



FuelCell Energy

World Leader in Ultra-Clean Power

Fuel Cell Power Plant Experience Naval Applications

**US Department of Energy/
Office of Naval Research
Shipboard Fuel Cell Workshop**

Washington, DC

March 29, 2011

reliable, efficient, ultra-clean



- **FuelCell Energy, Inc.**
- **Renewable and Liquid Fuels Experience**
- **HTPEM Fuel Cell Stack for Shipboard APU**
- **Solid Oxide Experience and Applications**





- Premier developer of fuel cell technology — founded in 1969
- Over 50 power installations in North America, Europe, and Asia
- Industrial, commercial, utility products
- 300 KW to 50 MW and beyond
- Research and development in MCFC, SOFC, PEM and Fuels



- High electrical and CHP efficiency
- Near zero NOX, SOX and lower CO2 emissions
- Reliable, Secure power
- Clean & Quiet Operation
- Ideal Shore Capacity - Low Profile, Easy Siting
- Connects to existing electricity and fuel infrastructure
- Multiple fuels



Naval Station Groton (Planned)



29 Palms Marine Corps Base



Renewable and Liquid Fuels



- Silent tactical 3/5 kW fuel cells (US Army) – M 232 methanol PAFC
- Remote site 3 kW DFC power unit plant (USCG) – M 232 methanol PAFC
- 32 kW DFC Demonstration power plant (DARPA) – DF2, JP-8
- 500 kW Ship Service DFC Demo Plant (Navy) – JP-5
- DFC300 Commercial Design Power Plant (US Army CERL) propane
- 5 kW adiabatic fuel processor (US Army CERL) – B-100 bio diesel
- Bench scale adiabatic reactor - ethanol

3 kW methanol fueled fuel cell power units were constructed and delivered to the US Army



This 3 kW methanol fuel DFC power plant operated unattended at Virginia Beach, VA site for 6 months



DFC300 power plant operated for 6 months on Propane with seamless transition to NG





A 0.5 MW fuel processor was integrated with an FCE Direct Fuel Cell Stack and operated with high sulfur naval logistic fuel (JP-5 jet fuel)

- Over 1000 Hours of Fuel System Operation
- Over 300 Hours of Operation on Load with Water Recovery
- Power Output up to 125 kW (50% of Stack Rating)
- Over 17,600 kWh Generated with Navy Logistic Fuel
- 17 Tons of Logistic Fuel Processed by HDS During Factory Test
- Sulfur Reduced in JP-5 from 1,100 ppm to 0.1 ppm





Pilot Scale Prereformer Operated over 1000 hr with Biodiesel fuel

Reformate Composition (dry basis)

CH ₄	40.3%
H ₂	32.0%
CO	0.7%
CO ₂	27.0%



Bench Scale Prereformer Tested with Ethanol

Reformate Composition (dry basis)

