SPIRE Program Kickoff

Topic 3A. Cell Degradation Studies / Degradation Studies
Durability of Low Pt Fuel Cells Operating at High Power Density

US DOE Fuel Cell Projects Kickoff Meeting
DOE Award: DE-EE0000469
October 1st, 2009

Program Objectives

Table 3.4.3. Technical Targets: 80-kW$_e$ (net) Transportation Fuel Cell Stacks Operating on Direct Hydrogen[a]

Characteristic	Units	2003 Status	2005 Status	2010	2015
Stack power density[b]	W/L	1,330	1,500[c]	2,000	2,000
Stack specific power	W/kg	1,260	1,400[c]	2,000	2,000
Stack efficiency[d] @ 25% of rated power	%	65	65	65	65
Stack efficiency[d] @ rated power	%	55	55	55	55
Cost[e]	\$/kW$_e$	200	70[f]	25	15
Durability with cycling	hours	na	2,000[g]	5,000[h]	5,000[h]
Transient response (time for 10% to 90% of rated power)	sec	<3	1	1	1
Cold start-up time to 50% of rated power					
@ –20ºC ambient temperature	sec	2	20	30	30
@ +20ºC ambient temperature	sec	<1	<10	5	5
Start up and shut down energy[i]					
from -20°C ambient temp	MJ	na	7.5	5	5
from +20°C ambient temp	MJ	na	na	1	1
Unassisted start from[j]	ºC	na	-20	-40	-40

The objective of this program is to study and identify strategies to assure durability of fuel cells designed to meet DOE cost targets.

