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2011 DOE Hydrogen Program Annual Merit Review

SPIRE

Sustained Power Intensity with Reduced Electrocatalyst

(aka: Durability of Low Pt Fuel Cells Operating at High Power Density)

Scott Blanchet (PI)

Presenter: Olga Polevaya (PM)

Nuvera Fuel Cells

5/11/2011

FC014

Overview

Timeline

- Kick-Off: December, 2009
- Nuvera and DOE agreed on extending to 4-year program ending 09/30/2013
- 25% Complete (03/11/2011)

Barriers

- Barriers addressed
  - Stack Durability with Cycling: **target: 5000hrs (2015)**
  - Stack Cost: **target: $15/kW (2015)**

Budget

- $5.642M Total Project
  - $3.875M DOE Share
  - $1.767M Contractor Share
  - $975,000 National Labs
- $1.162M received through FY10
- $0.915M planned for FY11

Partners

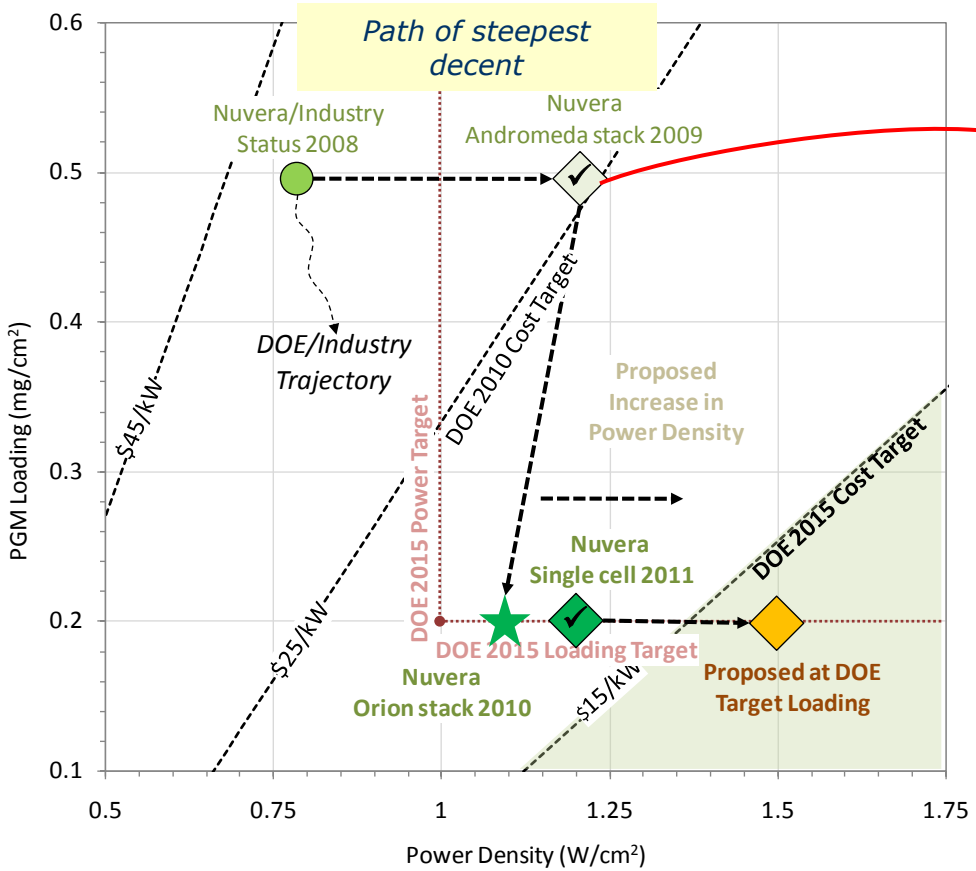
NUVERA FUEL CELLS

Argonne NATIONAL LABORATORY

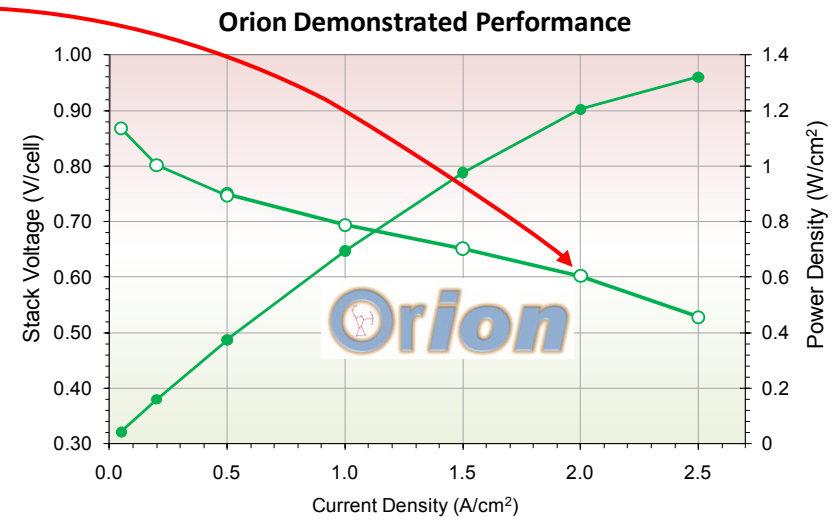
Los Alamos NATIONAL LABORATORY

Relevance: Objective and Deliverables

The technical objective is to identify and model PEMFC durability factors associated with low-Pt MEAs operating at high(>1W/cm²) power density.



Capable stack architecture

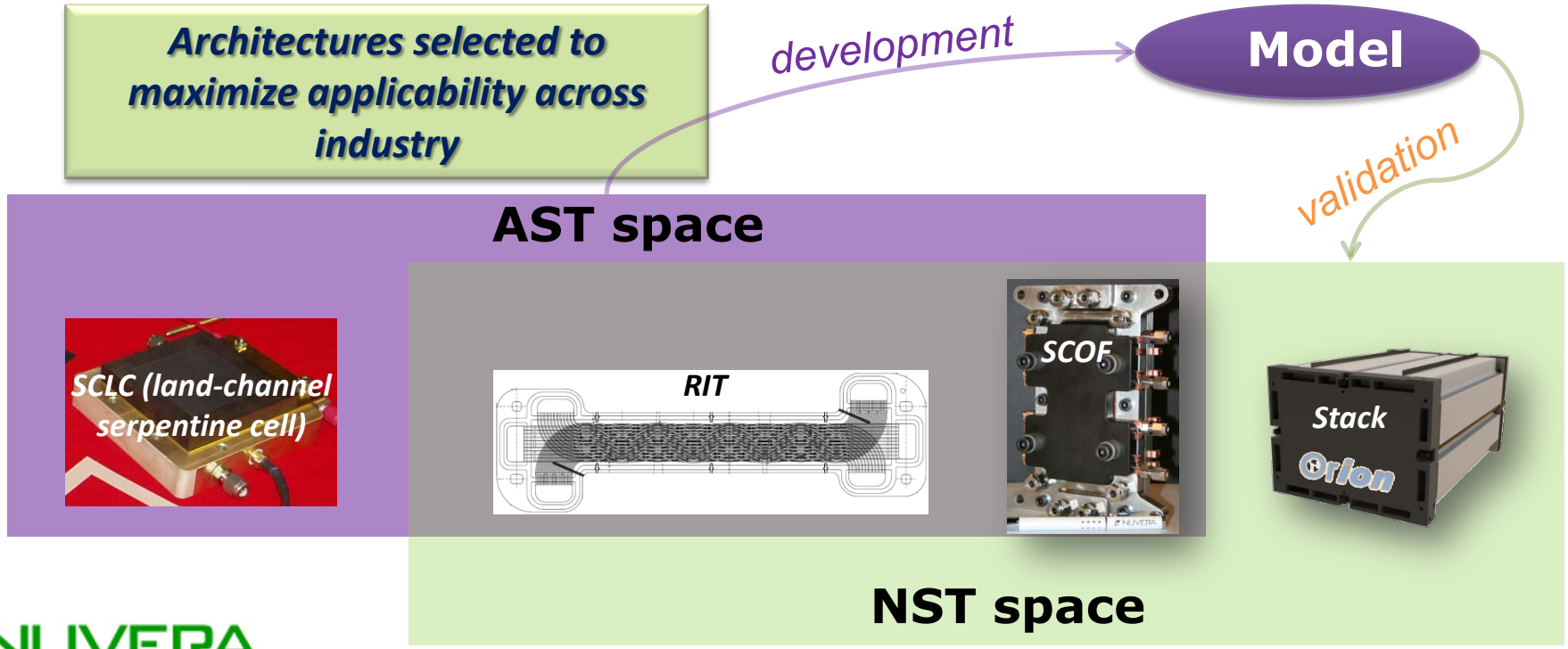


Iso-cost curves fit to 2008 DTI results for 500k vehicles per year with 2015 technology.

