



Office of Naval Research's

Fuel Cell Programs

Mr. Anthony D. Nickens
Office of Naval Research

Phone: 703-696-0614; Fax: 703-696-0001

E-Mail: nickena@onr.navy.mil

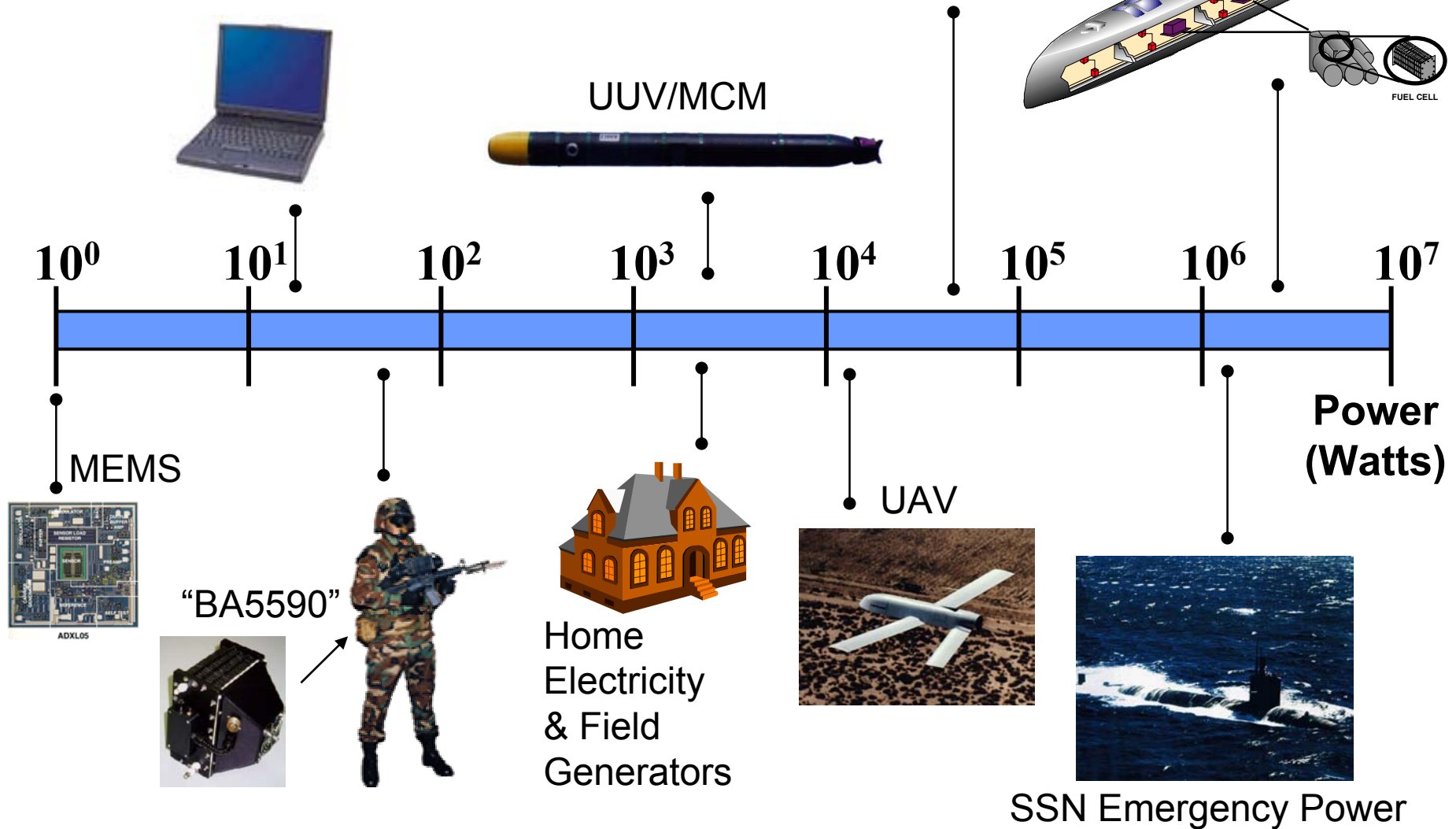
Grand Challenge



Electric Power Sources for the Navy and Marine Corps

Develop new, safe, efficient, environmentally friendly based sources of power and power generation concepts that would support portable long-lived power sources for all future Marine-carried equipment and electric power sources required for all-electric ships and other Naval warfighting platforms

Fuel Cell Power Ranges





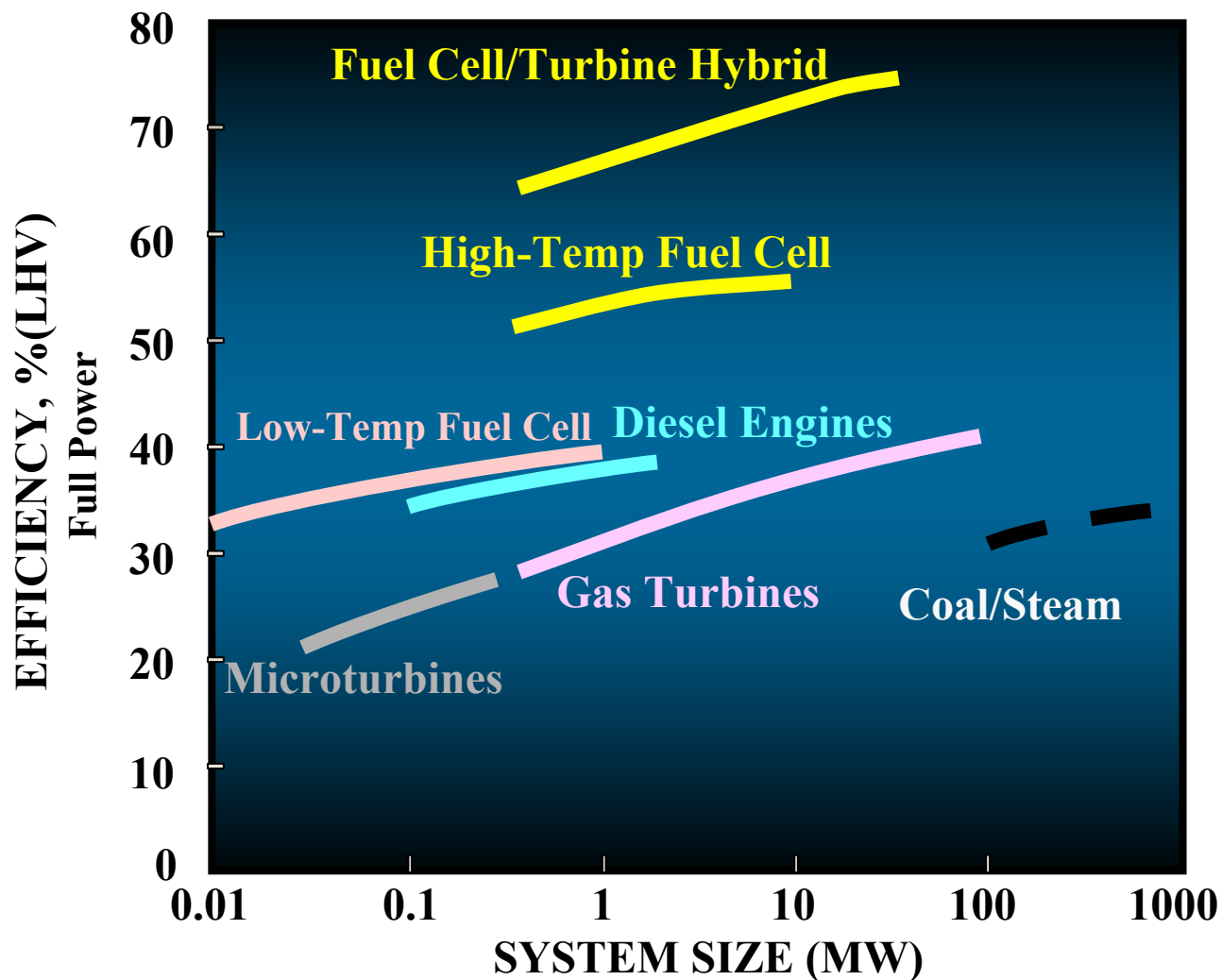
Why Fuel Cells for the Navy?

