Fuel-Cell Fundamentals at Low and Subzero Temperatures

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Objectives

- Fundamental understanding of transport phenomena and water and thermal management at low and subzero temperatures using state-of-the-art materials
  - Enable optimization strategies to be developed to overcome observed bottlenecks
    - Operational
    - Material
- Elucidate the associated degradation mechanisms due to subzero operation
  - Enable mitigation strategies to be developed

Technical Barriers

A. Durability

- Subfreeze startup and freeze cycles; degradation-mechanism identification and mitigation

C. Performance

- Efficiency and power density, especially at low temperature and with liquid water
- Novel materials (NSTF) for low-Pt catalyst layers

D. Water Transport within the Stack

- Critical water management, especially at the component level

E. System Thermal and Water Management

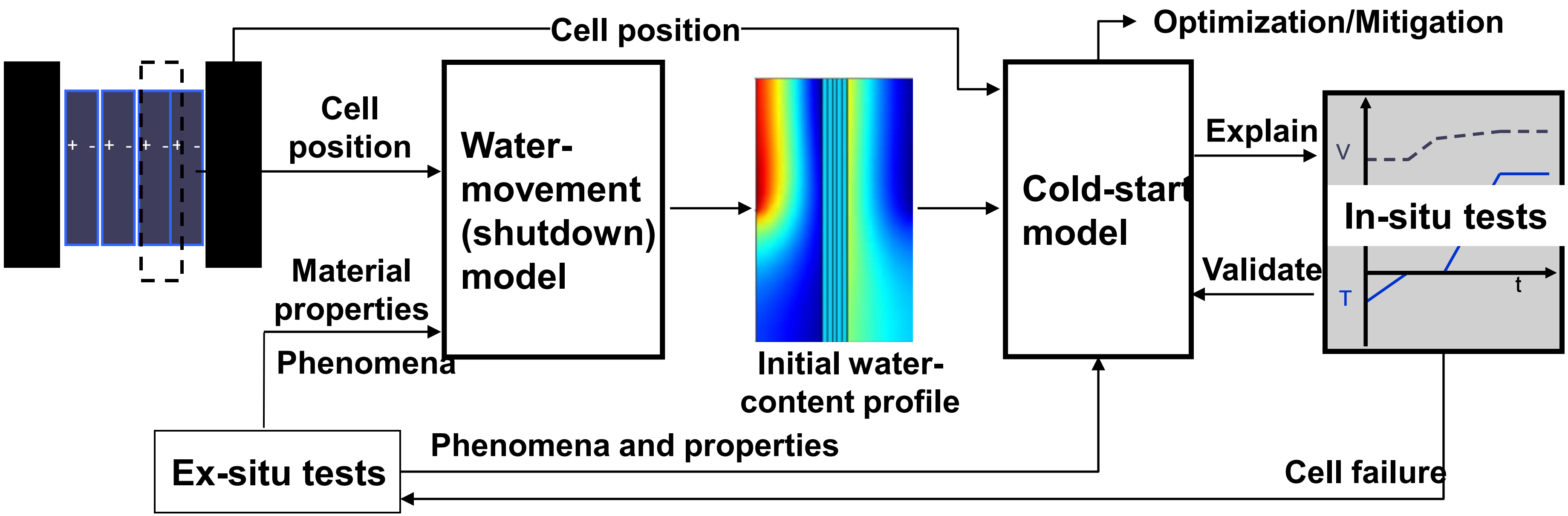
- Improved techniques to manage water during shutdown and cold and cool start

G. Start-up and Shut-down Time and Energy/Transient Operation

- Minimize energy consumption and time during cold start
- Examine shutdown scenarios and transients