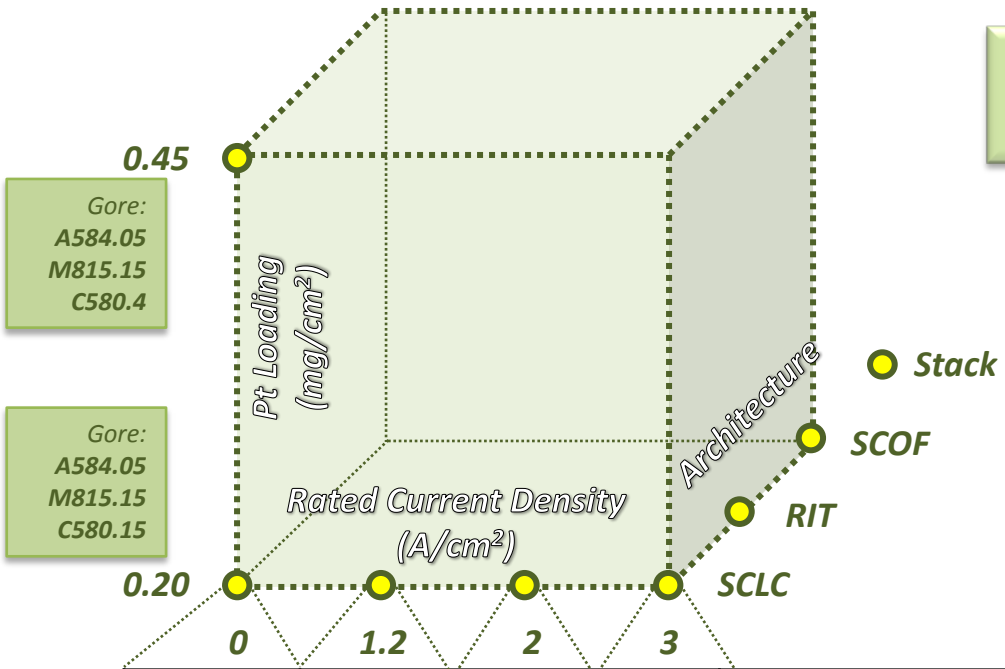
The key deliverable of this program is a durability model experimentally validated over a range of stack technologies operating at high power

Approach

- SPIRE program balances modeling and experimentation.
  - Performance decay model is being developed based on ASTs across selected 50-cm^2 cell architectures.
  - Relevance of ASTs (component stressors) to NSTs (New Stress tests in fuel cell power mode) is studied in new high power density SCOF (Single Cell with Open Flowfield) cell.
  - Full-area stack testing used to validate the model results throughout NSTs.



Technical Approach-Experimental Design



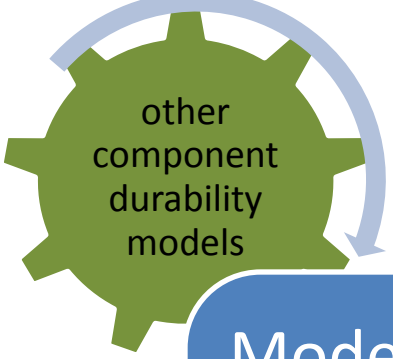
9 ASTs and 22 NSTs are planned
~25% complete

AST	NST			Purpose
B1		N1A-2		Benchmarking electrode stability to potential cycles with and without current *B1* potential limits equivalent to N1A-2*
B1*				
B4		N1B-2		Membrane mechanical stability with and without current
	N2A-1	N2A-2	N2A-3	FCTT combined load & humidity over range of RCD/ICD
		N3A-2	N3A-3	Combined city/highway drive cycle over range of RCD/ICD

component_durability_may_2010.pdf

Test ID	Protocol ID	Architecture ID	Material ID	Test Location	Test status
TID-1	B1	SCLC	A	LANL	Completed
TID-2	B1	SCOF	A	LANL	In progress
TID-3	B1	SCLC	B	LANL	Completed
TID-4	B4	SCLC	A	LANL	Completed
TID-5	B4	SCOF	A	LANL	Not started
TID-6	B4	RIT	A	LANL	Not started
TID-7	B1*	SCOF	A	LANL	Not started
TID-8	B1*	SCLC	B	LANL	Completed
TID-9	B1*	SCOF	B	LANL	Not started
TID-10	N1A-2	SCOF	A	Nuvera	In progress
TID-11	N1A-2	SCOF	B	Nuvera	In progress
TID-12	N1A-2	RIT	A	LANL	Not started
TID-13	N1B-2	SCOF	A	Nuvera	Not started
TID-14	N1B-2	SCOF	B	Nuvera	Not started
TID-15	N1B-2	RIT	A	LANL	Not started
TID-16	N2A-1	SCOF	A	LANL	Not started
TID-17	N2A-1	RIT	A	LANL	Not started
TID-18	N2A-2	SCOF	A	Nuvera	Not started
TID-19	N2A-2	SCOF	A	LANL	Not started
TID-20	N2A-2	Stack	A	Nuvera	Not started
TID-21	N2A-3	SCOF	A	Nuvera	Not started
TID-22	N2A-1	SCOF	B	LANL	Not started
TID-23	N2A-1	RIT	B	LANL	Not started
TID-24	N2A-2	SCOF	B	Nuvera	Not started
TID-25	N2A-2	SCOF	B	LANL	Not started
TID-26	N2A-3	SCOF	B	Nuvera	Not started
TID-27	N3A-2	Stack	A	Nuvera	Completed
TID-28	N3A-2	Stack	B	Nuvera	In progress
TID-29	N3A-3	Stack	A	Nuvera	Not started
TID-30	N3A-3	Stack	B	Nuvera	Not started
TID-31	N2A-2	Stack	B	Nuvera	Not started

Modeling Approach– Durability Model Framework



Model outputs: ECSA, PSD (particle size distribution), η (overpotentials), V(time, A/cm²)

Inputs
- Cell Architecture
- Use cycles
- ECP BOL

Validation on NST

Pt Electrode stability Model

Pt Ion Transport Model

AST B1 inputs

Pt Aqueous Kinetics

Oxide coverage
Pt ⇔ PtOx

Dissolution-Redeposition
Pt ⇔ Pt^{2+}

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- Pt wire
- Pt/C –Etek 0.5mg/cm²
- Pt/C – Gore C580.15

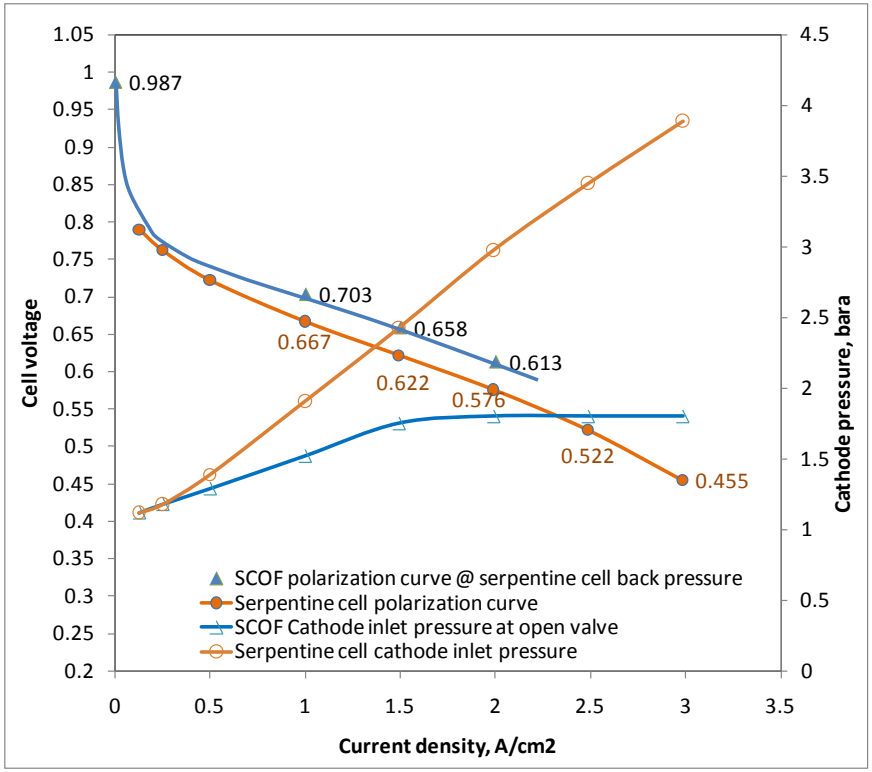
Spire activities are synchronized with other DOE durability programs to avoid duplication of effort

Technical Progress – Milestones

Milestone	Due date	Status
1. Model Block diagram published.	**FY2010, Q3**	**Complete**
2. SCOF hardware validated and delivered to LANL.	**FY2011, Q1**	**Complete**
3. Comparative data for SCLC and SCOF on AST protocol is published	FY2011, Q3	In progress
GNG decision: Demonstrate durability results (voltage decay, diagnostic and post-test measures) in SCOF are consistent with full-area short stack testing using baseline operating conditions and materials.	**FY2011, Q4**	**Moved to FY2012, Q1 with new 4-year plan**
4. Model correlations to full-area test results published.	FY2012, Q1	Moved to FY2012, Q4 with new 4-year plan
5. Validated model and data set published and available to industry	FY2012, Q4	Moved to FY2013, Q3 with new 4-year plan

