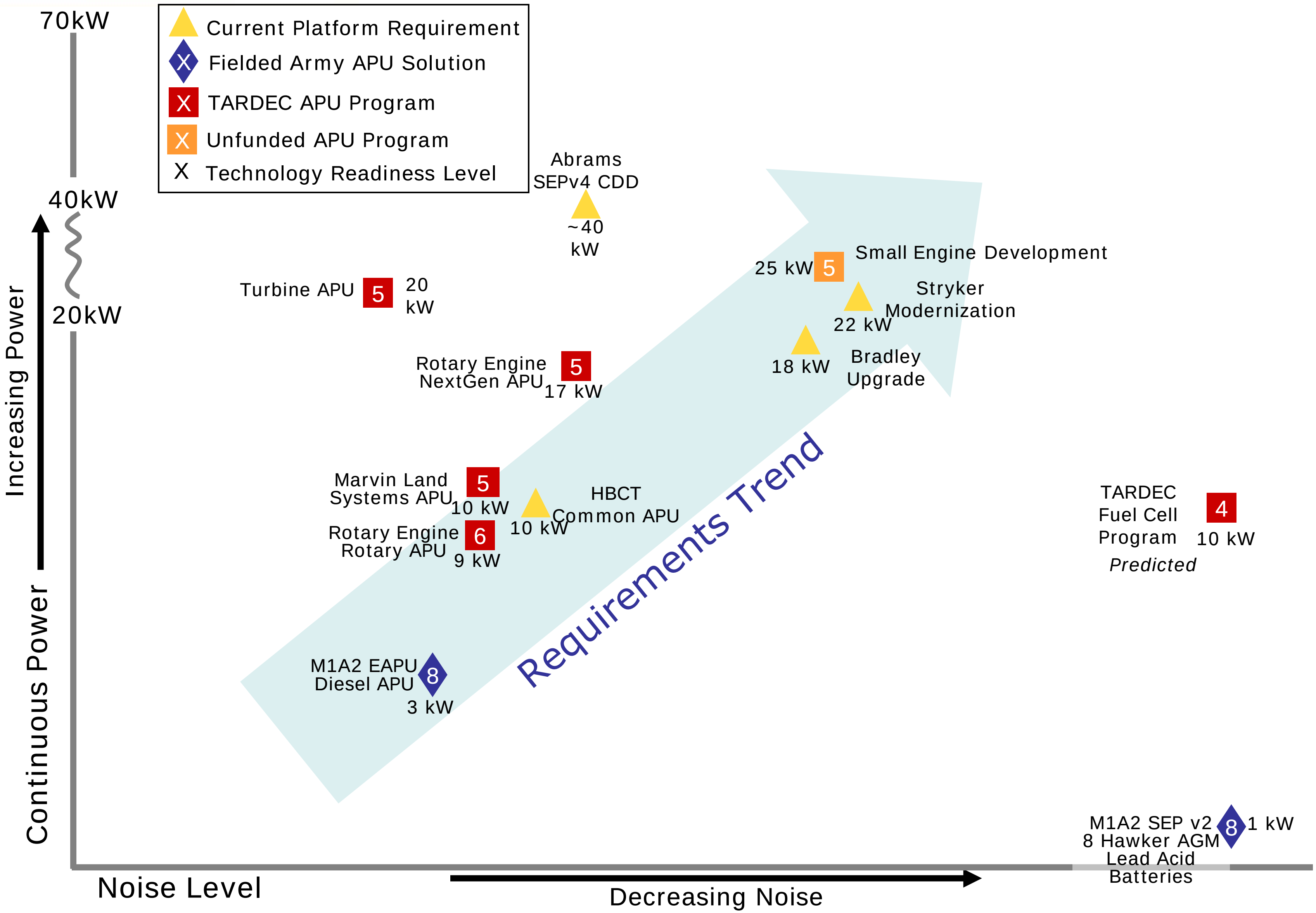
Common APU Performance Requirements

Requirement Traceability:

- APU requirement traces back to the M1A2 ORD page 11, paragraph 4.b (4) to require an under armor APU (UAAPU) on the tank.
- The PEO GCS/TARDEC Common APU IPT completed a gap analysis of Abrams, Bradley and Stryker on-board power requirements.
- This resulted in the Common APU performance specification and a Request for Information (RFI) was sent to industry 1st QTR 2006