Approach

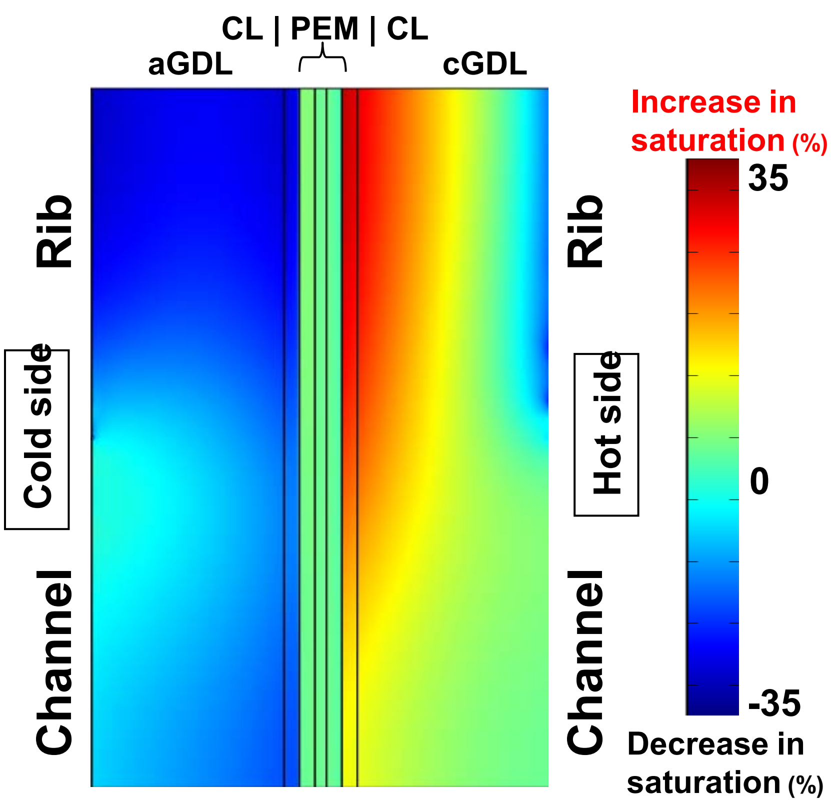
- Synergistic effort of modeling and experimental characterization

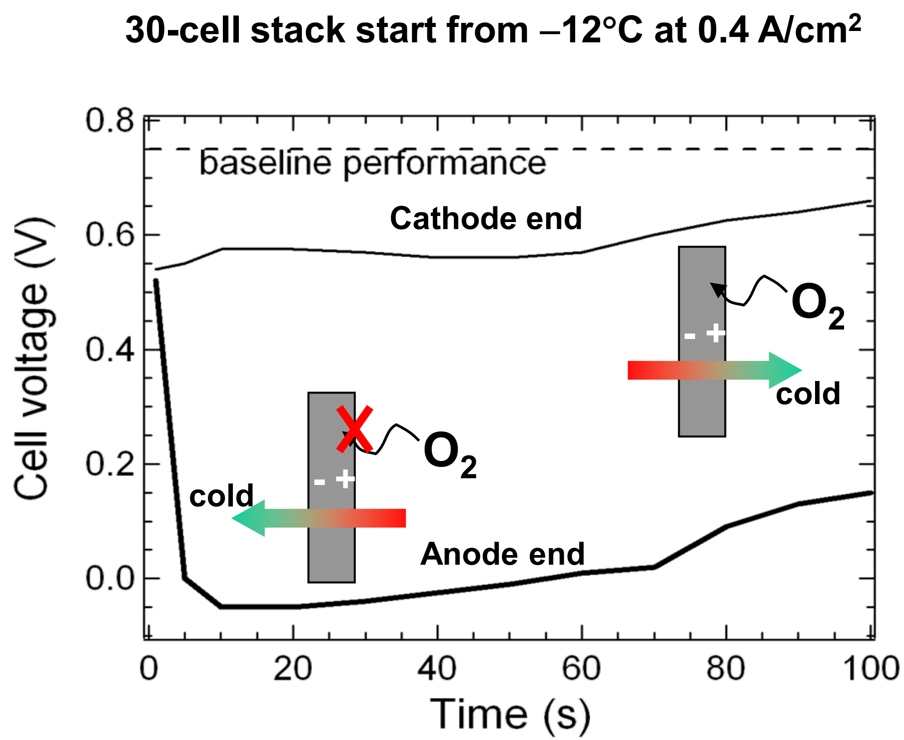


Approach

Multiscale, multiphysics continuum-based modeling

- Develop, validate, and refine a series of models for cell performance including cold and cool startup and shutdown
  - Model cells with respect to stack position in a 2-D+1 cell framework while also accounting for the component microstructure





Data: T. W. Patterson, J. O'Neill, and M. L. Perry, Report DE-FG36-06GO86042. D.OE (2007).