CH ₄	37.4%
H ₂	37.0%
CO	0.0%
CO ₂	25.6%





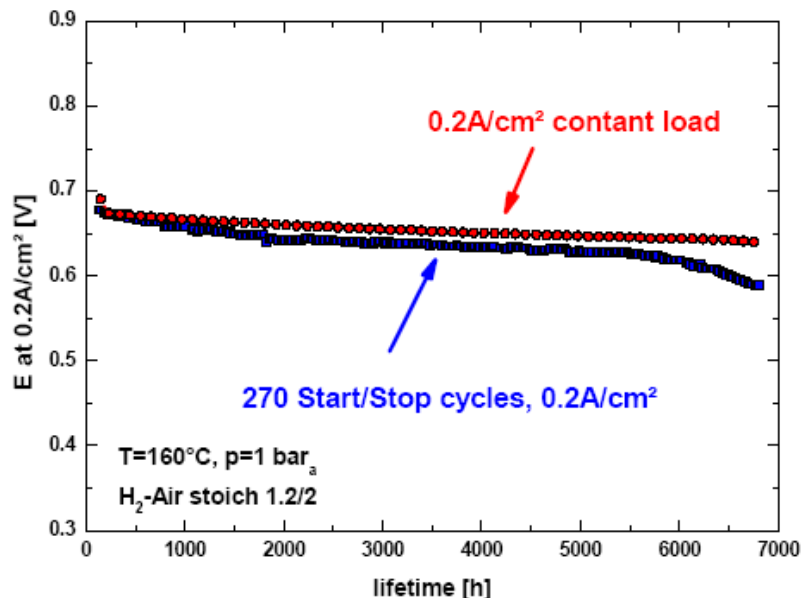
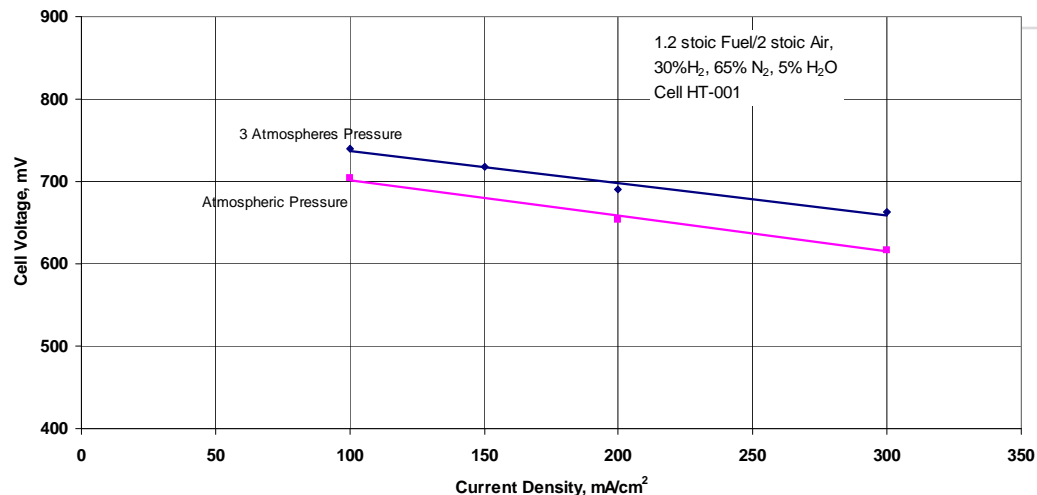
HTPEM Fuel Cell Stack for Shipboard APU





50 kW PBI Stack Module

V- I Characteristic for PBI Cell 1atm/3atm



Endurance Test of BASF P-2100 MEA



50 kW PBI Stack Module

Temperature: 180°C

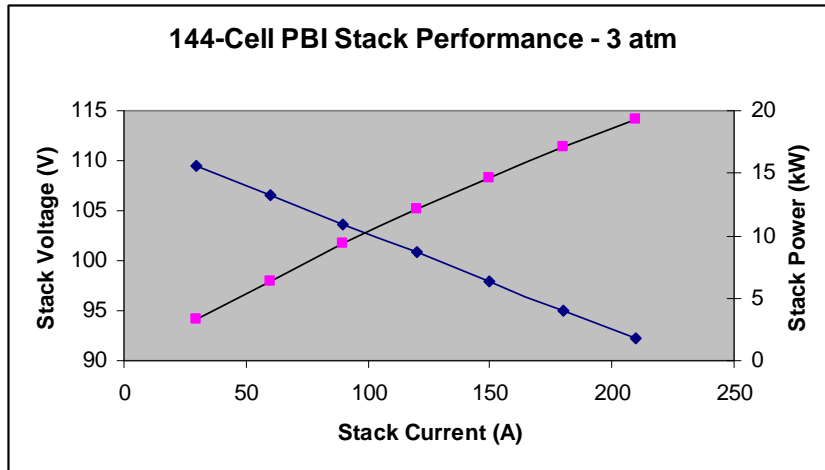
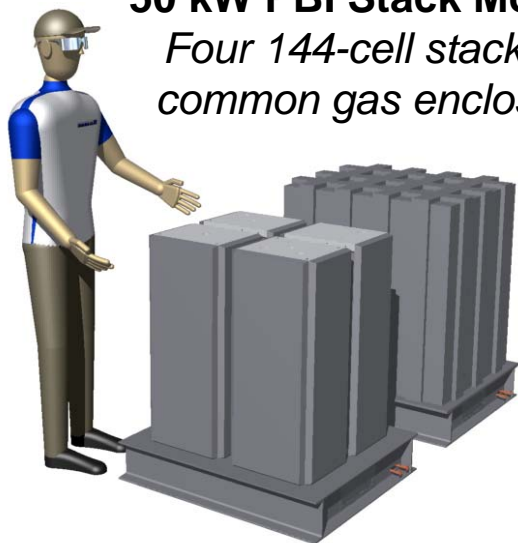
Pressure: 0 - 30 psig