NUVERA FUEL CELLS

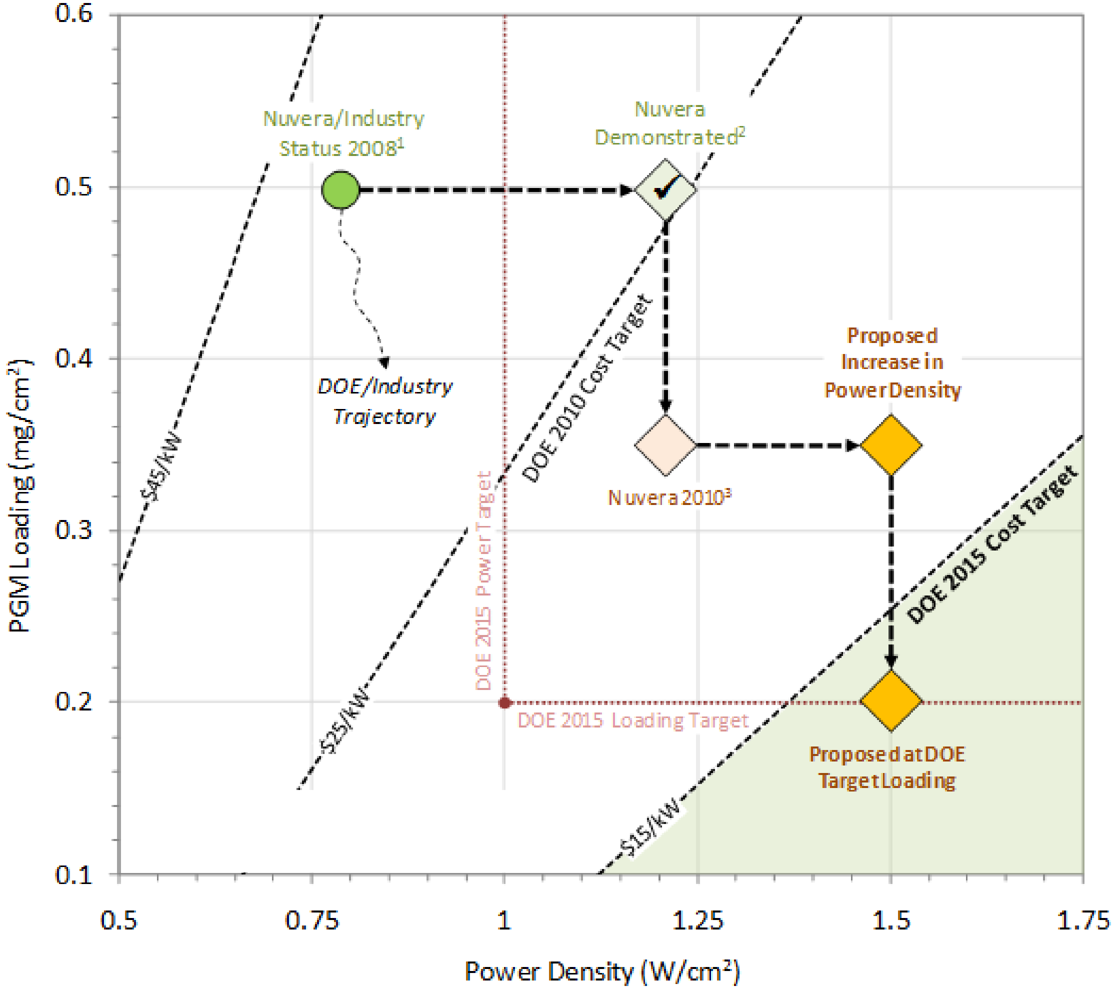
Technical Barriers

Barrier	Approach	Strategy
A. Durability	Reinforced, Stabilized Membrane	MEA Partner
	Durability-Enhanced Electrodes	Electrocatalyst/MEA Partner
	Optimized Operating Conditions	Parametric model & experimental studies
B. Cost	Low Pt Loadings (0.2 mg/cm^2)	Electrocatalyst/MEA Partner
	High Power Density (>1.0W/cm^2)	Open Flowfield Stack
	Metallic Stack Architecture	Incumbent Derivative

Premise: Exceeding the MEA power density target (>1 W/cm^2) while maintaining low total Pt loading (≤0.2 mg/cm^2) will enable cost targets to be met

Technical Objective

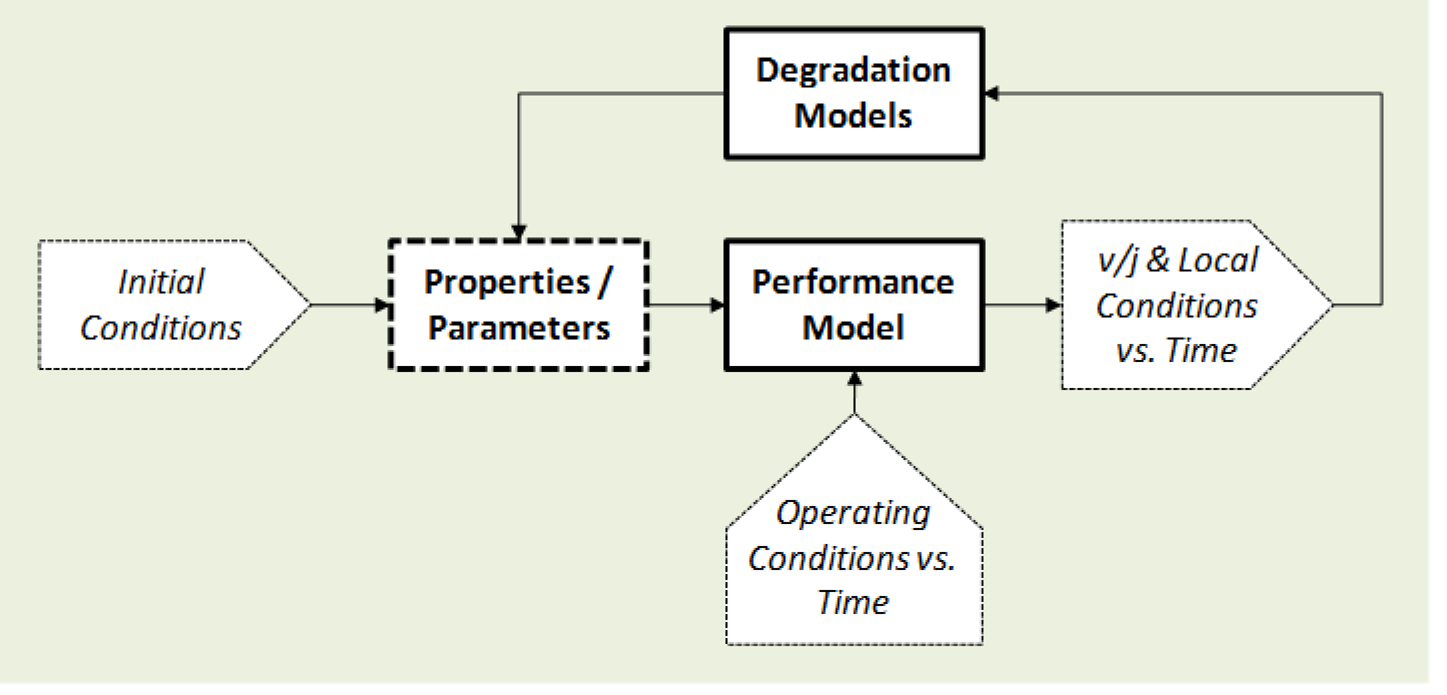
Goal: Define the rating current density (RCD) of an advanced stack technology consistent with DOE cost targets, and elucidate critical durability mechanisms at this RCD.