Approach

In-situ and ex-situ parametric studies

- Experimentally characterize component, cell, and stack properties and performance
  - Measure critical properties
  - Visualize water and ice distributions
  - Utilize various assemblies and components to elucidate governing phenomena

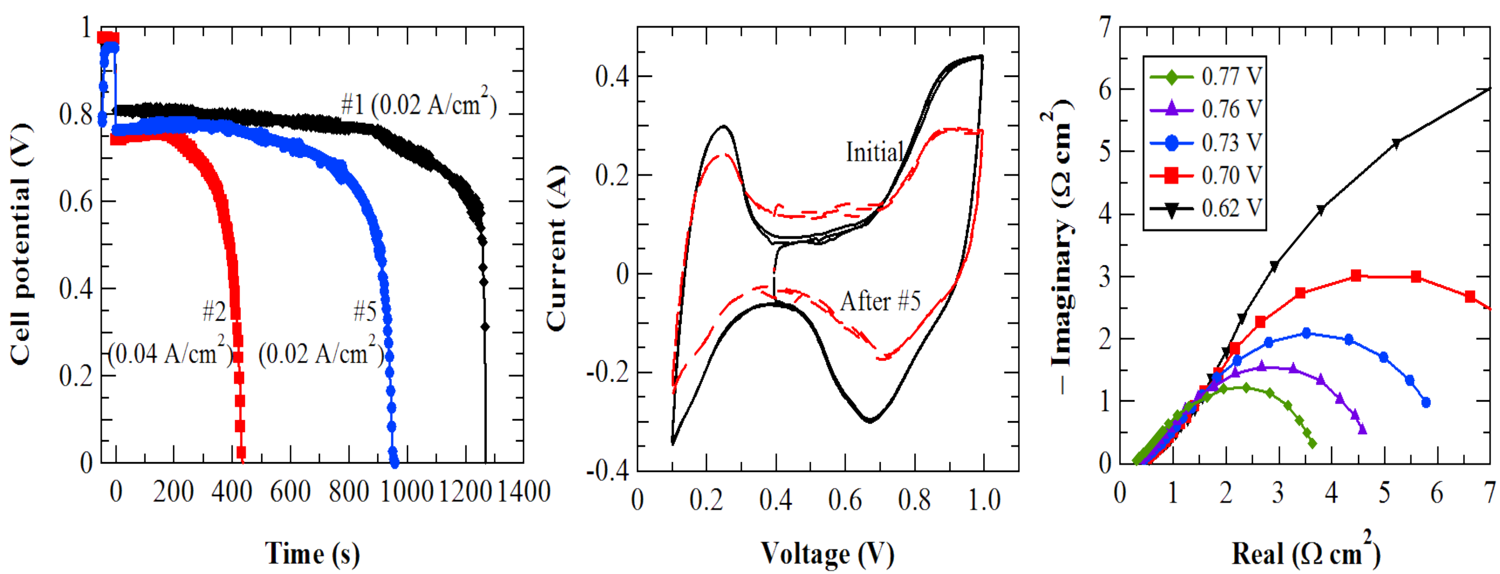
Material	Baseline	Alternative 1	Alternative 2
Membrane	3M 850 EW	Gore	3M variable thickness
Catalyst layer	NSTF PtCoMn	Supported carbon	NSTF advanced
GDL	Hydrophobized	SGL	SGL (more hydrophobic)
MPL	Hydrophobic	Very hydrophobic	Mixed property
Flow field	Quad serpentine	Parallel channel	Single channel
Bipolar plate	Solid	WTP	Hybrid (one WTP)

