Solid Oxide Fuel Cells (SOFC) as Military APU Replacements

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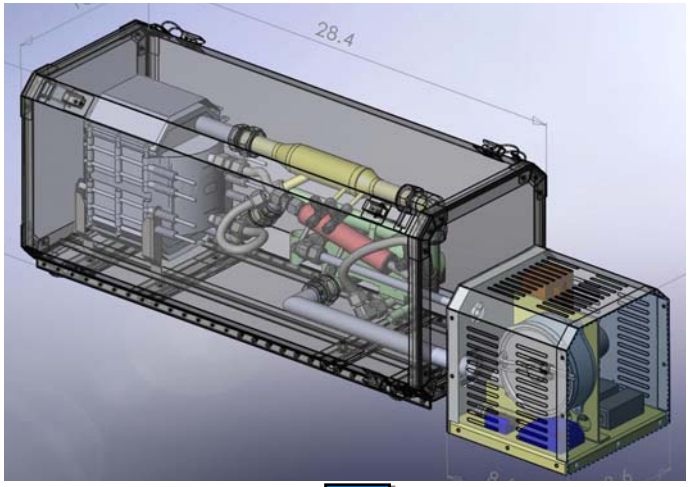
Background

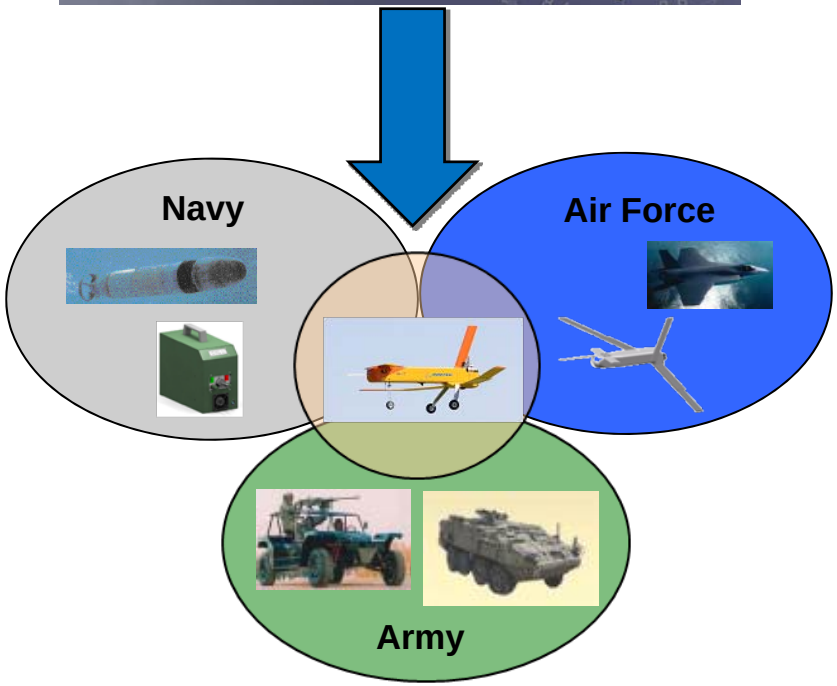
- **DOE and others are developing SOFCs emphasizing core technology, system reliability, and affordability**
  - Goals – Long life (40,000 hrs); Low cost (< $400/kW)
- **Gains can be leveraged to address specific needs for mobile and DoD applications**
- **Key challenges**
  - Increased power densities
    - System > 200 W/kg
  - Military logistic fuels
    - Sulfur, complex chemistries
  - Limited life, emphasis on high performance
    - 1000's of hours versus 10,000's of hours