NUVERA FUEL CELLS

Modeling Concept

The key deliverable of this program is a durability model experimentally validated over a range of stack technologies operating at high power.



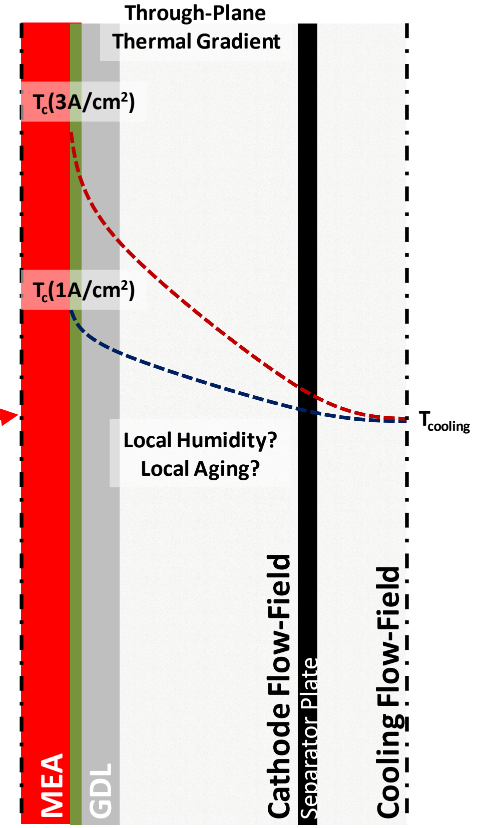
Requires: *Spatially and temporally resolved performance model (mechanistic)*
Accumulative material property degradation model (empirical)
Design/initial condition flexibility for BOL properties and time-varying conditions

Degradation Modes

Component	Function / Property	Degradation Modes	Causes

Membrane	• Ionic Conductivity
	• Gas Seal
	• Electrical Resistivity
	• Water Transport
		• Chemical
		  • Thinning
		  • Poisoning
		• Mechanical
		  • Excessive Stress
		  • Cyclic Fatigue
		  • Puncture
			• Oxygen cross-over / peroxide attack at low power (high voltage) idle conditions
			• Contamination from the system or corrosion of the flow-field / bipolar plate
			• Inadequate design / assembly
			• Temperature & humidity cycling due to changes in power

Electrode	• Ionic Conductivity • Electrical Conductivity • Electrochemical Activity • Gas Diffusivity • Water Transport	• Support Corrosion • PGM Migration • Ionomer Chem. Degradation • Delamination • Hydrophobicity Degradation	• Lack of fuel due to system issues or flooding • Potential cycling due to changes in power and start-stop • Temperature & humidity cycling due to changes in power • Temperature excursions / hot-spots • Low gas relative humidity • Freeze-thaw cycles
GDL	• Electrical Conductivity • Gas Diffusivity • Water Transport	• Corrosion • Mechanical Deterioration • Delamination • Hydrophobicity Degradation	• Potential cycling due to changes in power and start-stop • Cell reversal • Temperature & humidity cycling due to changes in power • Freeze-thaw cycles
Flow-Field / Bipolar Plate	• Electrical Conductivity • Gas Distribution • Gas Seal • Material Stability	• Corrosion • Mechanical Deterioration • Contamination / Blockage	• Material compatibility and/or coating integrity • Temperature excursions / hot-spots • Physical abuse • Process fluid cleanliness