	Abrams, Bradley and Stryker APU Performance Requirements
Continuous Power	8 kW (Threshold) / 10 kW (Objective)
Mission Duration	12 hours
Fuel Consumption	1.75 gal / hour (Threshold) / 1.5 gal / hour (Objective)
NPS Volume	 Abrams 275 L  Stryker 200 L  Bradley 100 L
NPS Weight	453 lbs. Abrams/Bradley (internal cooling system) 254 lbs. Stryker (can use engine's cooling system)
Procurement Cost	< $40K

Increasing Power Requirements



Rotary Engine 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

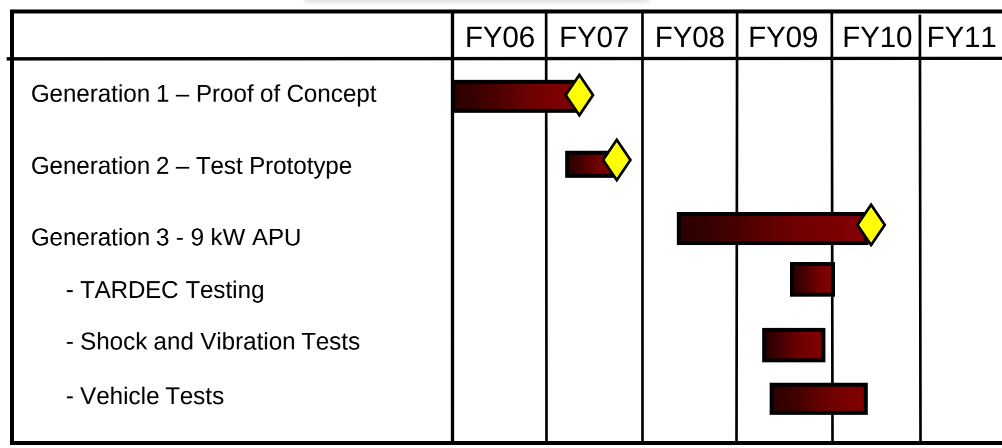
Program Status:

- Completed 200+ hours (2000 miles) of in-vehicle operational conditions
- 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
- Requires constant use of glow plug
- High maintenance requirement
- Minimal noise mitigation work done

Schedule/Funding



Diesel Engine APU

Project Purpose & Goals:

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

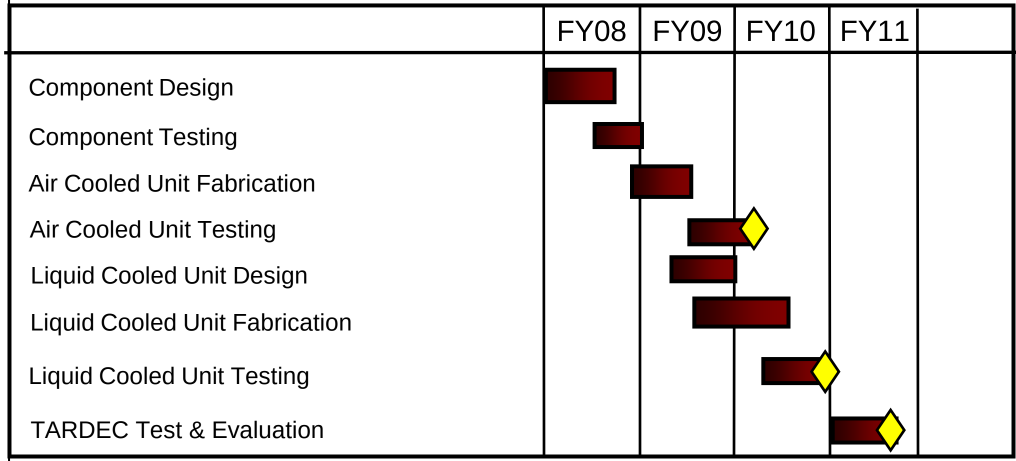
Technology Description:

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

Challenges

- o Consumes oil
- o Not a drop-in design
- o Minimal noise mitigation work done

Schedule/Funding



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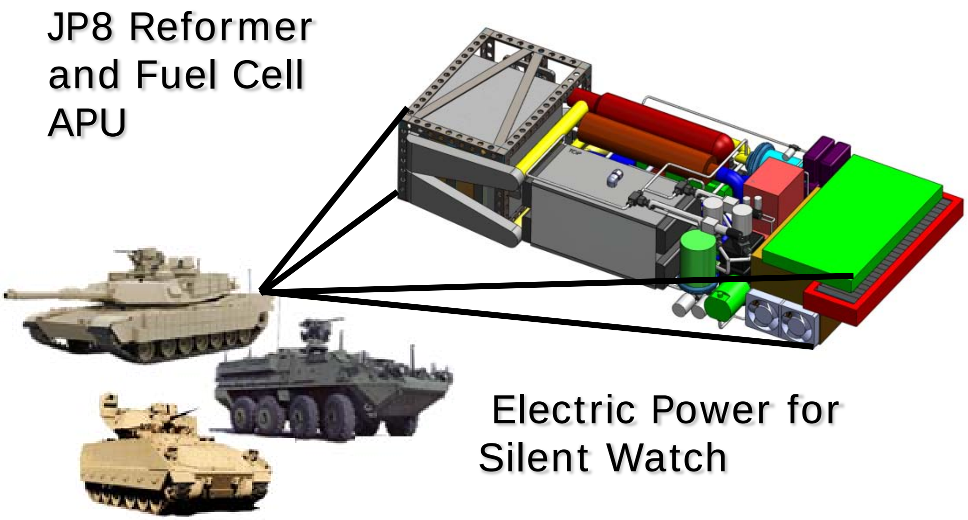
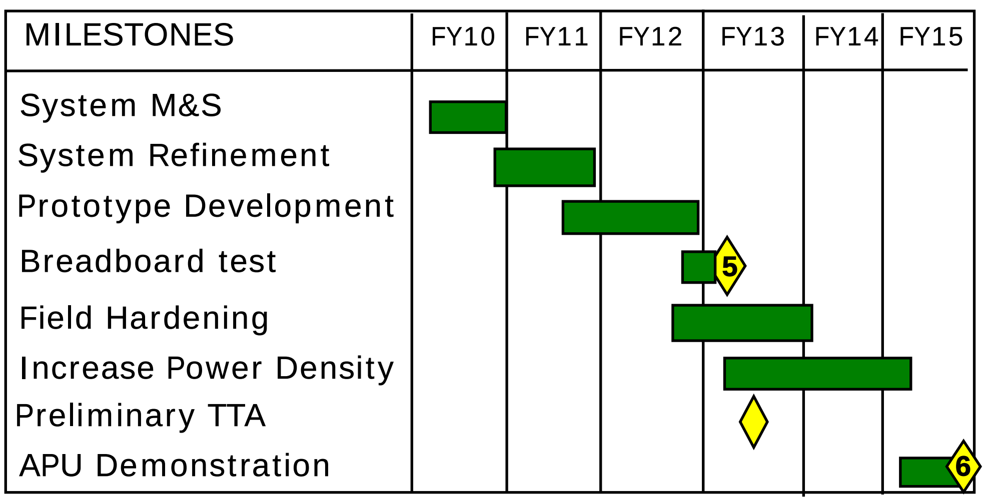
FY17

JP8 Fuel Cell Auxiliary Power Unit (APU)

TARDEC



Schedule/Funding



Purpose:

- Provide quiet, continuous, non-primary electrical power for extended engine-off operation with reduced acoustic and thermal signatures in a fuel cell-based auxiliary power unit.

Product:

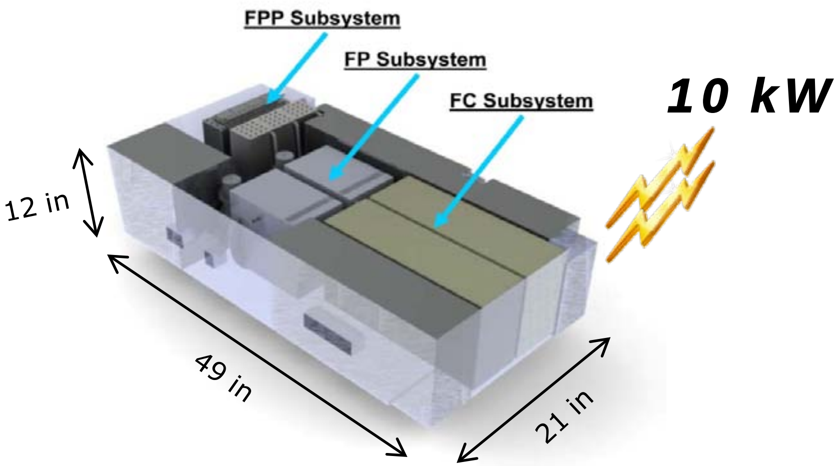
- Multiple ruggedized, power dense, JP8 Fuel Cell Auxiliary Power Units for Abrams capable of producing >15 kilowatts of vehicle electrical power demonstrated at TRL 6+; to include shock and vibration testing, hot and cold temperature testing, on-vehicle testing, adverse weather and storage testing.