DOE Stationary System

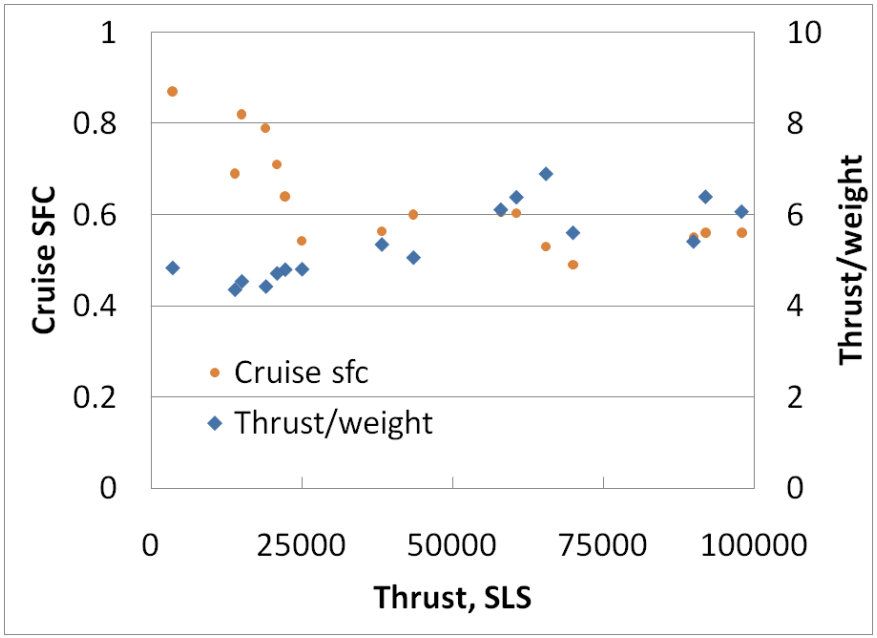
USAF SOFC Systems for Aviation Applications

- **Focus on smaller, sub-units (<10kW)**
- **Cooperative Army/USAF Activities**
  - Air Force UAV, Army Silent Watch
- **Technical Challenges**
  - Compact system integration
  - JP-8 utility
- **Near Term Demo on UAS (FY11)**
  - ~26% Efficient, S-8 Fuel
- **Future System Development**
  - 50-hr SOFC Hybrid Power System
  - >35% Efficient, >200 W/kg
- **Other Goals**
  - Autonomous System Operation





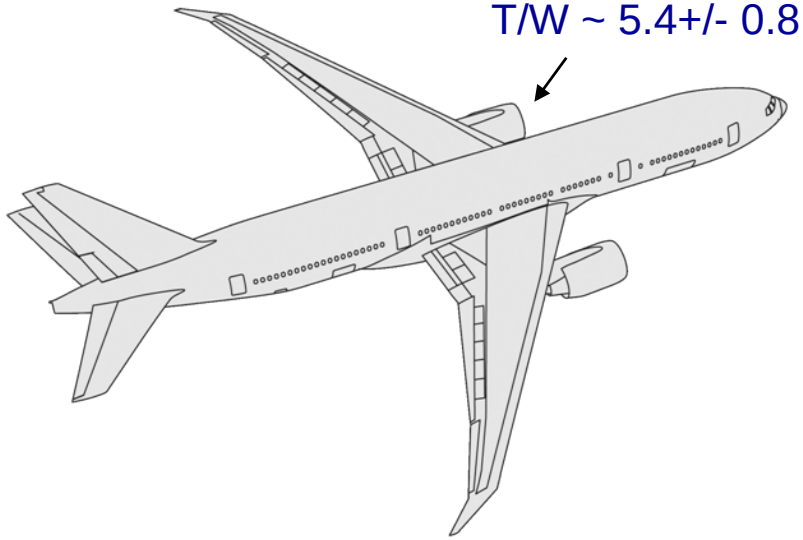
It is hard to compete with a high-bypass engine…but not impossible



Current Engine Technology

SFC ~ 0.6+/-0.1 at Cruise

T/W ~ 5.4+/- 0.8



- **High-bypass turbines are both efficient and compact**
- **SOFC-based APUs have many challenges to overcome**