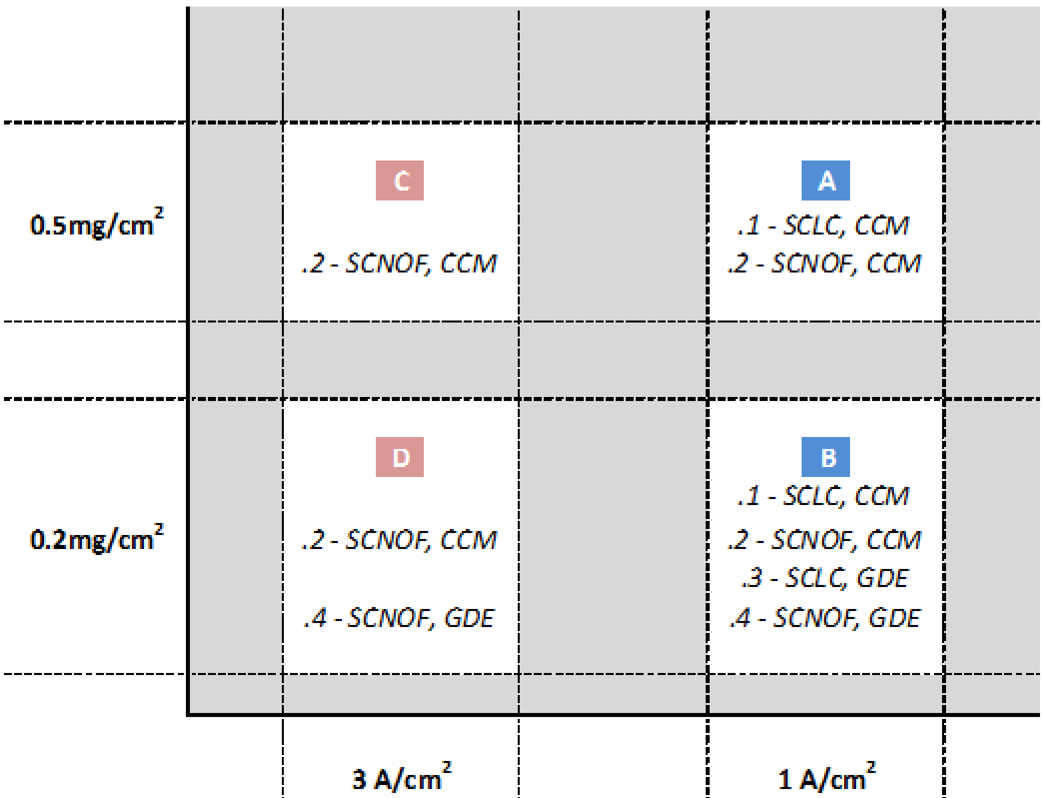
What modes are most important at high current density?

What are the appropriate empirical relationships and upon which variables do they depend?

Parameter Space

<u>Approach</u>: *Single cells will be run on a combination of AST and NST ("new stress test") protocols to calibrate the model over a wide range of material configurations.*

<u>Experimental Design</u>



<u>Sensitivities Tested</u>

a. Loading
   - A.1 - B.1 & B.3 (AST 1-3)
   - A.2 - B.2 & B.4 (AST 1-3)
   - C.2 - D.2 & D.4 (NST-3A)