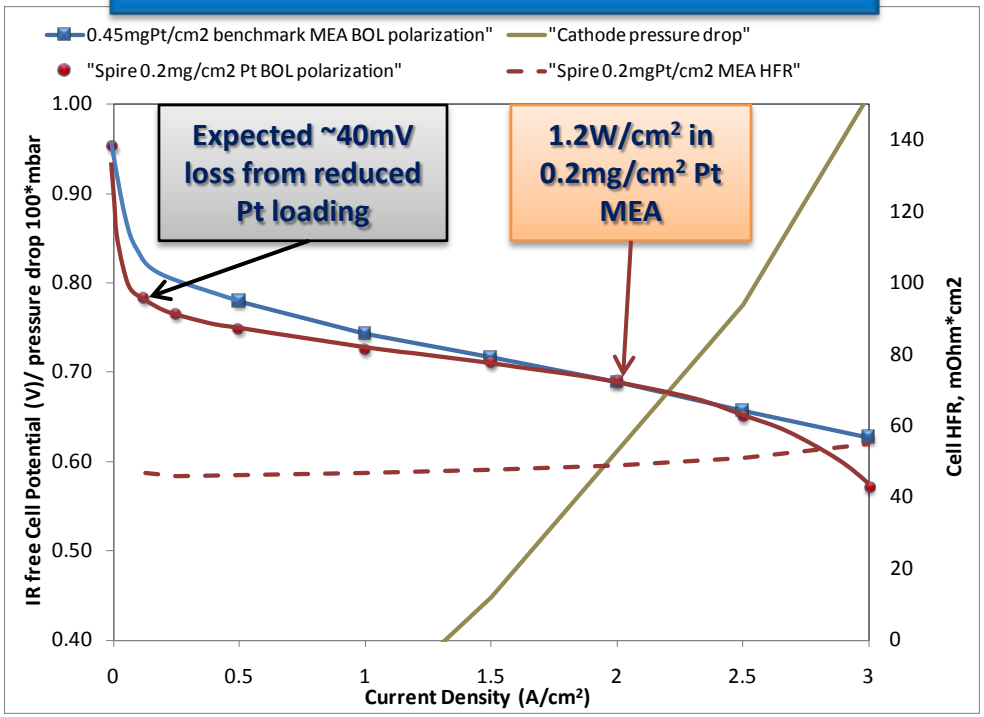
Technical Progress – Single Cell

SCOF vs. Serpentine Cell, High Pressure



Open flowfield single cell showed benefits both at elevated and lowered cathode pressures

Dry cathode, Low Pressure Operation 1.8bara inlet



SCOF hardware is delivered to LANL for validation in ASTs and NSTs.

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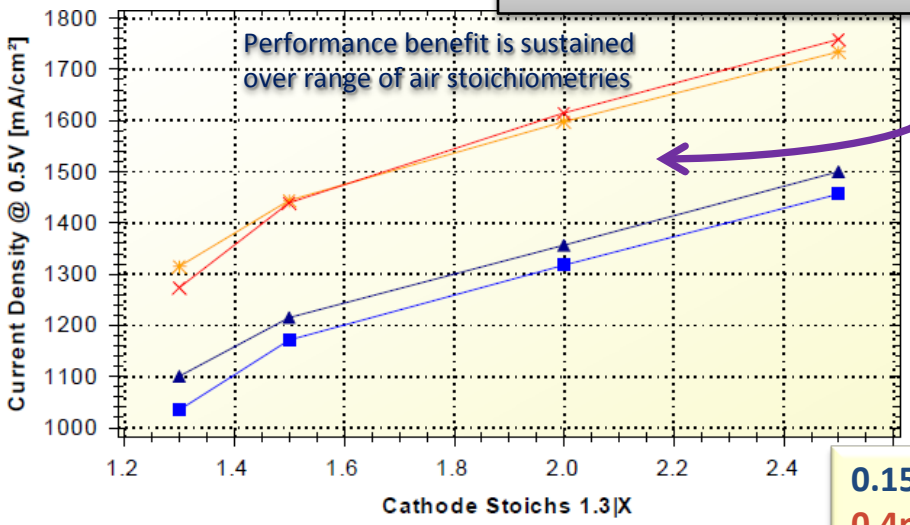
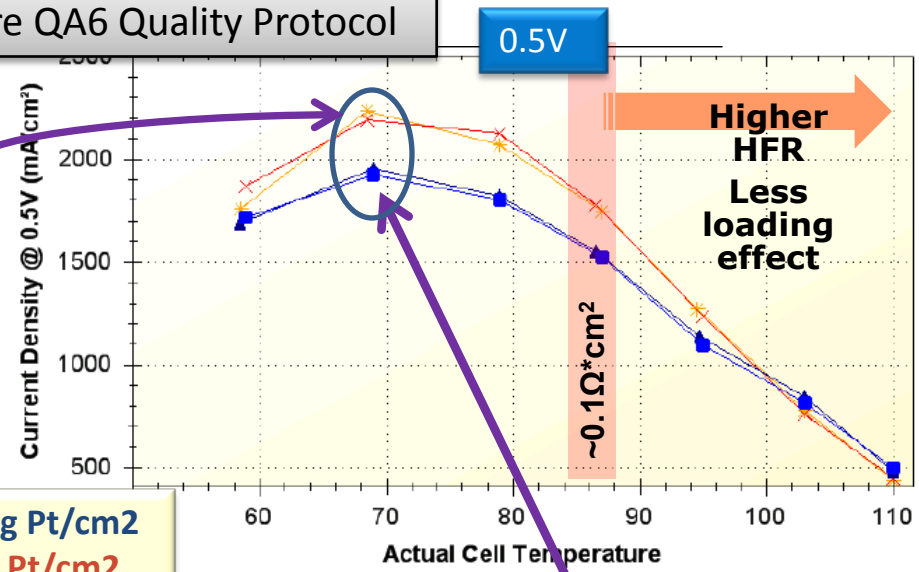
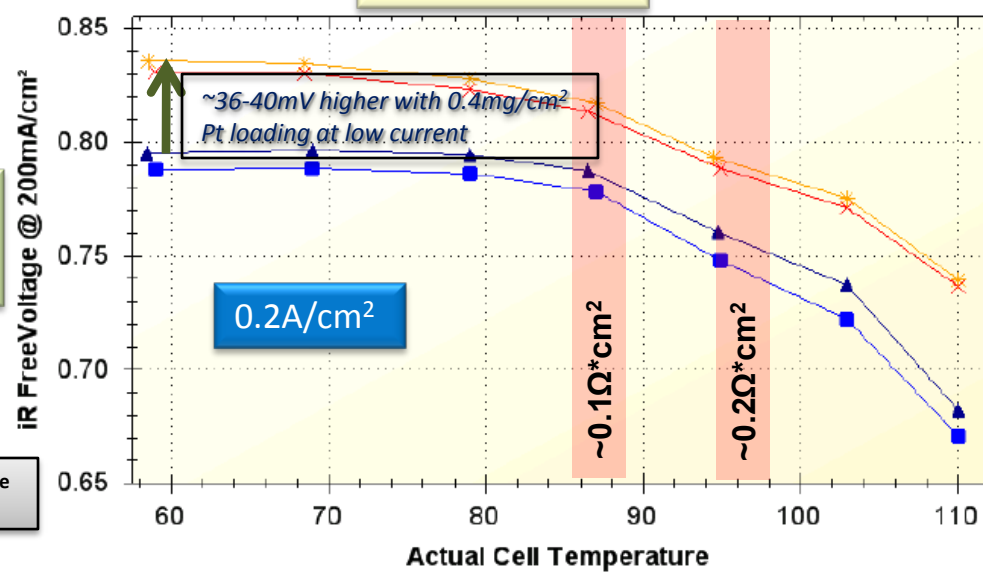
Technical Progress
Reduced Pt Loaded Cathode MEA – BOL

Sensitivity Data from Gore QA6 Quality Protocol





0.15mg Pt/cm2
0.4mg Pt/cm2



Confirmed in LANL and Gore cells

RCD limited to <= 2A/cm² due to serpentine cell architecture.