Approach

Durability and degradation

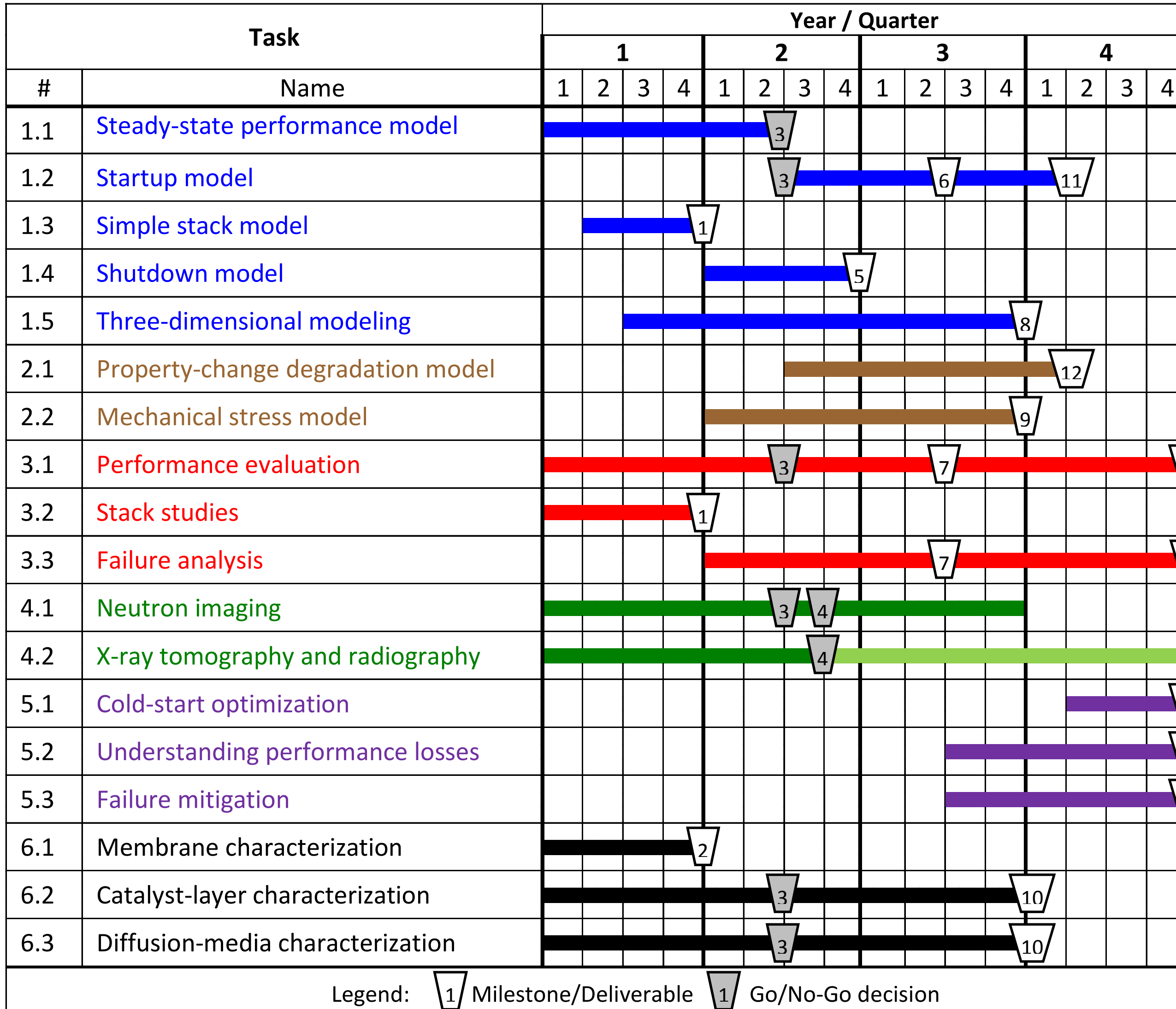
- Elucidate and mitigate critical degradation and failure mechanisms related to cold and cool operation and start
  - Experimentally observe and characterize failed cells
    - Teardown analysis
    - Replicate failure
  - Model stress effects and help identify and mitigate failure mechanisms
  - Leverage off of existing LANL water-transport project

5 sequential isothermal starts from –10°C



Project Timeline

- Main tasks
  - Performance modeling
  - Durability modeling
  - Cell and stack characterization
  - Imaging
  - Mitigation and optimization
  - Component characterization



Project Timeline

Begin 09/09 — M1 09/10 — G1 03/11 — G2 06/11 — M2 09/11 — M3 03/12 — M4 09/12 — M5 09/13 — End 12/13

Major Milestones/Deliverables

M1: Stack-study data and model agree (< 10%) with respect to thermal and mass boundary conditions and cell position.