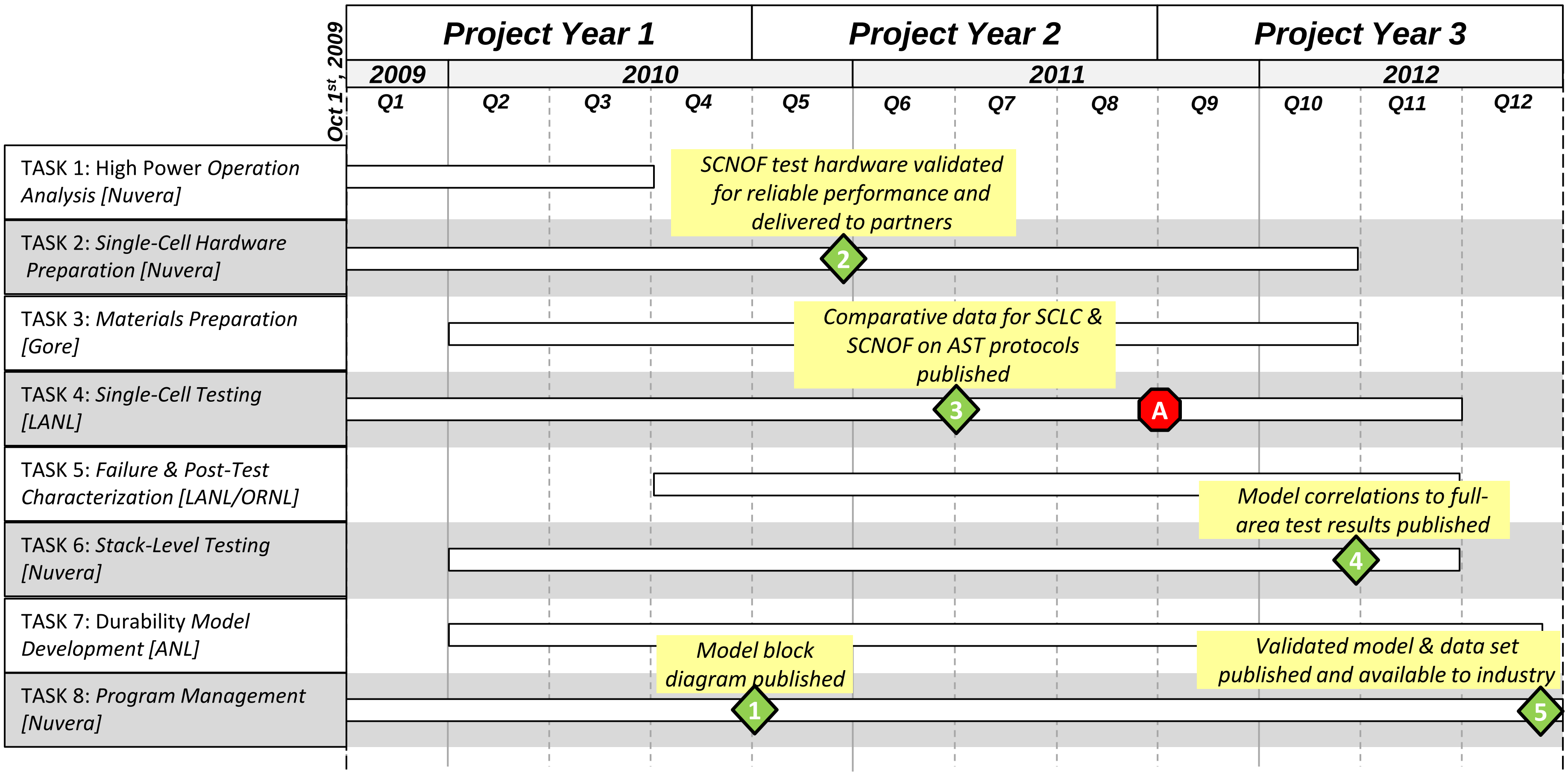
b. Current
   - B.2 - D.2 (NST-1A/3A)
   - B.4 - D.4 (NST-1A/3A)
   - A.2 - C.2 (NST-1A/3A)

c. Flow-field architecture
   - A.1 - A.2 (AST 1-4)
   - B.1 - B.2 (AST 1-3)
   - B.3 - B.4 (AST 1-3)
   - C.1 - C.2 (AST 1-3)

d. Electrode structure
   - B.1 - B.3 (AST 1-3)
   - B.2 - B.4 (AST 1-3, NST-1A)
   - D.2 - D.4 (NST-3A)

Experimental Design Space

Schedule



A → *Demonstrate data variability between Nuvera and Los Alamos National Lab is within 3-sigma bounds of the variation established during the USFCC round-robin AST testing. [End of Q8]*

NUVERA FUEL CELLS

Rev. 8/26/2009

Program Team

SPIRE Budget

Funding by Fiscal Year

$/000	Federal Funding		Cost Share		Total Value
FY09	297		94		391
FY10	1,192		374		1,566
FY11	1,467		458		1,925
FY12	919		295		1,214
Total	**3,875**	76%	**1,221**	24%	**5,096**

NUVERA FUEL CELLS

Summation

- Increasing rated power density is an effective and largely unexplored way to reduce the cost of fuel cell systems in both the near- and long-term.
- Limited operating experience leaves open questions regarding alternate or accelerated degradation mechanisms at high (>1.0W/cm^2) power density.
- This project will reveal those new factors that would challenge durable operation under these cost-effective conditions and help clarify what developments are needed for success.

NUVERA FUEL CELLS


NUVERA
FUEL CELLS
EXPERIENCE
The Future of Energy®