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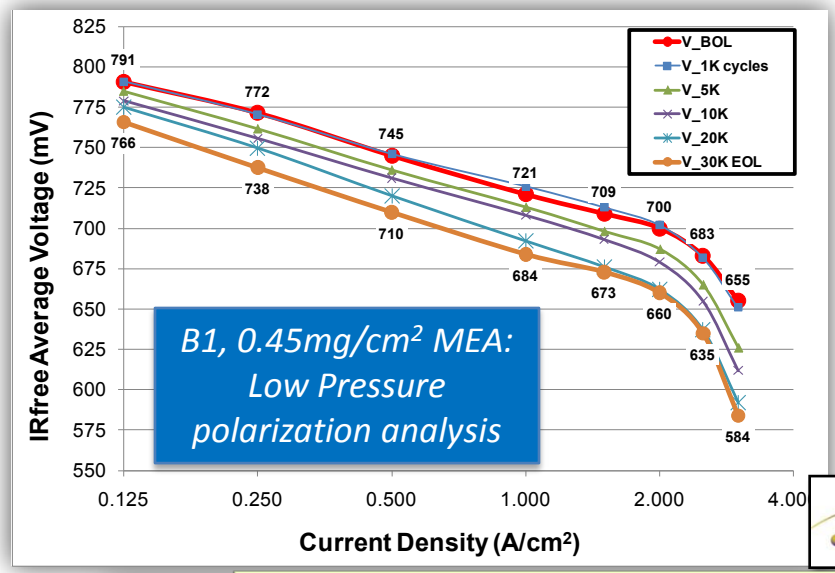
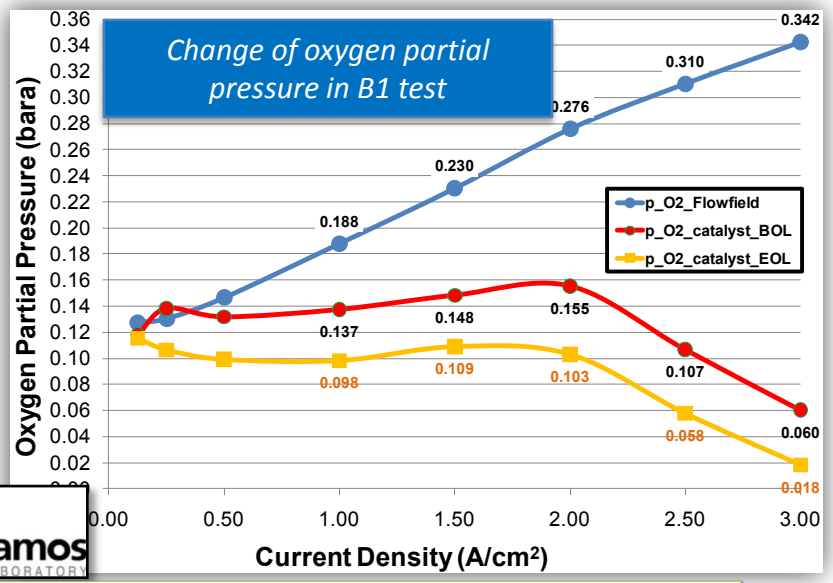
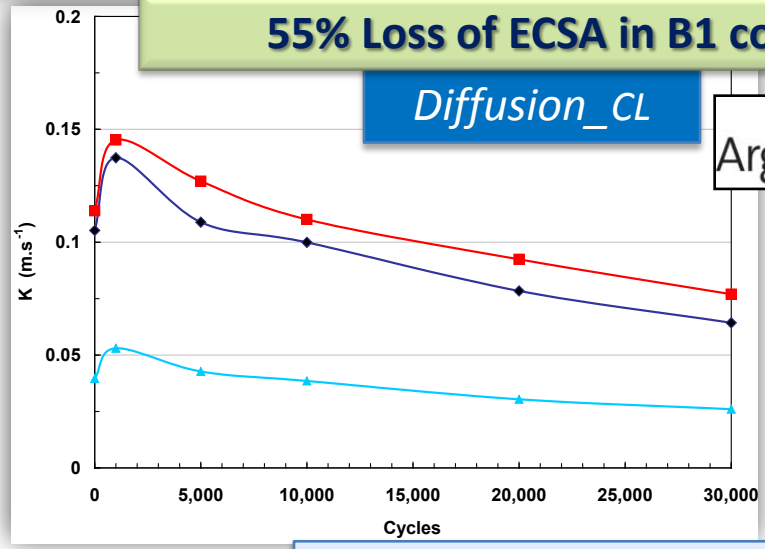
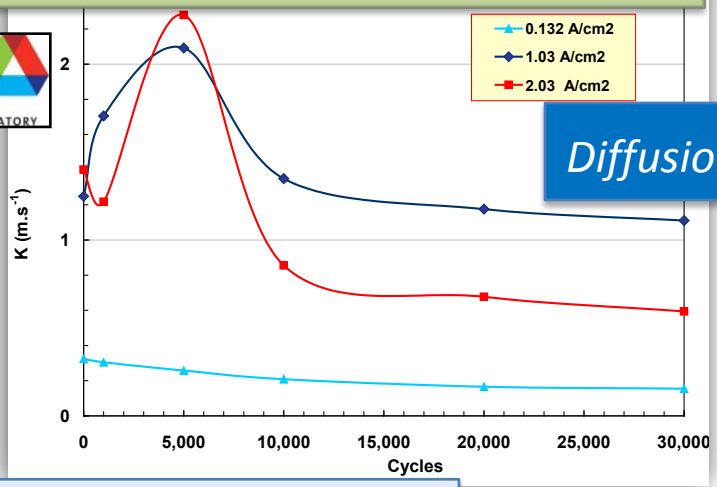
Technical Progress – ASTs





55% Loss of ECSA in B1 consistent in CV and V-I curve analysis



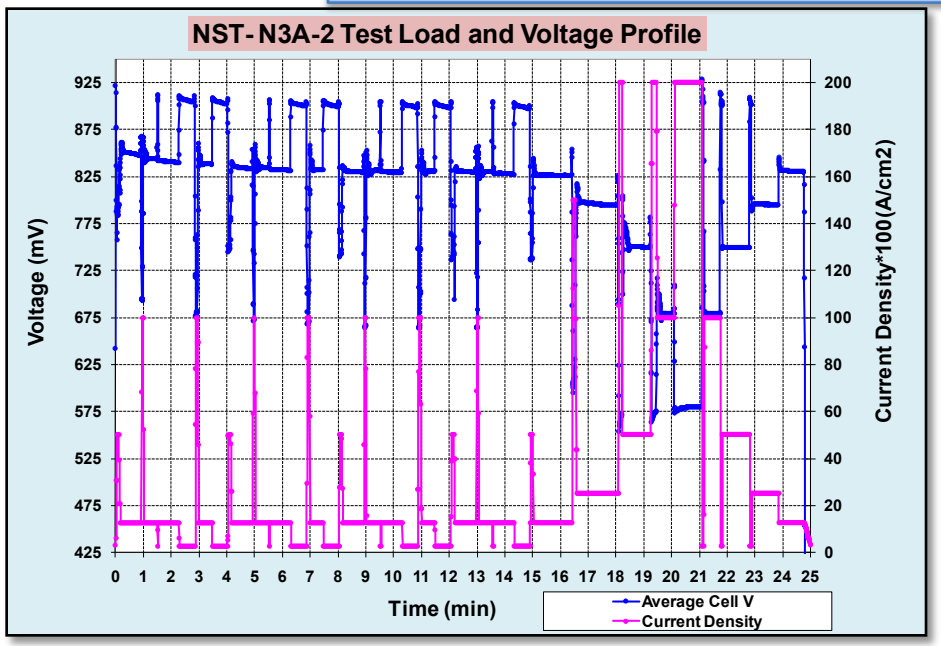


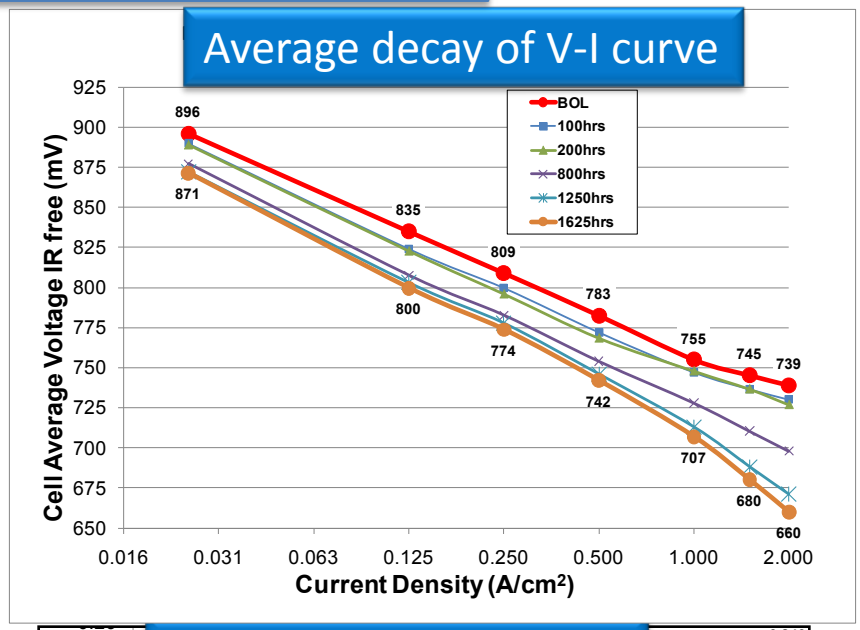
Oxygen mass transfer decreased in both catalyst and GDL by 30K cycles

Technical progress - Stack durability

NST-N3A-2 cycles to 2A/cm^2 Rated Current Density.

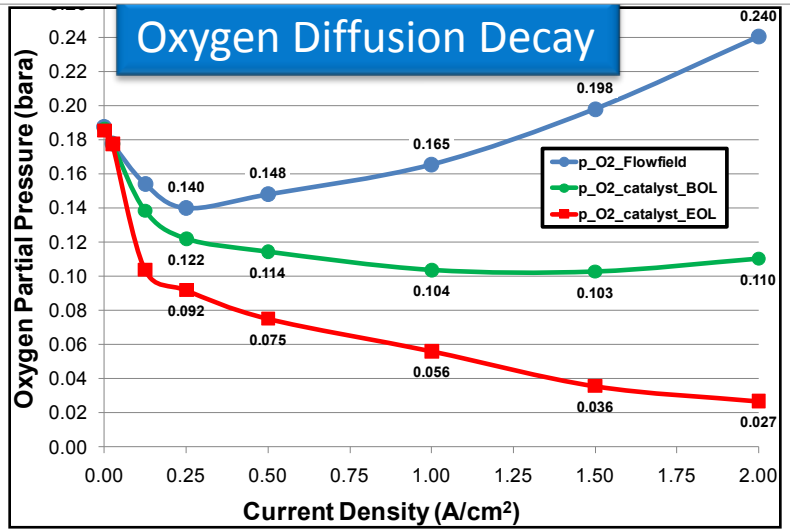
8-cell stack , 360-cm^2 cell, 0.45mg/cm^2 total Pt loading