- **Cost Savings -**
 - ***Higher Efficiency***
 - ***Reduced Fuel Consumption***
 - ***Lower Maintenance***
 - ***Reduced Shipboard Workload***
- **Reduced Emissions**
 - ***Reduced Exhaust Emissions***
 - ***Reduced Acoustic and Infrared Signature, Reduced Radar Cross Section***



Navy Shipboard Fuel Cell Program

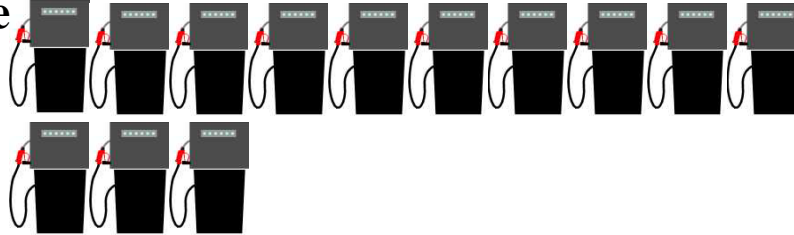
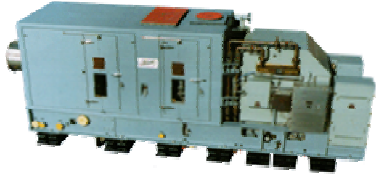
COMPARISON OF EFFICIENCIES FOR ELECTRIC POWER PLANTS





Annual Fuel Consumption (3,000 Operating Hours)

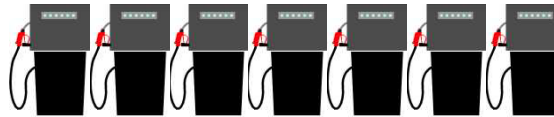
DDG 51 Gas Turbine Generator Set



641,465 Gallons

\$628,636

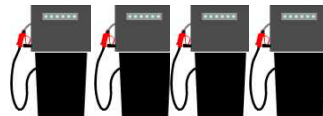
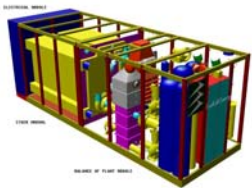
AOE 6 Diesel Generator Set



321,703 Gallons

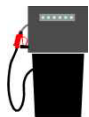
\$315,268

Ship Service Fuel Cell



214,315 Gallons

\$210,028



= 50,000 gallons; (\$.98/gallon)



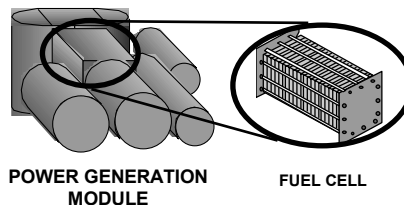
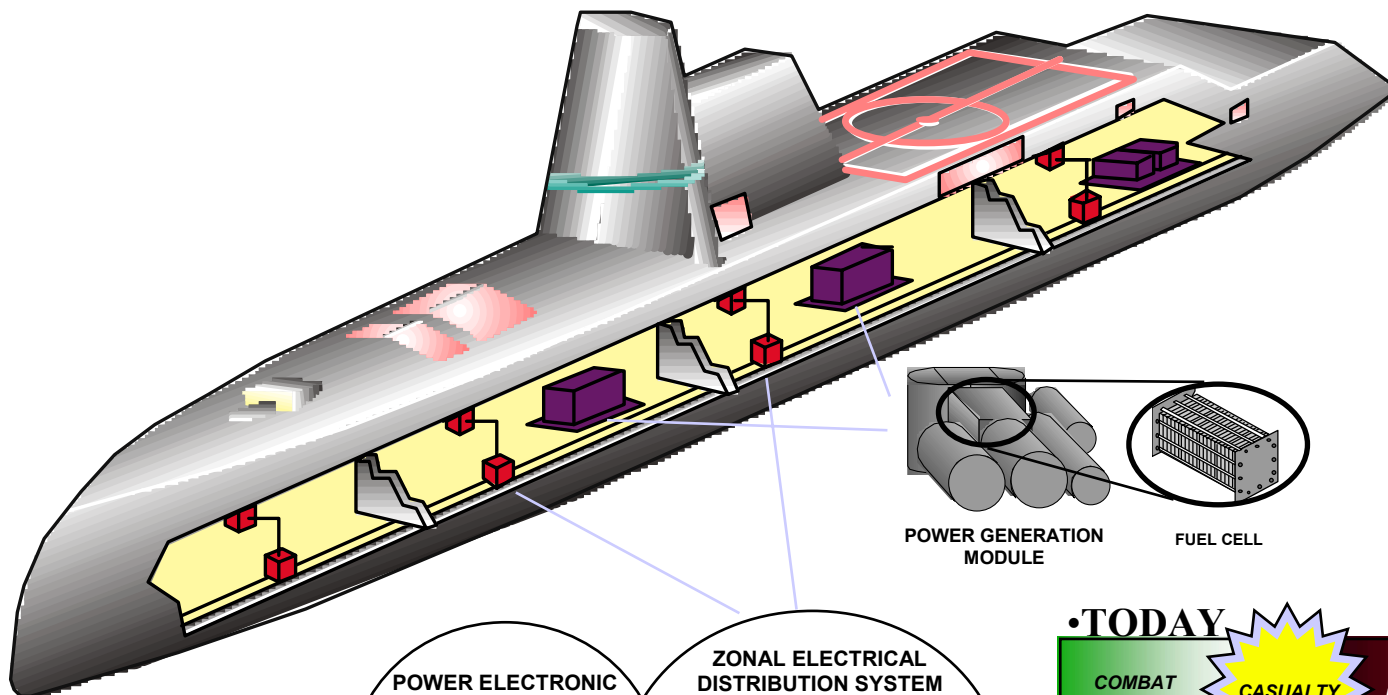
Additional Benefits