M2: Shutdown model is completed.

M3: Complete data for the baseline cell and interim report on the experimentally observed leading causes of freeze-related failure and performance losses.

M4: Scaling expression for 3D and rigorous gas-channel effects developed. Mechanical-analysis model including GDL compression and freeze/thaw and humidity-cycling effects completed.

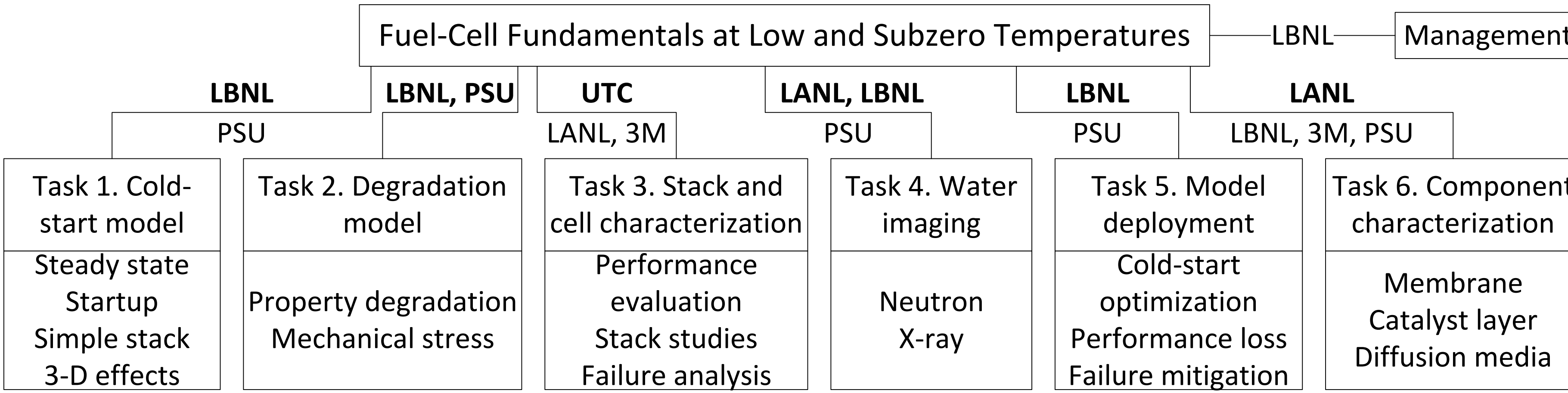
M5: Final report on the parametric study of low and subzero operation including causes of performance loss and possible mitigation strategies.

Go/No-Go Decision

G1: Start of transient modeling. Go means that < 10% difference between model and data. No-Go means more fundamental studies and detailed component models are required.

G2: Continued study of X-ray tomography depending on ability to gain information on water and ice distributions with resolution that is better than the available neutron imaging.

Organization



LBNL

- Project management and coordination
- Model development
- GDL and membrane characterization including x-ray tomography

LANL

- Ex-situ component characterization
- Single-cell durability tests
- Neutron imaging

3M

- Material supplier and testing knowledge

UTRC

- Stack and cell parametric studies
- Identify and characterize failure mechanisms
- Real-world guidance

PSU

- Help with x-ray studies and traditional catalyst-layer diagnostics
- Develop 3-D scaling expressions and mechanical stress model

Budget

DOE Cost Share	Recipient Cost Share	TOTAL
$4,700,000	$445,273	$5,145,273
91%	9%	100%

Organization	Year 1 ($k)	Year 2 ($k)	Year 3 ($k)	Year 4 ($k)	Cumulative ($k)
LBNL	575	525	475	446	2021
LANL	150	150	300	300	900
UTRC	147	314	336	234	1031
3M	103	133	118	88	443
PSU	187	187	188	188	750

Inputs/Needs

- Material properties and expressions
- Knowledge gained from others examining low and subzero temperature operation
- Discussions on validated modeling approaches, results, and critical needs
  - Modeling working group?