Military APUs Have Different Requirements

- **Similar APUs to commercial but lower cooling requirement reduces size**

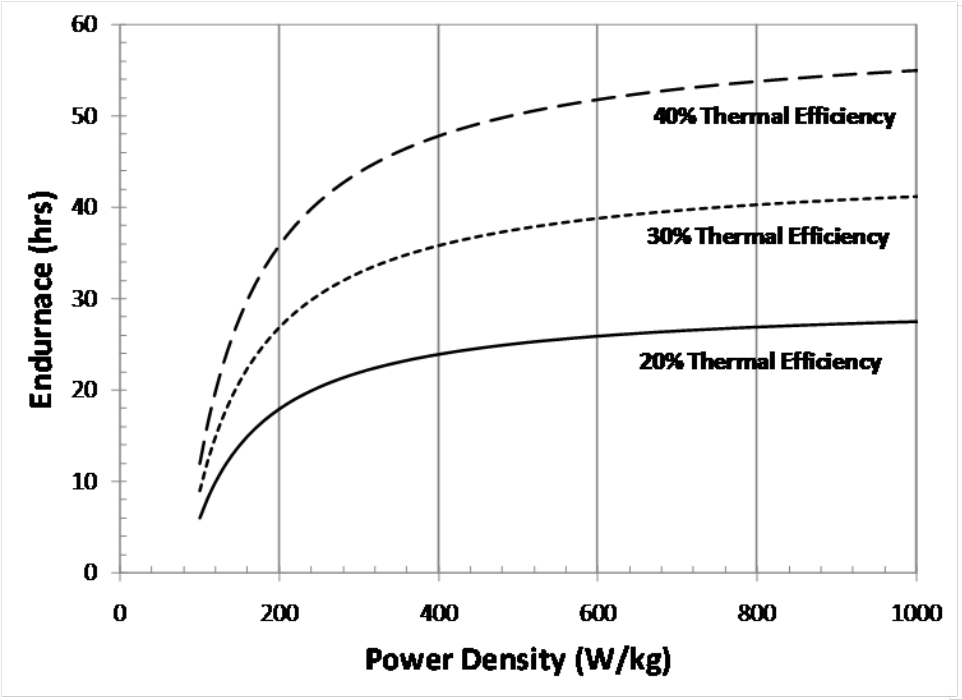
Aircraft	Manufacturer	Power Output (kW)	Size (lb)
C-130	**HW (85)**		
C-5	**HS (APS-3400) X 2**	**125**	**314**
C-17	**HW (331-250)**	**90**	