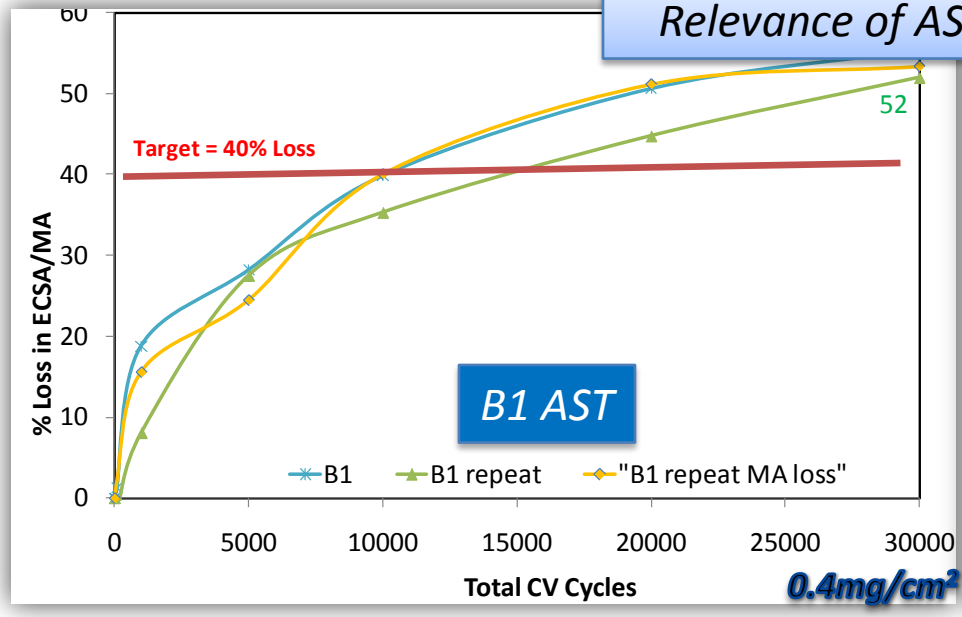
- **Cathode ECSA loss 46-48% is consistent by CV and V_{IR_free} analysis**
- **Diffusion increase by 75% loss of Po_2 at reaction sites by V-I analysis.**

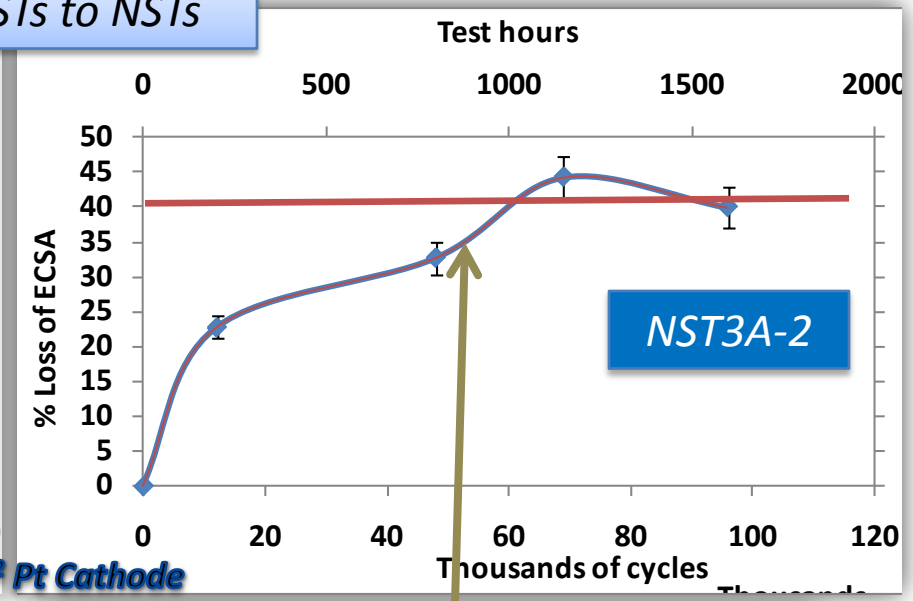
$$\Delta\eta_{MT} \propto \ln \frac{P^{BOL}_{O2,cat}}{P^{EOL}_{O2,cat}}$$



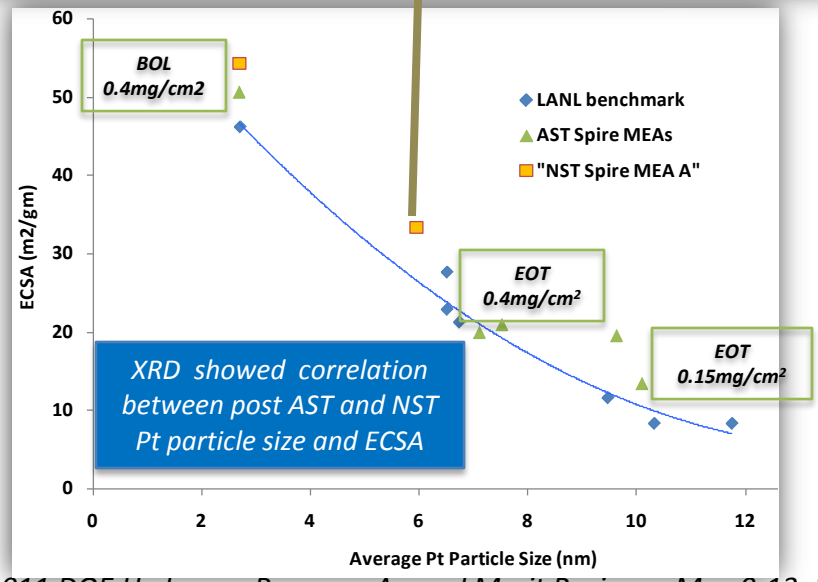
Technical Progress: Catalyst stability

Relevance of ASTs to NSTs





0.4mg/cm² Pt Cathode



B1 AST accelerates ECSA loss by 5-6 times versus NST3A-2

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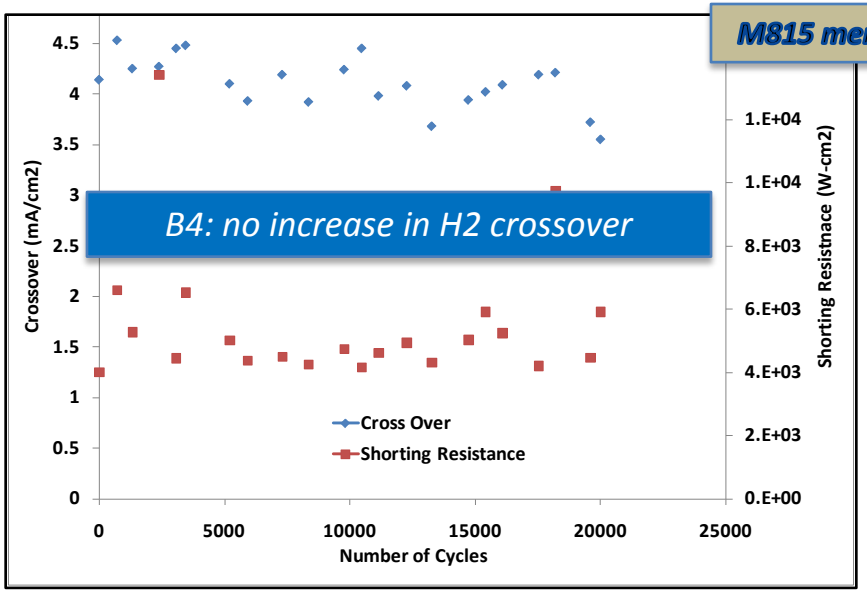
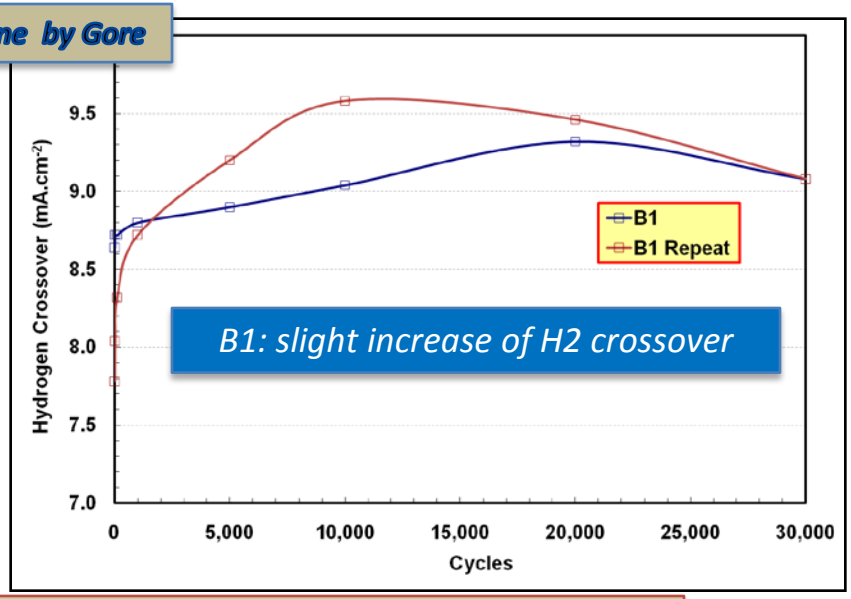
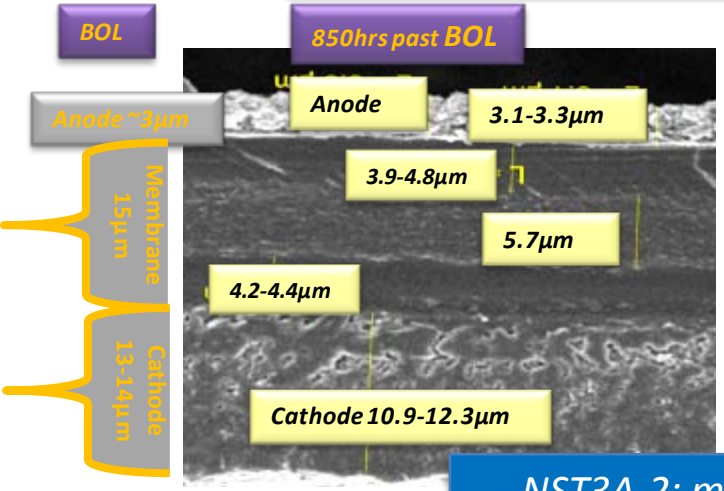
Technical Progress – Membrane stability