- *Ship Design Flexibility*
- *Modular Approach Applicable to all Ship Power Requirements*
- *Applicable to Multiple Platforms*
- *Facilitates All-Electric Ship with Integrated Power System and Zonal Electrical Distribution System*
- *Permits use of alternate and synthetic fuels*



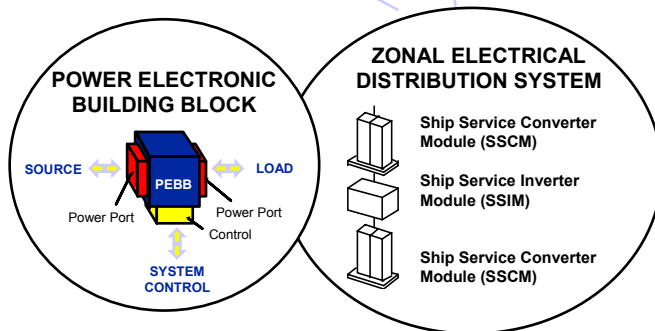
Navy Shipboard Fuel Cell Program

Reconfigurable, Survivable Electric Power Systems

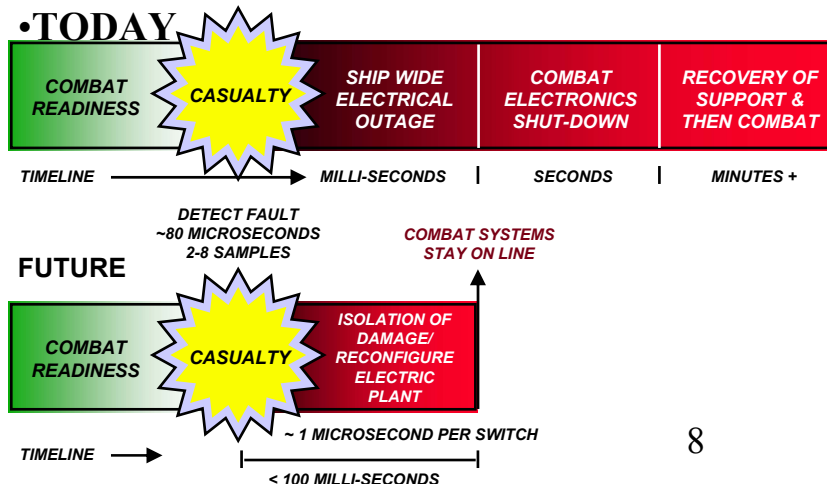


Challenges:

- ↑ System Efficiency
- ↑ Power Density
- ↑ Energy Density
- ↑ Resource Management and Control



POWER DISTRIBUTION MODULES



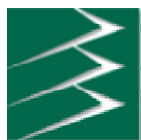


Fuel Cells for the Navy & Marine Corps

- Fuel Cell Applications
 - Shipboard power
 - Autonomous vehicles
 - Person-portable power
 - Field generators
 - Ground and sea combat vehicles
- Major Challenges
 - Operation on logistics fuels
 - Future fuels under consideration (e.g., synthetic diesels)
 - Operation in all marine environments
 - Undersea vehicles require oxidizer source
 - Compact, lightweight, rugged



ONR Fuel Cell Programs



FuelCell Energy

Clean Energy for the World





Investments in Fuel Cell Technology

- **Molten Carbonate Ship Service Fuel Cell System**
 - 625KW System with a Molten Carbonate Fuel Cell
 - Diesel inlet fuel
- **PEM Ship Service Integrated Fuel Cell Processor**
 - 500KW Fuel Processor with simulated PEM Fuel Cell Stack
 - Diesel inlet fuel
- **Basic Research in Fuel Cell and fuel processing technologies**



Navy Shipboard Fuel Cell Program

Objective:

- Demonstrate suitable fuel cell system technology for ships using diesel fuel as the source of hydrogen.

Approach:

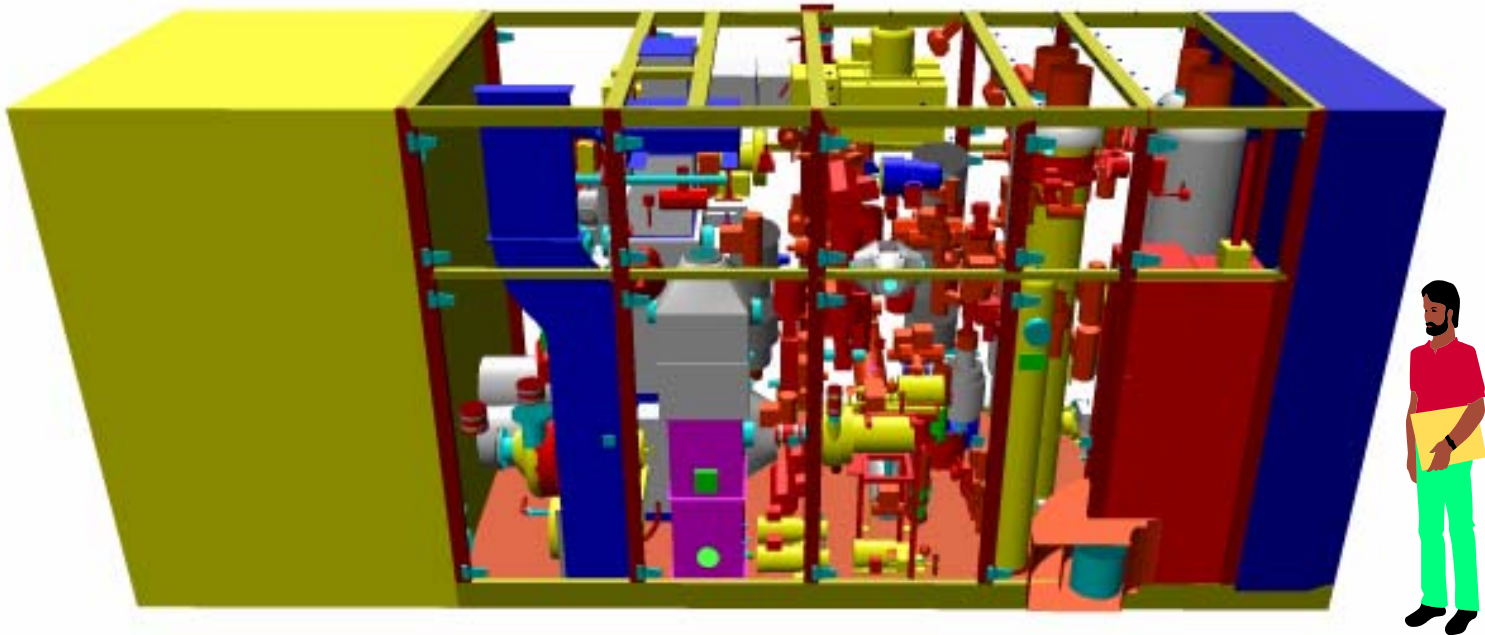
- Develop fuel cell power systems and components to enable commercial fuel cell equipment to be used in the unique Naval shipboard environment.
- Leverage commercial and government investment in Fuel Cell technology.
- Keep options open for different types of fuel cell (pursue dual paths).
- Investment focused on diesel processing and reforming.