Payoff:

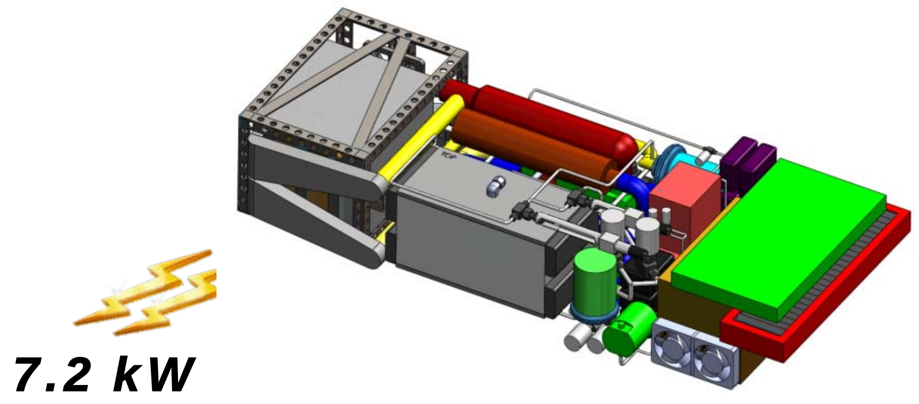
- Provide low signature, non-primary vehicle power generation for C4ISR and auxiliary systems (engine off)
- Increase the Warfighter's survivability and lethality through decreased signature during extended silent watch missions.
- Increase overall vehicle fuel efficiency

JP8 Fuel Cell Auxiliary Power Unit (APU)

Technology Solution 1



Technology Solution 2



System Components:

- **Fuel Preprocessor (FPP) Subsystem**
  - Fractionator: Separates JP-8 fuel to light and heavy portions; reforms light end fuel for fuel cell, burns heavy end fuels for system heat
  - Regenerable Organic Sulfur Trap (OST): Reduces sulfur levels to below 15 parts per million (ppm);
  - Polishing OST: Removes any remaining sulfur in fuel
- **Fuel Processor (FP) Subsystem**
  - Pre-reformer: Partially reforms desulfurized JP-8 fuel; 2 step reformation reduces operating temperature versus conventional reformers
  - Reformer: Completes fuel reformation process
  - Water-Gas Shift (WGS): Converts residual Carbon Monoxide (CO) from the reforming process to hydrogen utilizing steam
- **High Temperature Proton Exchange Membrane (HTPEM) Fuel Cell**
  - More efficient and power dense than conventional PEM fuel cells; operating at 160°C - 180°C; converts fuel reformate to power

System Components:

- **Regenerable Liquid-phase Sulfur Removal System**
  - Reduces sulfur levels in fuel from 3000 ppm to 40 ppm; when less than 400 ppm sulfur is used; the sulfur removal system is bypassed
- **Auto-thermal / Catalytic Partial Oxidation (ATR/CPOX) Fuel Reformer**
  - Reformer starts in a CPOX reformer mode and transitions to a more efficient ATR mode once system is at temperature for ATR to begin.
- **Solid Oxide Fuel Cell (SOFC)**
  - Converts fuel reformate to power; operates between 600°C – 1000°C; Extremely sulfur tolerant.

JP8 Fuel Cell Auxiliary Power Unit (APU)

1. What is the problem?
- The need exists for improved non-primary electric power that will support military ground vehicle engine-off operations. The means of generating this electricity must offer better fuel efficiency and have lower thermal and acoustic signatures than idling the main engine. Current battery, alternator and APU technology cannot meet silent watch requirements.