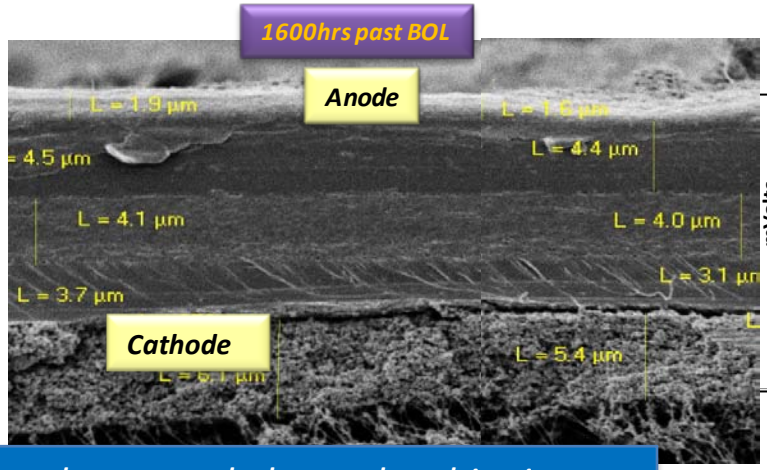
M815 membrane by Gore

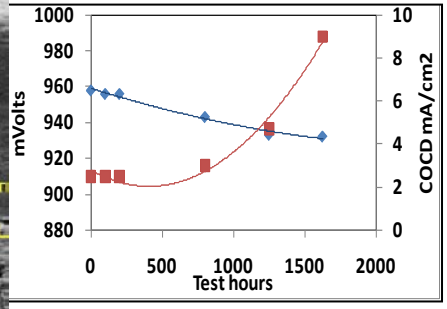




B4 results had no correlation with NST3A-2







NST3A-2: membrane and electrodes thinning, loss of OCV, increased crossover

Collaborations

- Nuvera Fuel Cells (Industry) – prime contractor
  - Program management,
  - SCOF Development, validation and high power NSTs,
  - Stack NSTs.
- Los Alamos National Lab (Federal)– subcontractor
  - Single cell AST/NST testing,
  - Post-test characterization.
- Argonne National Lab (Federal) – subcontractor
  - Developer of Platinum stability and fuel cell durability model.
  - Lead data analysis and post-processing for LANL and Nuvera.
- Durability Work Group – Borup/Myers lead
- W.L. Gore & Associates (Industry) – lead MEA developer

Proposed Future Work

FY2011

- Publish Comparative data for SCLC and SCOF on AST protocols – Milestone #3.
- Accumulate sufficient NST data sets (SCOF versus stack) in approaching GNG decision.

FY2012

- Continue NST campaign

  (SCOF, RIT – LANL, full-area cells - Nuvera).
- ANL to reconstruct model polarization curves using inputs from ASTs and initiate validation of model results on NST data sets.
- ANL to conduct model sensitivity tests.

Summary

Relevance: SPIRE addresses two of the most critical targets in the hydrogen program – cost and durability.

Approach: Combined experimental and modeling campaign to elucidate durability-critical factors at low Pt loading and high current density.

Technical Accomplishments and Progress:

Good progress in ASTs and NSTs for catalyst aging. Performance in SCOF demonstrated at 1.2W/cm^2 at 0.2mg/cm^2 Pt loading.

Technology collaborations:

Spire activities are synchronized to other durability projects through the Durability Work Group.

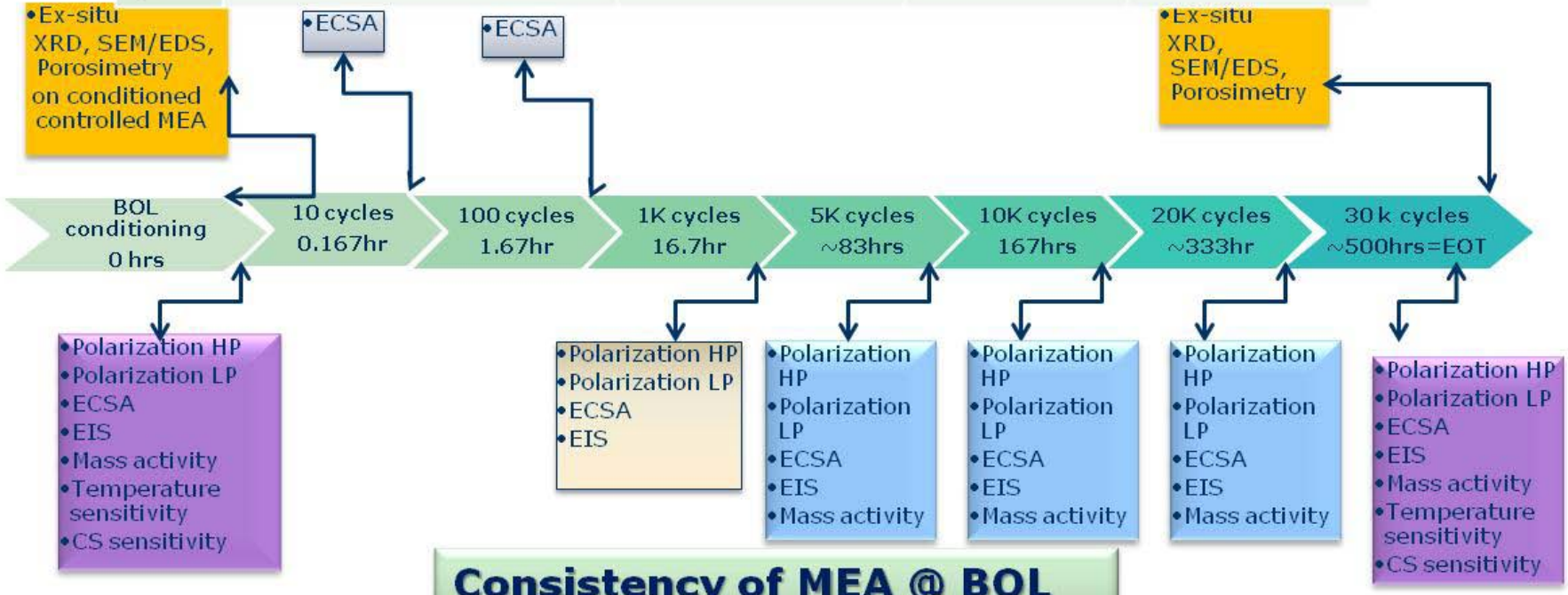
Proposed Future Work:

Remaining tests with different cell architectures and reduced Pt loading are critical to elucidate the effects of load cycles in stressing MEA degradation.

Technical Back-Up Slides

Technical Approach – AST B1 timeline

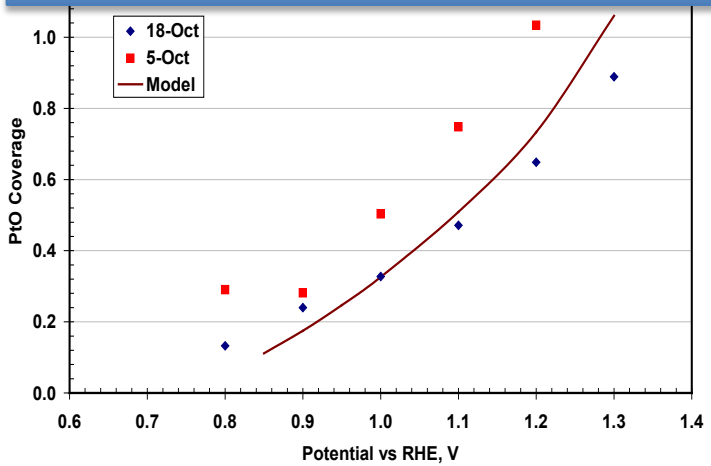
TID	Protocol ID	Architecture ID	Material ID	Location
1	B1: 30sec potential cycle 0.6-1.0Volt, Cell @80C Anode/Cathode 100% RH H_2/N_2, 150kPa	SCLC 50cm2	A	LANL
2		SCOF 50cm2	A	LANL
3		SCLC 50cm2	B	LANL
7	B1*:30sec , potential cycle 0.582 -0.883Volt, Cell @80C Anode/Cathode 100% RH H_2/N_2, 150kPa	SCOF 50cm2	A	LANL
8		SCLC 50cm2	B	LANL
9		SCOF 50cm2	B	LANL

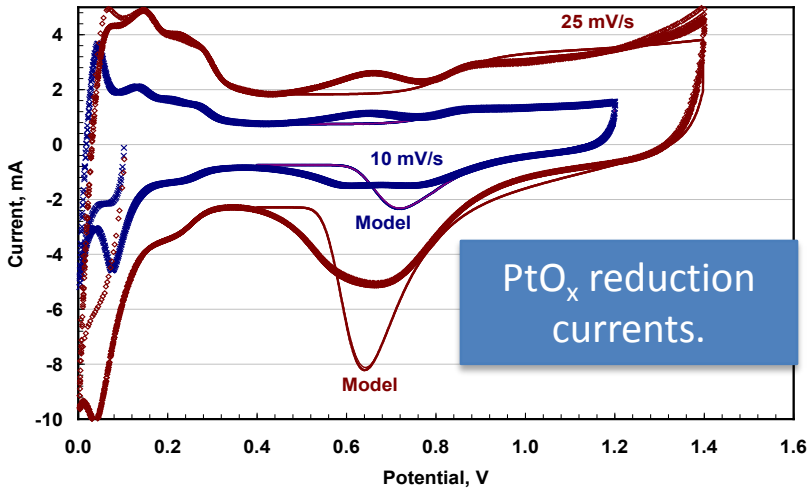


Consistency of MEA @ BOL is critical for data analysis

Technical Progress – Modeling Pt dissolution

Potential dependence of equilibrium O/Pt.