625 kW Ship Service Molten Carbonate Fuel Cell System



FuelCell Energy



26.5' x 8.3' x 11'

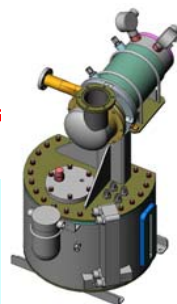
**FuelCell Energy 625 kW, 53% Eff, 450VAC
Molten Carbonate SSFC Power System**



FuelCell Energy



Fuel Cell Stack



Turbo Generator



ZnO Regeneration
Recuperator



HDS Recycle
Compressor



Anode Exhaust Regenerator
And Condenser



Catalytic Oxidizer



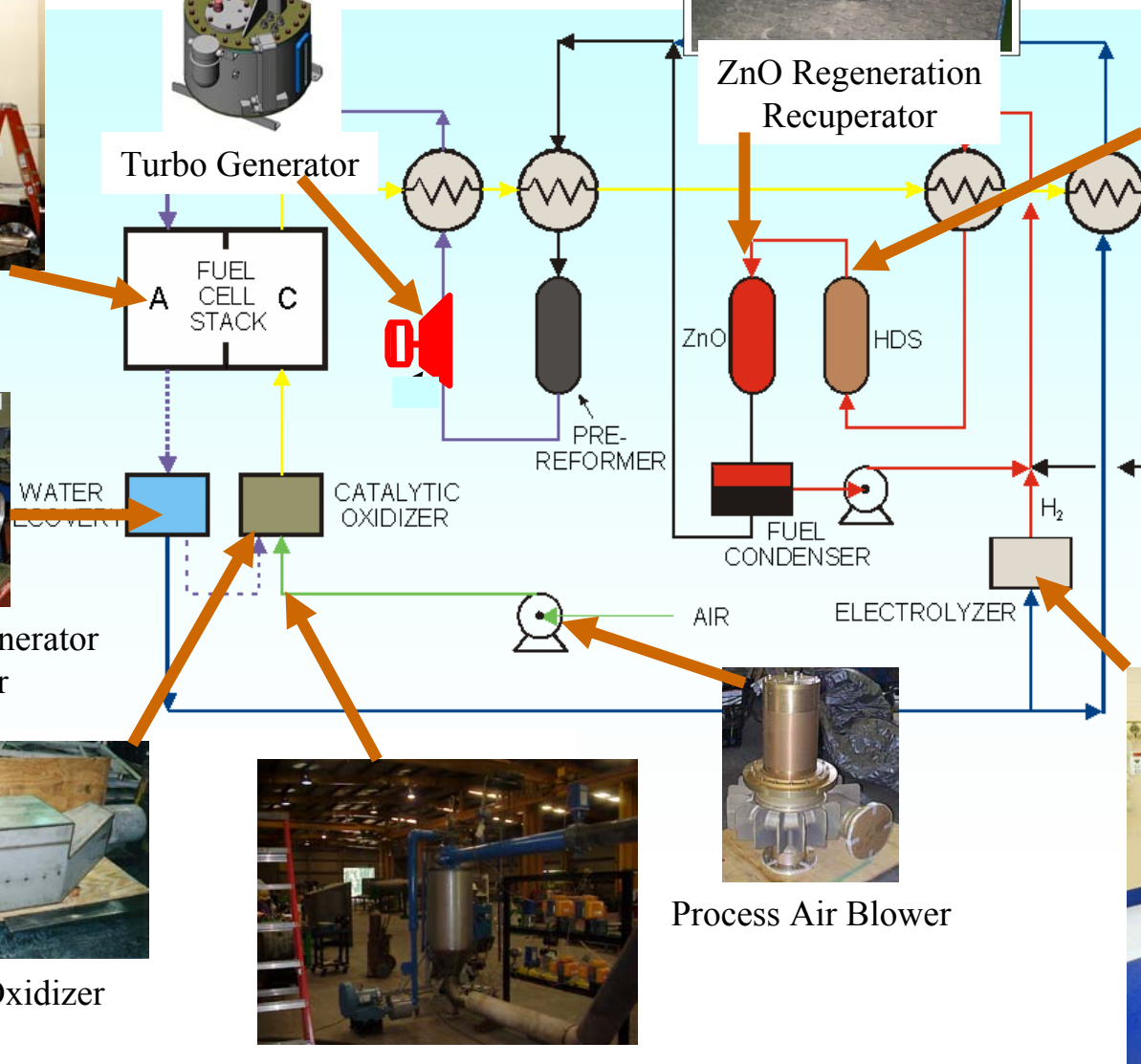
Start Burner



Process Air Blower

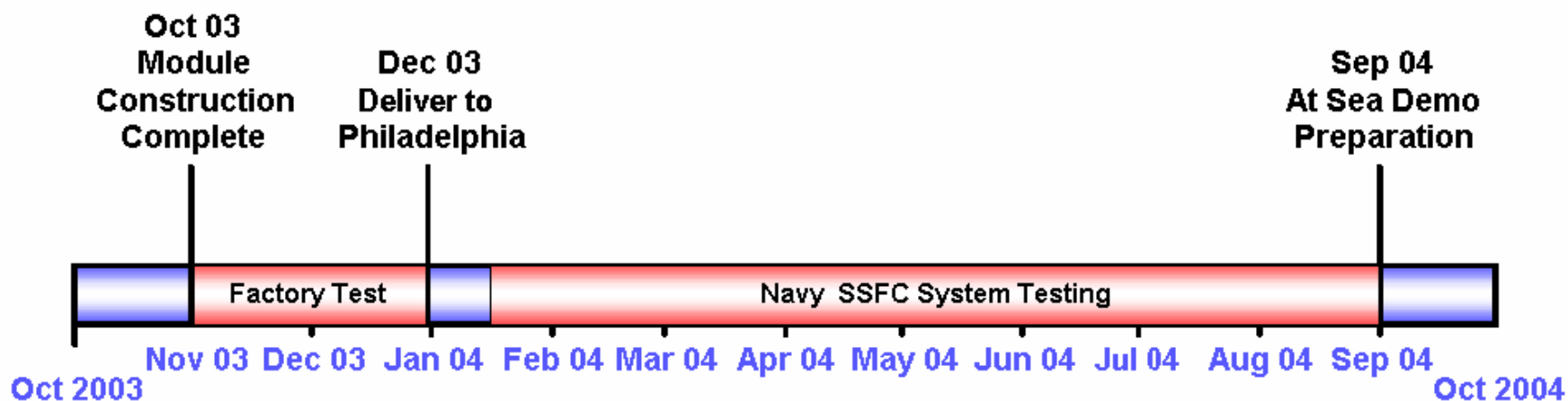
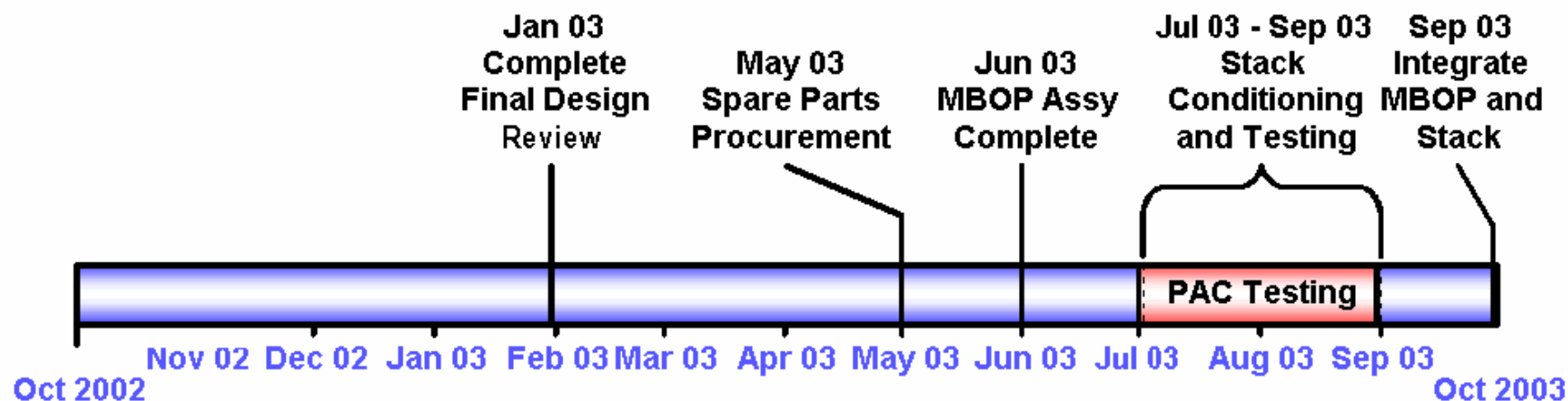