CO Tolerant to 2%

Two phase liquid cooling

50 kW PBI Stack Module

Four 144-cell stacks in common gas enclosure



Projected Module Power Output

The 4-stack module generates 50.4 kW at 125 A

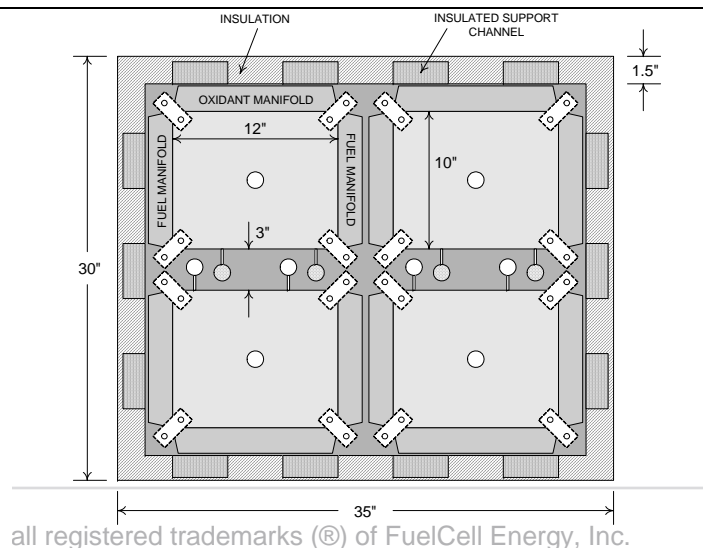
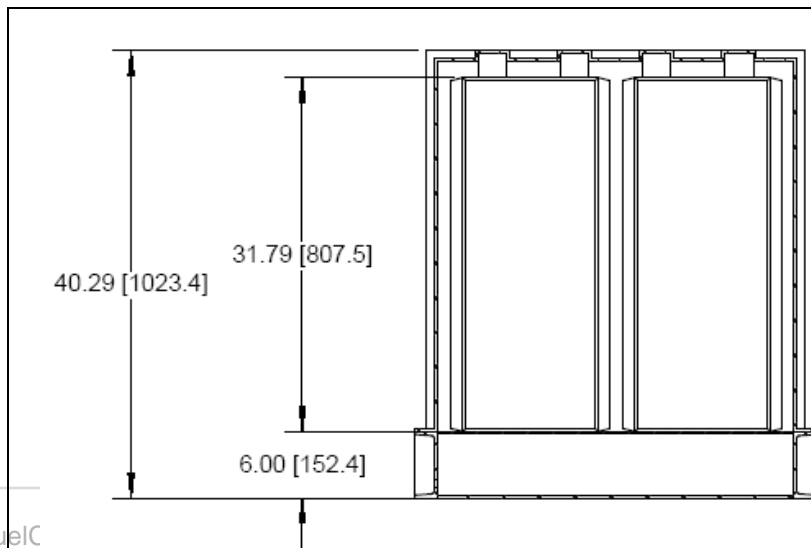
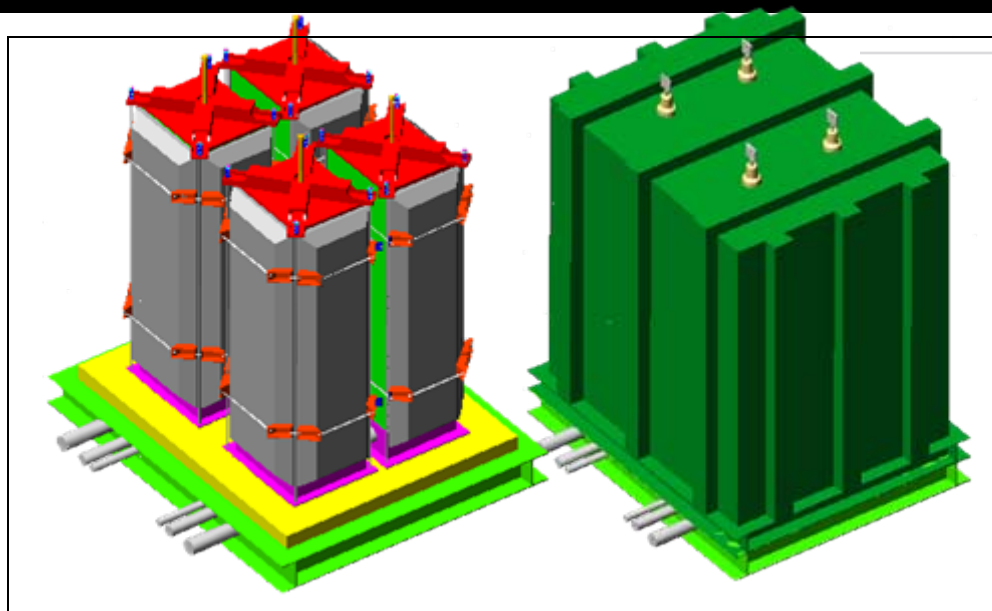