2. What are the barriers to solving this problem?
- There is no technology in the Army inventory besides batteries that can meet the acoustic signature requirements of silent watch.
- Army mandated use of JP8 fuel as only fuel option eliminated simpler prepackaged fuel APU options.

3. How will you overcome those barriers?
- Fully integrate the complex components of reformation, energy storage and fuel cell technologies; design for military use; operate for 1000 hours.
- Develop fully characterized M&S tools for optimization of reformer, fuel cell and energy storage interactions across multiple mission profiles.
- Leverage heavily off of on-going JP8 reformation programs DOD wide.

4. What is the capability you are developing?
- Warfighter Outcome Title – Alternative Power for Platforms, Alternative Power for Dismounted Soldiers, Alternative Energy Sources, Increased Fuel Efficiency, FOC 09-03, 09-04, 09-01

5. What is the result of this effort?
- A never before designed JP8 reformer system and fuel cell combined into a defined space claim to produce non-primary power for engine-off operations.

6. Quantitative Metrics:

Component Technology	Current	Program Obj.	Army Objectives PEO GCS CNPS	TRL
Noise Level		Undetectable[3] at XXm	Half as loud as main engine	Start 4 End 5
SW Avg Power	1.2 kW[1]	5kW (T) 10 kW (O)	8 kW (T) 10kW (O)	Start 4 End 5
SW Duration	~5 hrs[1]	12+ hrs	12 hrs	Start 3 End 5
System Efficiency	15%[2]	25%	18%	Start 3 End 5
System Reliability / MTBF	500 hrs	1140 hrs*	1140 hrs	Start 3 End 5
Power Density	15.5 W/L[2]	35 W/L	32 W/L	Start 4 End 5

1. From M1A2 SEP v2 w/ UAAPU compartment filled with 6 extra 6T VRLA batteries. * Design to goal for follow on
2. From PM-MEP 5 kW APU, MEP model # 952B 3. Defined by MIL-STD-1474D Level I aural nondetectability limits

7. How are we leveraging other tech programs:

DOD program leveraging
- OSD High Temperature Fuel Cell (SOFC) Based Auxiliary Power Unit program (ONR managed)
- AFRL Power Dense Solid Oxide Fuel Cell Power Units for Military Applications program
- ARL JP8 reformer laboratory testing and sulfur sensor development.

TARDEC program leveraging
- In-house reformer and fuel cell modeling (ASPEN)
- FY06 JP8 Reformation for Alternative Power Sources

8. Endorsements:
- TRADOC 13 Apr 09
- Maneuver COE Mounted Requirements Division, 13 Apr 09
- Marine Corps Systems Command PM Tanks: 11 Dec 09
- PEO GCS, PM HBCT: 29 Apr 09
- PM MEP: 26 Feb 09 (Written Concurrence)

Fuel Cell APU Challenges

Sulfur Tolerance

o 10 – 20% of system volume is consumed with sulfur removal technologies or devices

o Implement sulfur sensor technologies to optimize catalyst bed replacement schedules to avoid wasteful replacement of a useful device

o Implement sulfur sensor technologies to optimize control of regeneration cycles to reduce unnecessary cycling, which lowers capacity with each cycle

o Develop sulfur tolerant fuel cell stacks to reduce the amount of space dedicated to sulfur and gas cleanup

o Develop sulfur tolerant reformers to reduce the need for sulfur treatment

Cost and Reliability

o Reduce cost of fuel cell stacks through robust and reliable manufacturing

o Follow standard quality control practices to ensure fuel cell stacks have limited variations or defects to ensure predictable performance

o Decrease precious metal content

o Keep voltage degradation rates low for extended stack life

Fuel Cell APU Suggestions

Long Term Testing

o Military fuel cell systems require operation off logistic fuels

o More long term testing of fuel cells and reformer systems operating together in a complete integrated system is needed

o Balance of plant components are a big problem area that has not been fully addressed

o Test data sharing amongst military organizations is necessary to reduce expense of tests and system builds

Militarization

o Manufacture robust fuel cell stacks with the operational environment in mind

o Perform additional environmental testing of fuel cell stacks and balance of plant components

o Perform shock and vibration tests of stacks and support hardware