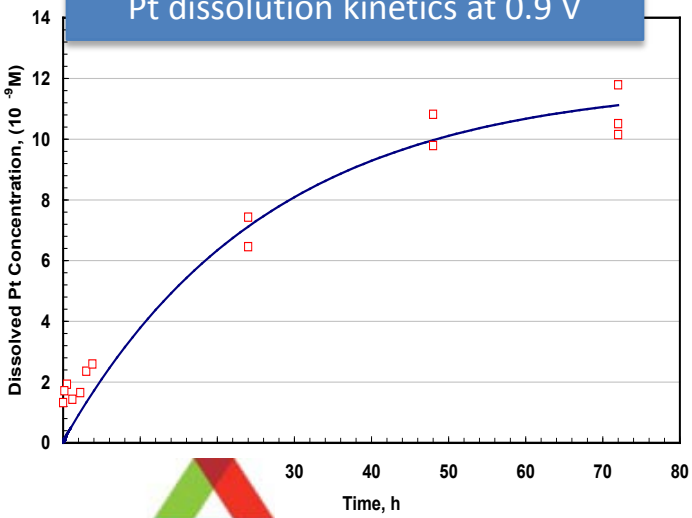




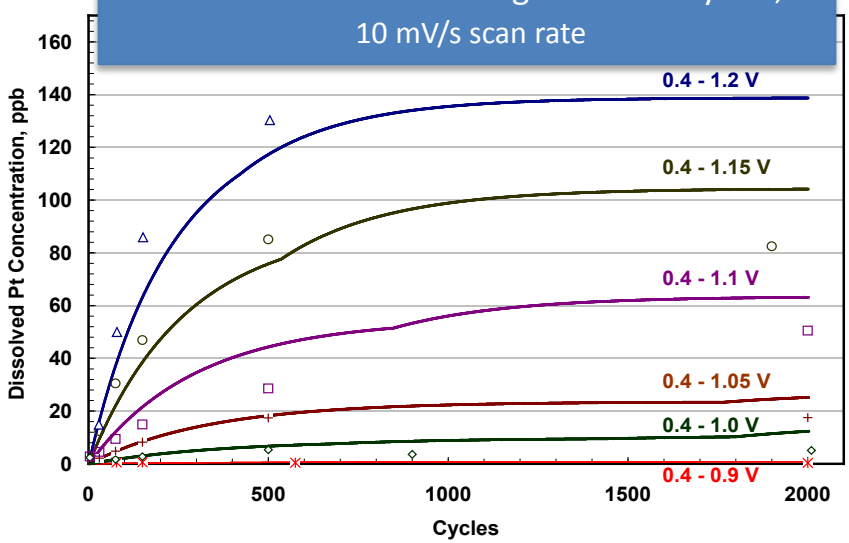
PtO_x reduction currents.