PBI 2KW Short Stack with 24 600cm² Cells



50 kW PBI Stack Module

Estimated Dimensions and Performance of a 50 kW PBI Stack Module Meets Navy's Shipboard Fuel Cell Goals



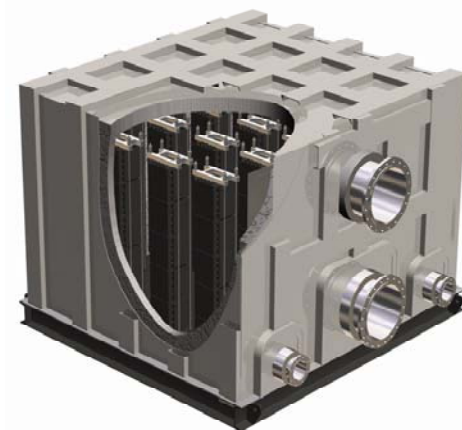
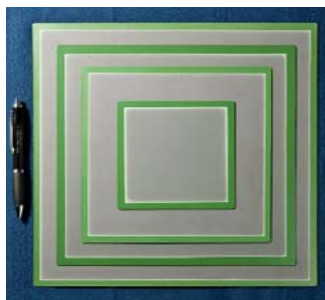
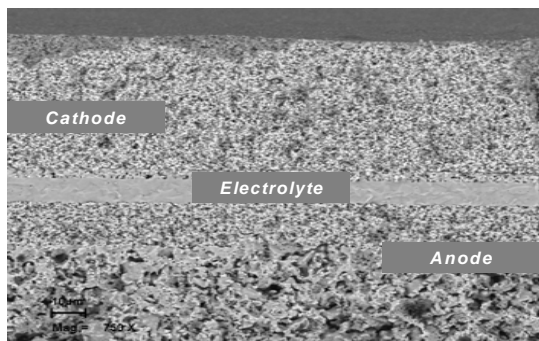


Solid Oxide Experience and Applications





- FCE utilizes VPS (Versa Power Systems) fuel cell technology in FCEs SOFC stack modules and systems.
- FCE/VPS team is engaged in Phase II of Solid State Conversion Alliance (SECA) Program for development of MW-scale SOFC systems

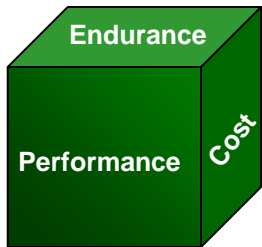


SOFC MW Module

- Planar anode supported cells (up to 33 x 33 cm²)
- Capable of operating from 650°C to 800°C
- Ferritic stainless steel sheet metal interconnect
- Cross-flow gas delivery , manifolds integrated into the interconnect but not through the cell
- Compressible ceramic gasket seals
- Standardized stack blocks configurable into stack towers for various power applications



SECA SOFC Development Path



Develop SOFC stack technology that meets performance & cost objectives, is scalable, and is used as the building block for assembling stack towers and large-scale power modules.