Electrolyzer



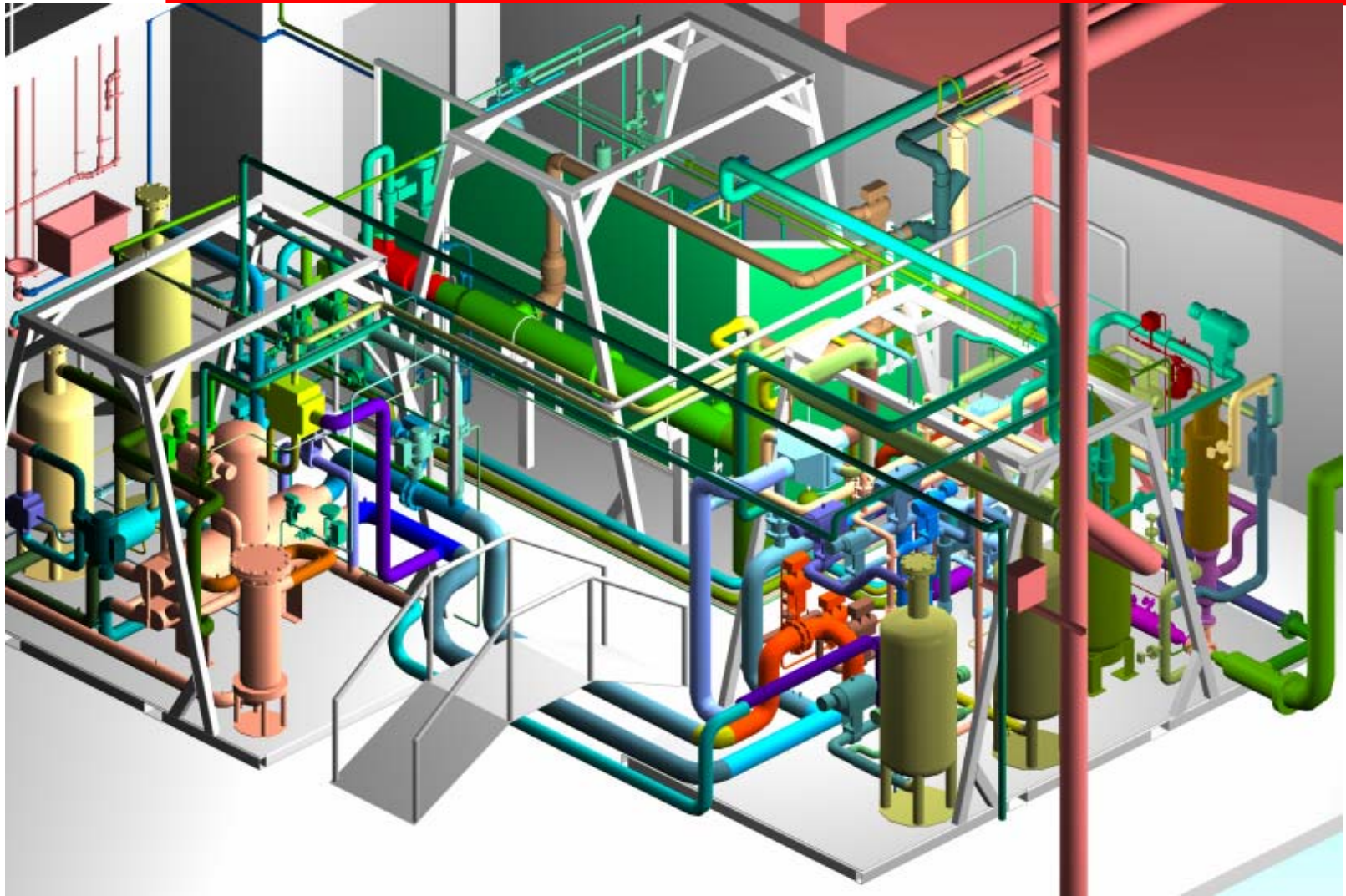


Ship Service Fuel Cell Timeline



SSFC (MCFC) Demonstration Timeline

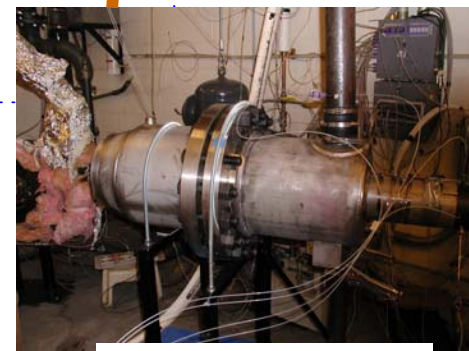
500 kW Integrated Fuel Processor



**500kW Integrated Fuel Processor, 35% Eff.
PEM Fuel Cell, Autothermal Reformer**



Steam Generator



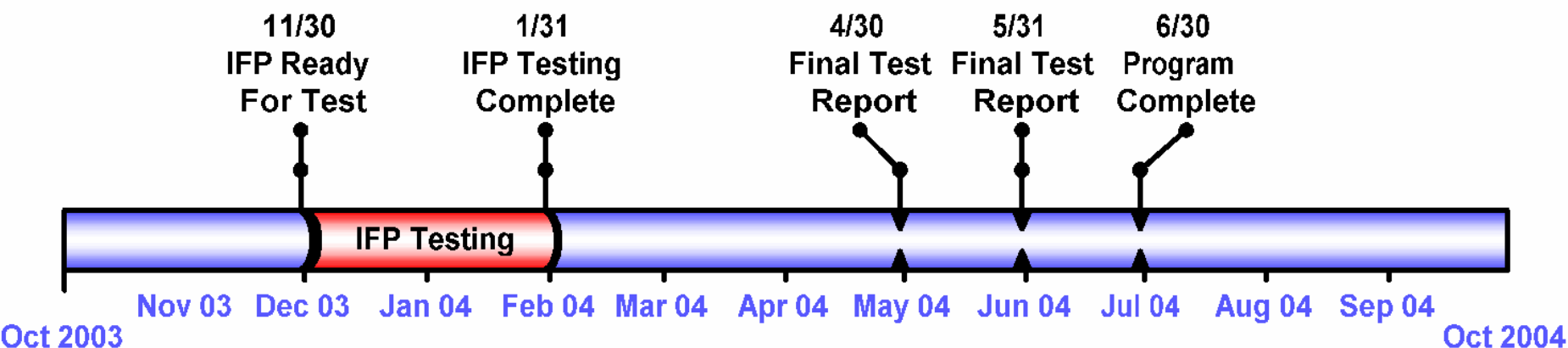
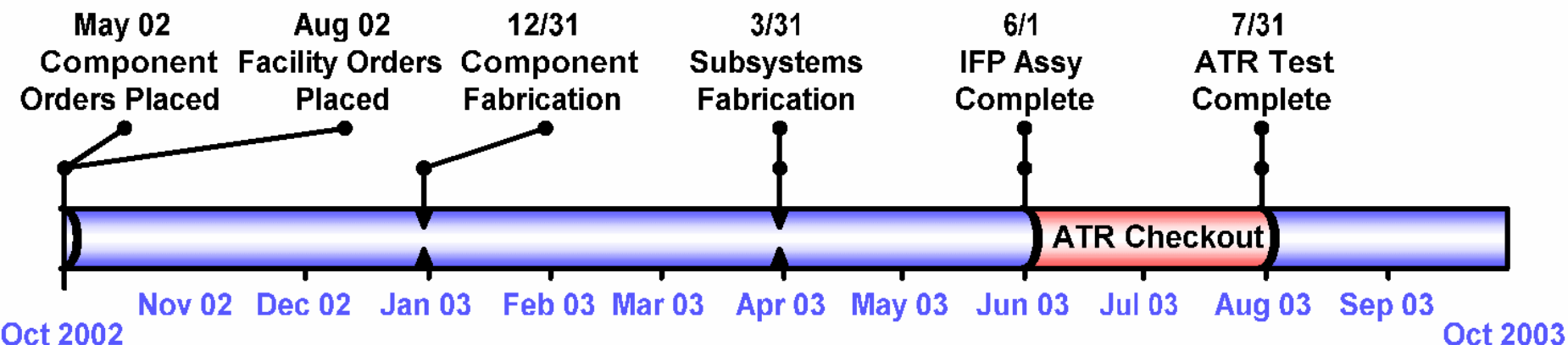
Simulated Fuel Cell