Ground work for Pt stability model in aqueous media is complete

Pt dissolution kinetics at 0.9 V

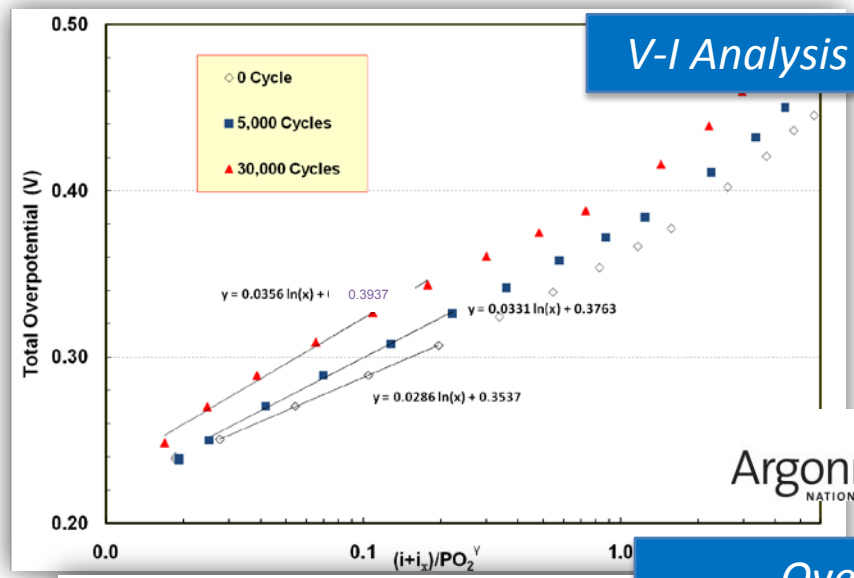


Pt dissolution with triangular wave cycles, 10 mV/s scan rate

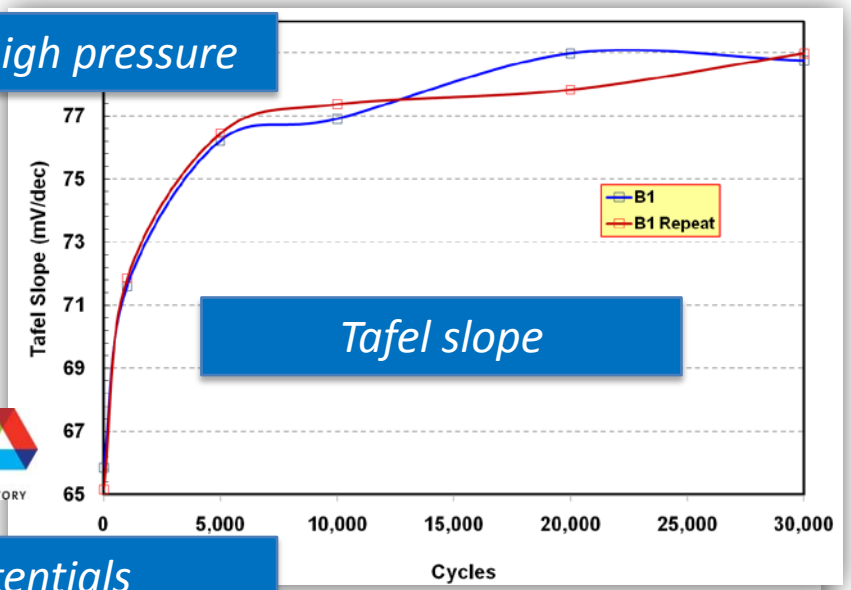


Technical Progress – AST B1 Data Analysis

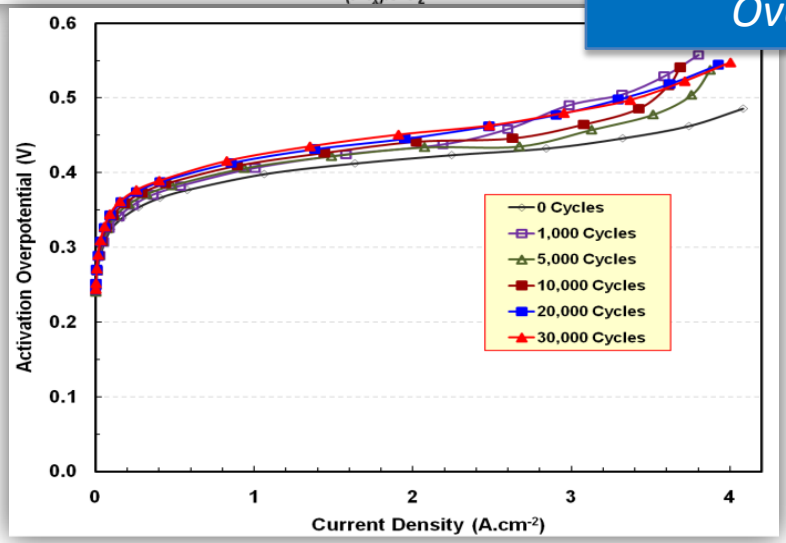
V-I Analysis at high pressure

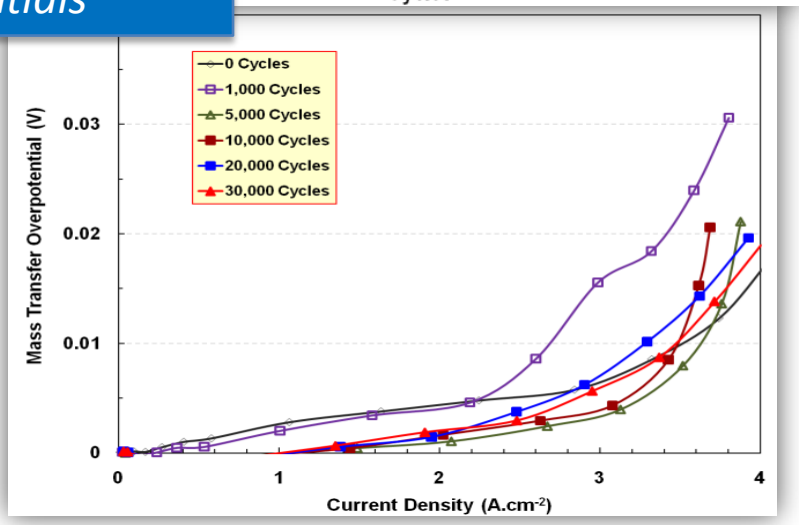


Tafel slope



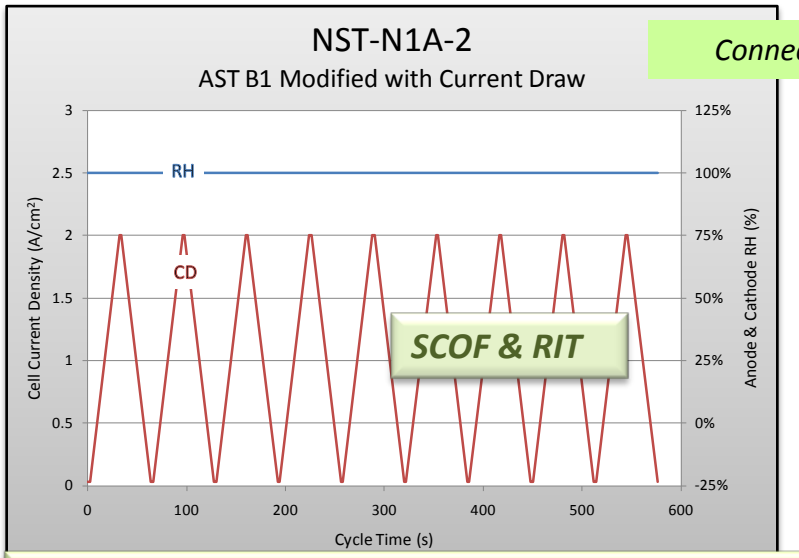
Overpotentials



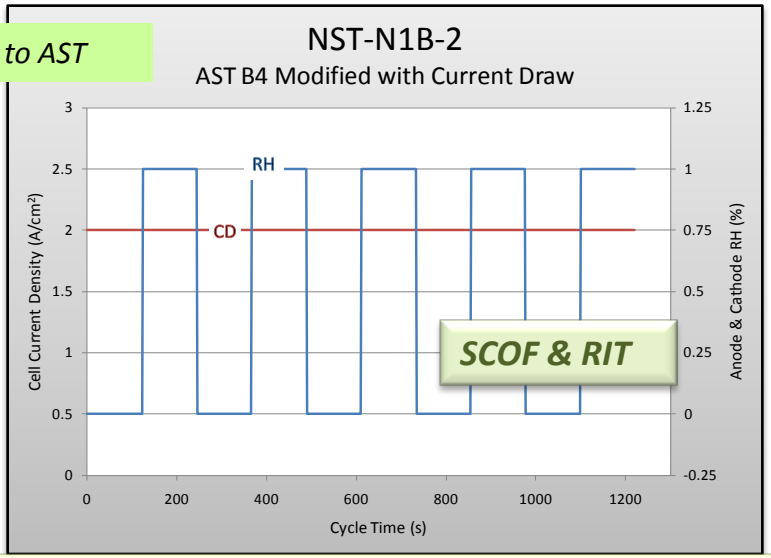


Activation and Mass Transfer overpotentials increase with time

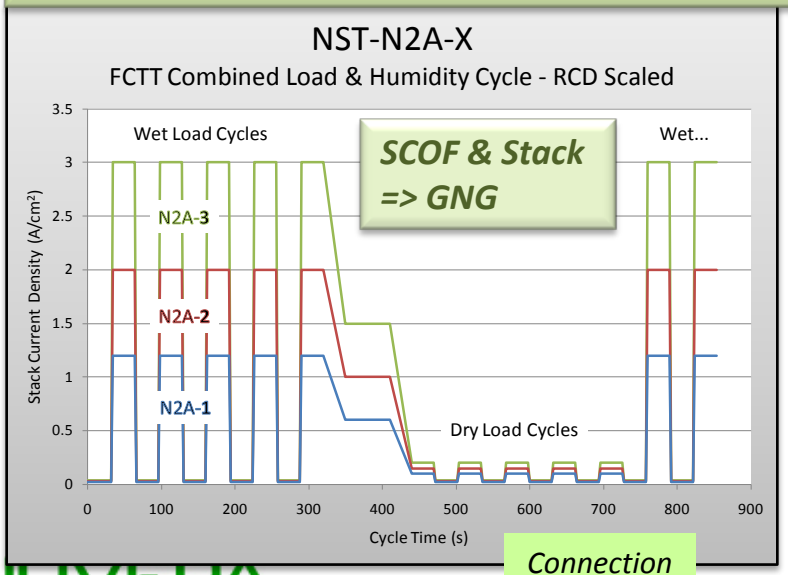
NST load and humidity profiles

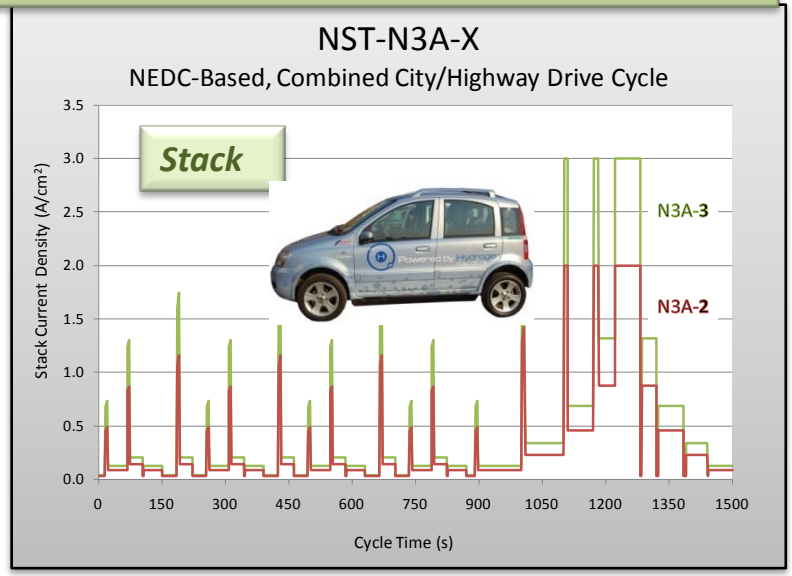


Connection to AST



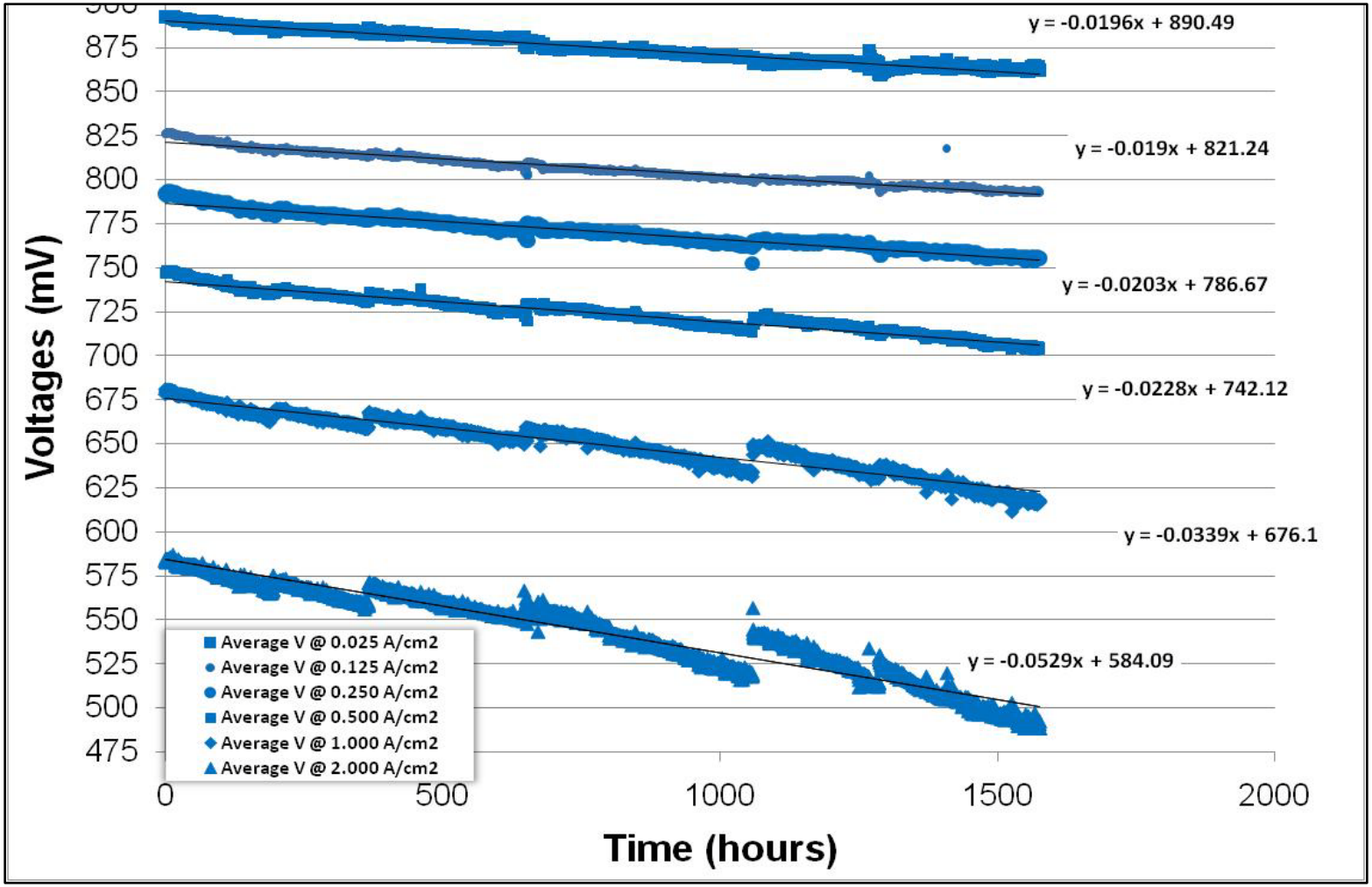
NST protocols are designed to stress ECP under fuel cell operating conditions





Connection to industry

Technical Progress – stack NST3A-2



Decay values were consistent in three full-area (250-360cm²) cell tests