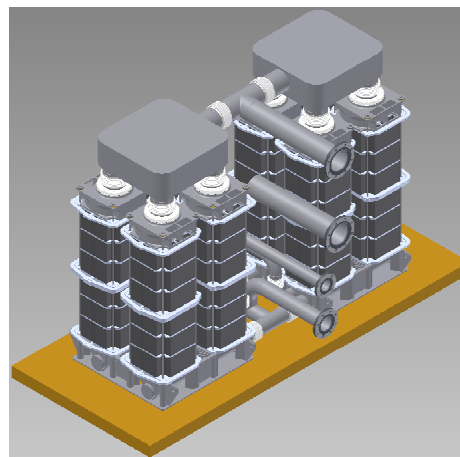
2006
1 kW Stack



2008
10-20 kW Stack



2010
Stack Tower



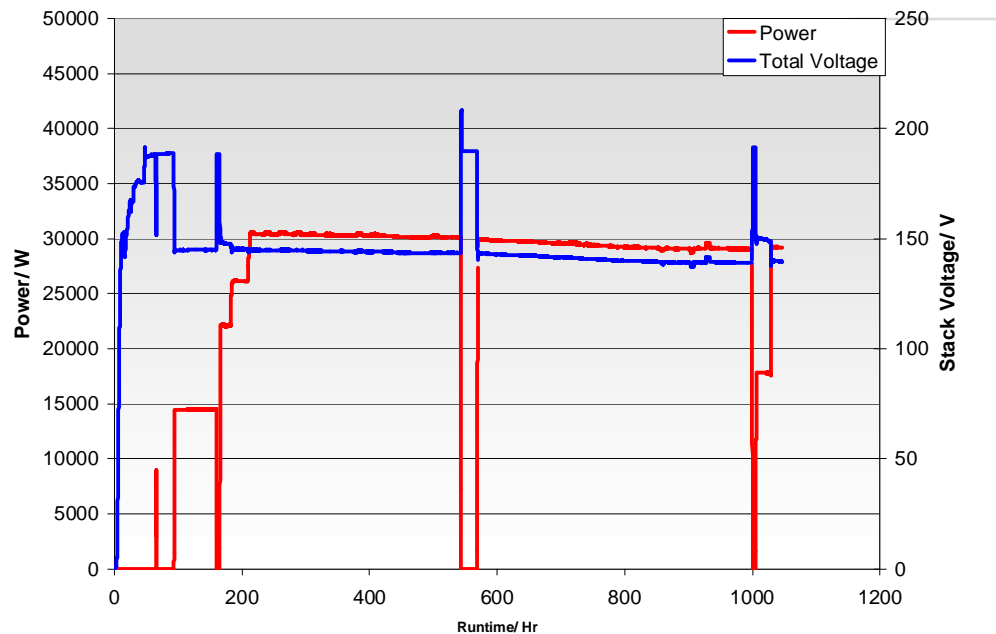
SOFC Stack Module

Prime Power and Auxiliary Applications





Stack Tower (SO-30-3) Test

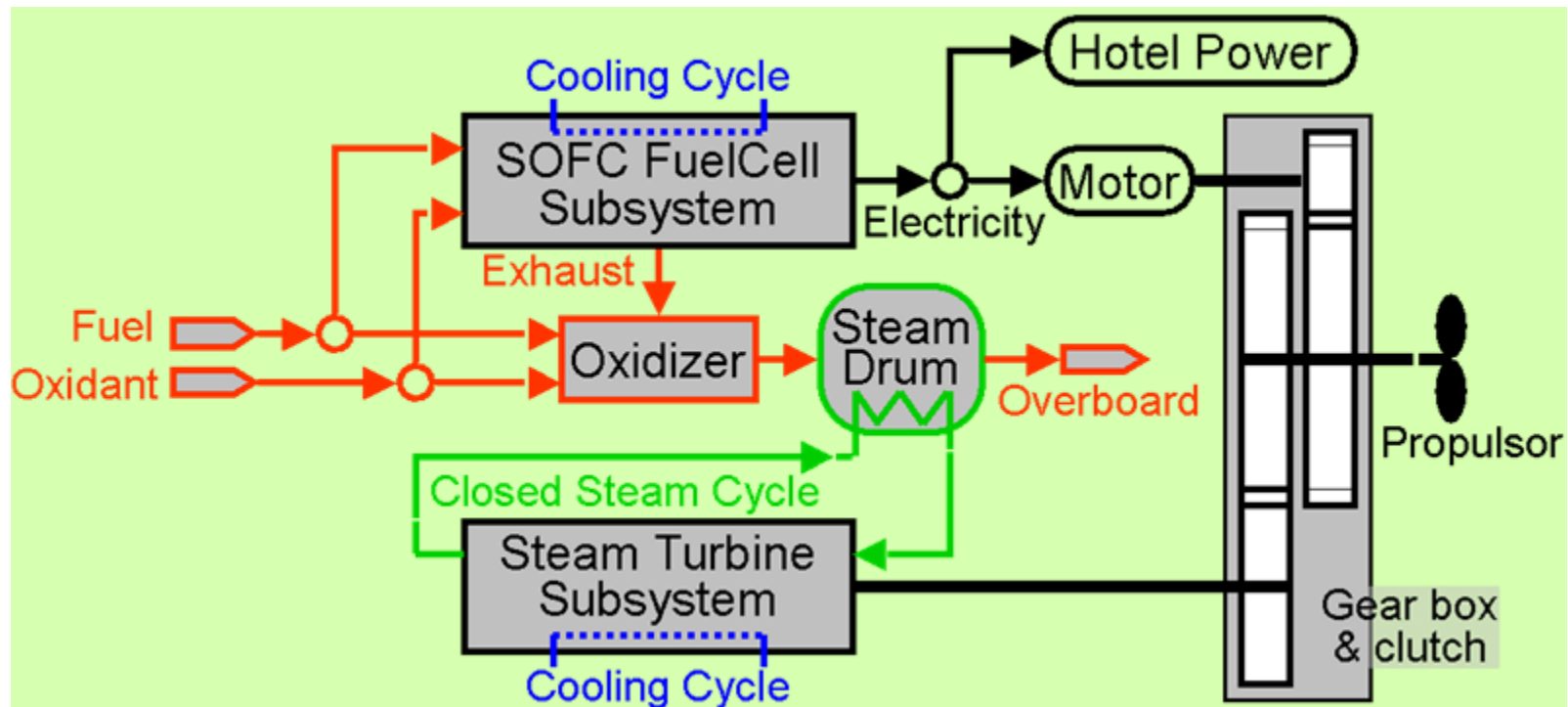


- **Demonstration of stack tower operation in a simulated power plant environment, using 2x92-cell stack blocks.**
- **A Power Rating of 30 kW was established during the operation.**



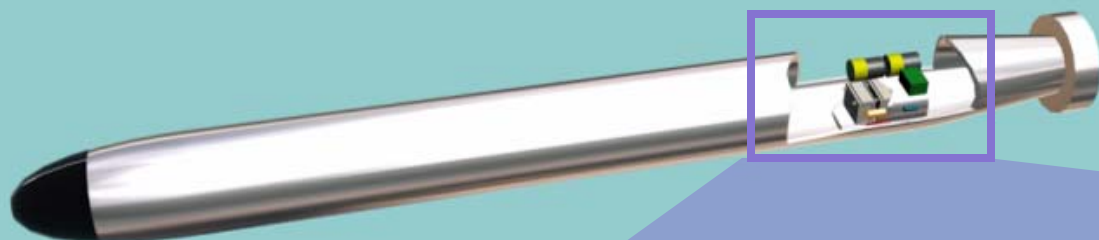
Hybrid System for Underwater Vehicles and Weapons