Turbo Compressor Lube Oil System

Turbo Compressor



Integrated Fuel Processor Timeline



Integrated PEM Fuel Processor Timeline



Lessons Learned

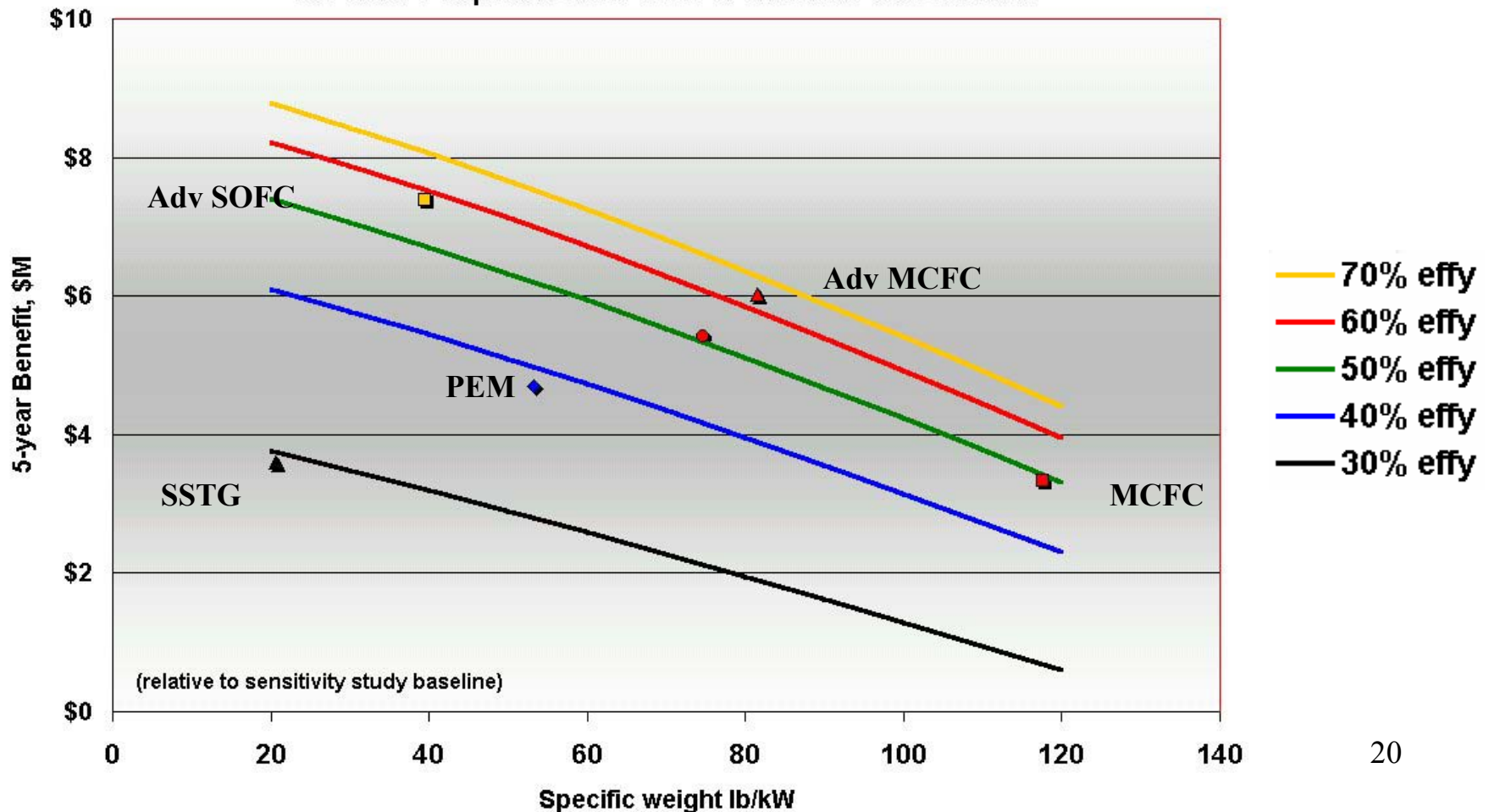
- Scale up limited by volume and system complexity.
- Integral de-sulfurizer has major volume impact
- Fuel cell system requires carefully integrated air cycle design
- Large reactor gas and low flammability point fuel storage increases system complexity and venting requirements.