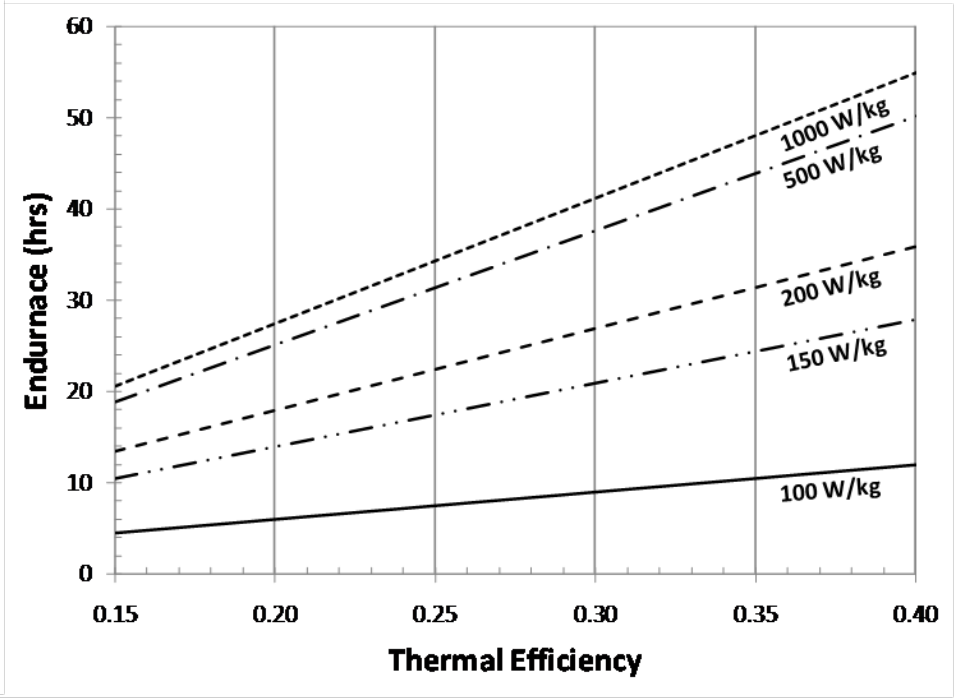
- **Location is different**

- **Primary functions include engine restart, HVAC on ground, electric and pneumatic power, cargo door operations**

- **Power at altitude power from 4 @ 90 kVA Generators**

Impact of Technology Improvements

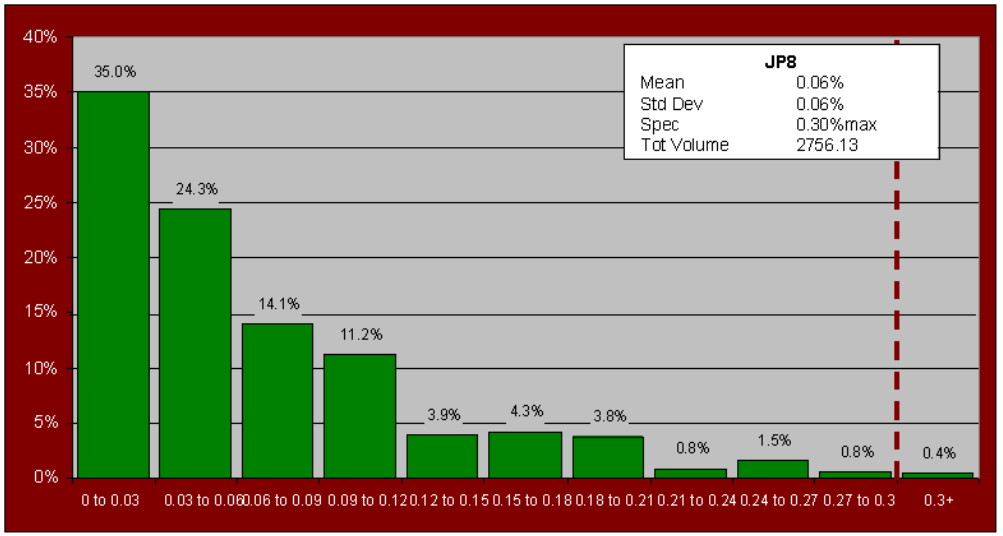




- **Example calculation for long-endurance SOFC power system**
  - Fixed wt (Fuel + Power System)
- **Largest initial endurance gains derived from power density increases**
  - 100 W/kg to 400-500 W/kg
- **Thermal efficiency impact greater at larger power densities**
  - > 200 W/kg

Key Technical Challenges

- **JP-8 Operability**
  - Must tolerate up to 3000ppm Sulfur
  - Hetero-atom content, complex chemistry
- **Compact Packaging**
  - Extremely high power density required (>1000W/kg)
- **Operational Characteristics**
  - High efficiency cooling/cathode air at 40kft
- **Lifetimes**
  - MTBF > 10000 hrs under vibration, thermal shock, etc
- **Other issues**
  - Rapid Start
  - Load Following



World-wide JP-8 Sulfur Content

Honeywell APU
~0.88 kW/kg

Summary

- **DOE/DOD partnership is strong**
- **APUs are pretty good…but there may be a pony in there**
- **AFRL has interest in this area**
  - Logistic-based fuel cell system for ultra-long UAS
  - Both In-house and contractual efforts supporting development of high power density, logistic-fuel tolerant systems
- **Key challenges exist which must be overcome**

Thanks!