- Project Support by Office of Naval Research (ONR) through STTR programs:
 - Phase I STTR, “Hybrid Propulsion System for Undersea Weapons” (N00014-05-M-0183)
 - Phase II STTR, “Hybrid Propulsion System”(N00014-06-C-0406)

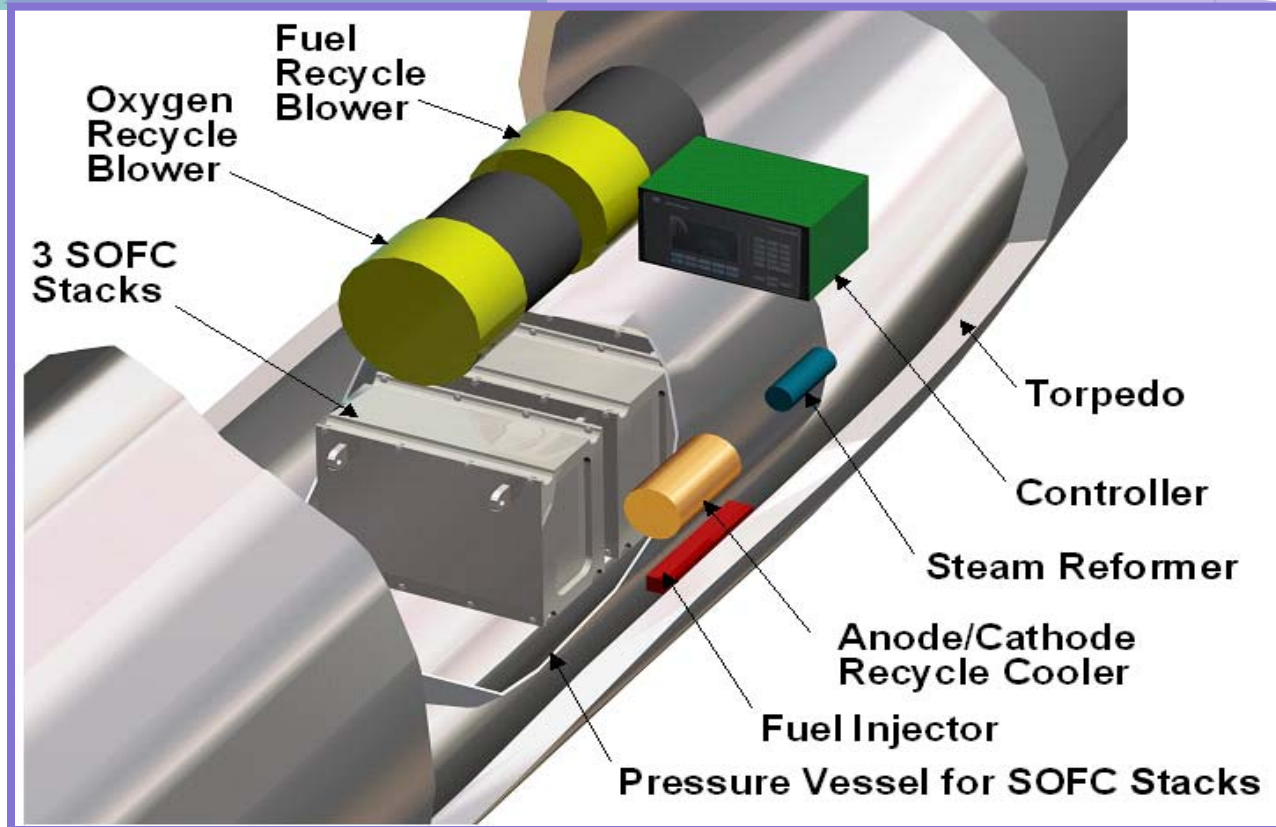


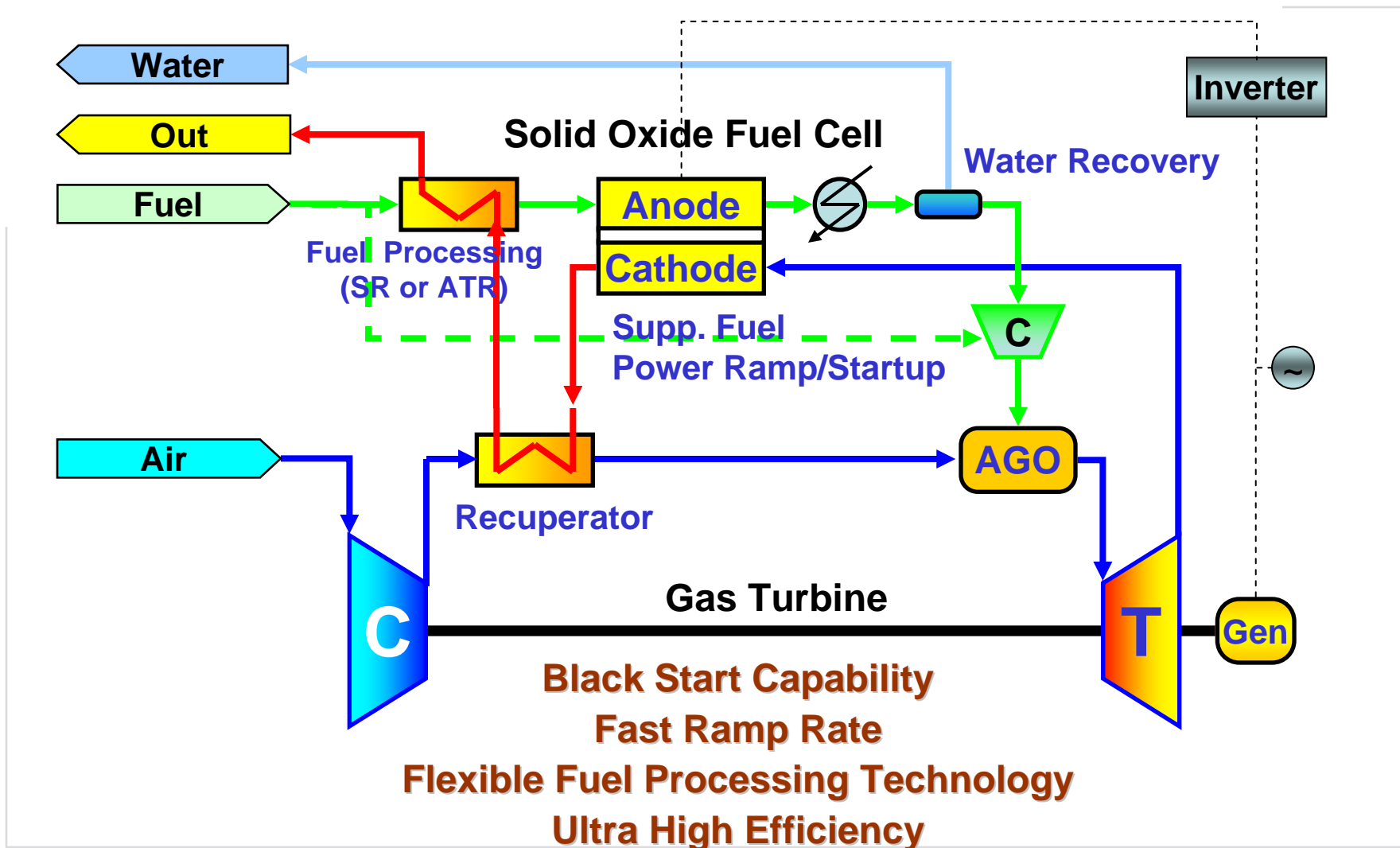


SOFC Based Torpedo System Design



- Very compact
- Designed to fit in torpedo cross section
- Length depends on power/stack size
 - ~ 13" for 5 kW
 - ~ 18" for 8 kW
 - ~ 22" for 10.7 kW
 - ~ 33" for 16 kW







Summary

- **FCE DFC Fuel Cells ready now to provide shore based power**
- **FCE has multiple process Liquid Fuels Experience**
- **HTPEM Stack Experience can be Advanced to Demonstration**
- **Solid Oxide (SOFC/T) holds promise as high efficiency cycle**