- Higher system thermal mass significantly increases start time.



PGM 3 Ship Service Fuel Cells

5-year Benefit

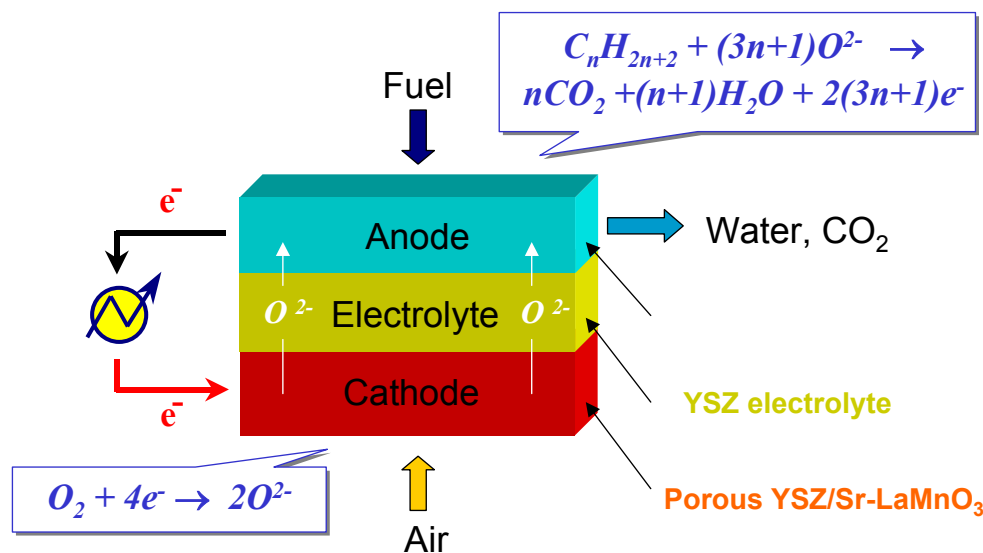
Single ship, 5-year Benefit (ship impact plus fuel only),
for SSGT replacement on IPS Surface Combatant.



Basic Research

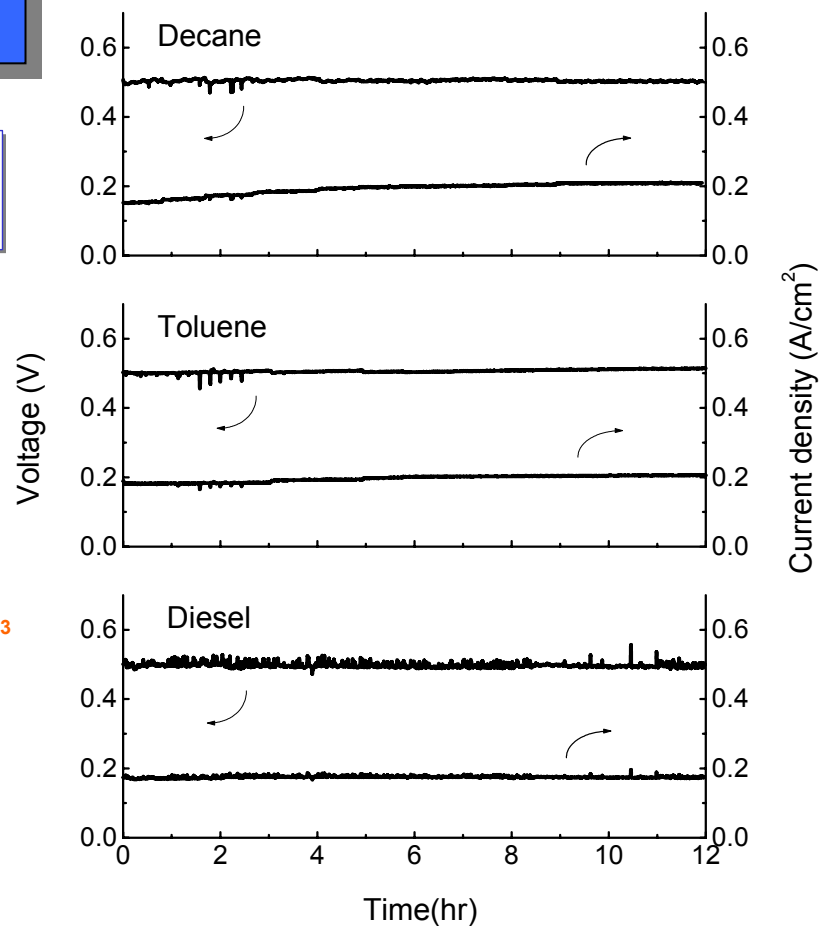
Direct Electrochemical Oxidation (DECO)

Diesel Fuel \Rightarrow Electricity



R. J. Gorte, J. M. Vohs, W. L. Worrell
University of Pennsylvania

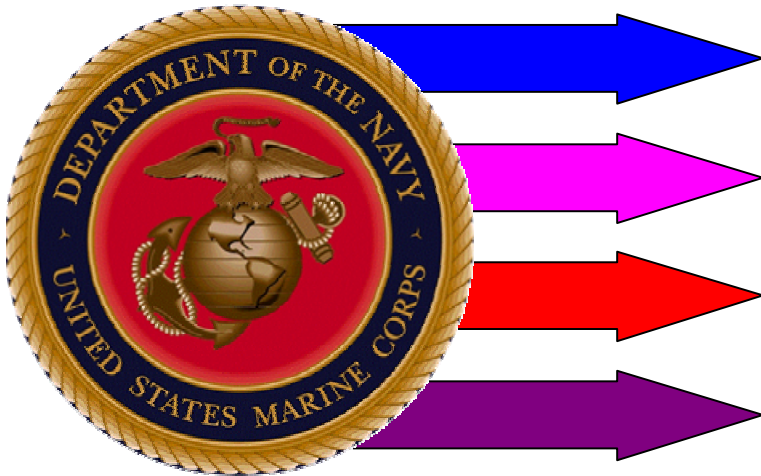
Liquid Fuels @ 700°C





Direct Diesel-to-Electric SOFC

*Marine Corps
Electrical Power*



- Field Generators
- Individual Marine
- Future Vehicles
- Autonomous Vehicles



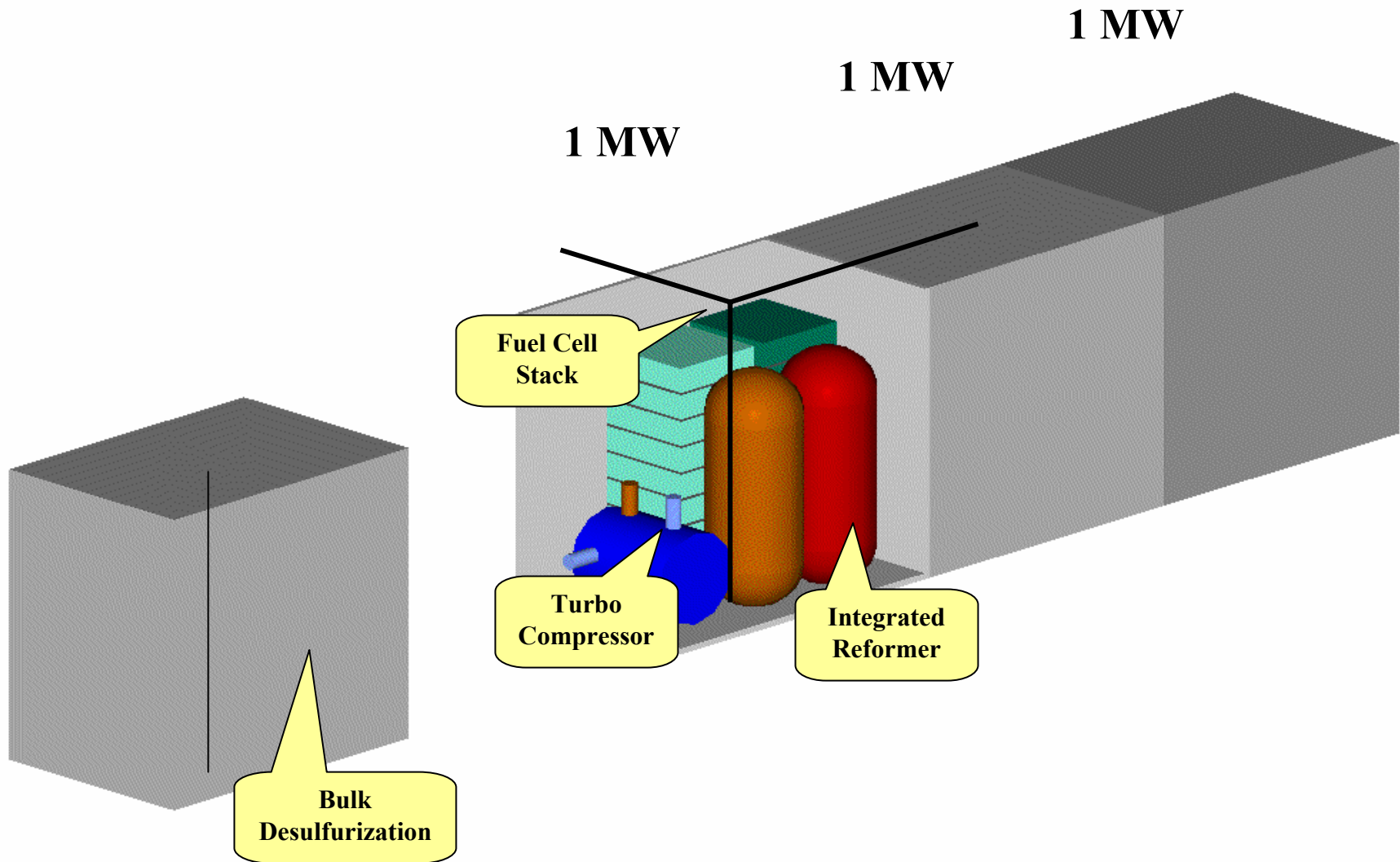


Continued Interest in Increasing Power Density

- Advanced reforming
- Membrane separation
- Sulfur tolerant water gas shift reactors
- Improve catalyst efficiencies
- Bulk sulfur removal processes
- High efficiency air cycles



Future Concept





Summary

- Fuel Cell and associated Reformer Technology offers the Navy and Marine Corps many benefits.
- Navy Shipboard Fuel Cell Program addresses unique Navy and Marine Corps technical challenges, while leveraging commercial fuel cell advancements.
- 625kw Molten Carbonate and 500kw PEM based FC System with diesel reforming capability currently being pursued.
- Additional Science and Technology investments required to optimize fuel cell power and cost benefits
- S&T development approach will leverage state-of-art commercial fuel cell and processing technologies.



***Powered by
Naval Research***

TM/SM