



# Development of Improved Composite Pressure Vessels for Hydrogen Storage

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Project ID#  
STP\_15\_Newhouse

# Overview

## Timeline

- Phase 1 start 1 Feb 2009
- Phase 1 end 31 Jan 2011
- 3% complete

## Budget

- Project funding \$2,000,000
- Phase 1 funding \$761,466
  - DOE share \$609,156
  - Contractor share \$152,290
- FY08 = \$ 0
- FY09 = \$300,000 (plan)

## Barriers

- Barriers addressed
  - A. System Weight and Volume
  - B. System Cost
  - G. Materials of Construction
- Targets (2010)
  - Gravimetric capacity > 6%
  - Volumetric capacity > 0.045 kg H<sub>2</sub>/L
  - Storage system cost < \$133/kg H<sub>2</sub>

## Partners

- HSECoE  HSECoE  
SRNL, PNNL, LANL, JPL, NREL, UTRC,  
GM, Ford, LC, Oregon State Univ, UQTR
- Project lead = Don Anton,  
SRNL 

# Objectives

- **Meet DOE 2010 and 2015 Hydrogen Storage Goals** for the storage system by identifying appropriate materials and design approaches for the composite container

	<u>2010</u>	<u>2015</u>
Gravimetric capacity	> 6%	> 9%
Volumetric capacity	> 0.045 kg H <sub>2</sub> /L	> 0.081 kg H <sub>2</sub> /L
Storage system cost	< \$133/kg H <sub>2</sub>	< \$67/kg H <sub>2</sub>

- **Maintain durability, operability, and safety characteristics** that already meet DOE guidelines for 2010 and 2015
- **Work with HSECoE Partners** to identify pressure vessel characteristics and opportunities for performance improvement
- **Develop high pressure tanks** as are required to:
  - Enable hybrid tank approaches to meet weight and volume goals
  - Allow metal hydrides with slow charging kinetics to meet charging goals

# Phase 1 Approach

- *Establish and document baseline* design, materials, and manufacturing process
- *Evaluate potential improvements* for design, material, and process *to achieve cylinder performance improvements* for weight, volume, and cost
- *Down select* most promising engineering concepts
- *Evaluate* design concepts and ability *to meet Go/No-Go requirements* for moving forward
- *Document progress* in periodic reports and support HSECoE Partner meetings and teleconferences

# Phase 1 Milestones

- Establish baseline design and identify options for improvement
- Document baseline design summary
- Report on Phase 1 evaluation of design, material, and process improvements
- Identify the of most promising engineering concepts
- Report on Phase 1 selection of most promising design, material, and process improvements
- Document revised baseline design summary
- Evaluate likelihood of composite container meeting system and DOE objectives

# Progress – Baseline Design/Materials

- Design

- Fiber reinforced composite structure
- Plastic liner /permeation barrier
- Metallic end bosses
- 350 bar pressure capability



- Materials

- Carbon fiber
- Epoxy resin
- HDPE liner
- AA 6061-T6 bosses



# Progress – Potential Improvements

- Reinforcing fibers with higher delivered strength per unit cost
  - Decreased weight, decreased cost, increased volume
  - *Two higher strength commercial carbon fibers identified*
    - *Indicated 5%-10% higher strength*
    - *One is same cost as baseline, one is higher cost*
- Resin systems with lower cost per unit volume
  - Reduced cost, but must be traded against performance and manufacturability

# Progress – Potential Improvements

- Toughened resin systems that provide better damage tolerance, allowing thinner composite walls
  - Decreased weight, increased volume
  - *Toughening agents for resin systems have been identified*
    - *ATBN has shown some promise in high energy impact testing*
    - *Additional materials have been identified for inclusion in study*
- Resin systems with high temperature capability
  - Meet safety goals in case of accidental thermal excursion

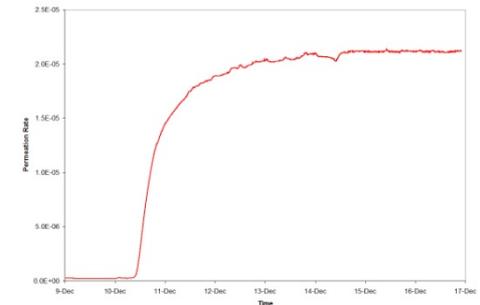


# Progress – Potential Improvements

- Decrease safety factor requirements for reinforcing fibers
  - Decreased weight, decreased cost, increased volume
  - *Evaluate stress rupture, fatigue and damage tolerance characteristics further through Leader-of-the-Fleet testing*
    - *Leader-of-the-Fleet program has been drafted, is in review and comment by collaborators*
  - *Evaluate damage vs. impact to characterize safety and ability to remain in service after damage*
  - *Evaluate NDE as a means of monitoring the structural integrity, allowing thinner laminates and removal from service before rupture*
    - *Low cost AE sensors have been identified, are in evaluation for inclusion in LOTF program*

# Progress – Potential Improvements

- Liner materials with lower permeation and absorption
  - Thinner liner decreases weight, increases volume if envelope limited, but may increase cost
  - Less absorption reduces potential for contamination
  - *Permeation testing with 5% $H_2$  / 95% $N_2$  is being conducted*
    - *Baseline results for HDPE liner material*
    - *Filled HDPE material showed no benefit*
    - *Filled alternate material showed 90% - 95% reduction in permeation, need to confirm other properties of alternate material*
    - *Additional filled materials are in process*
    - *Coatings are being evaluated*



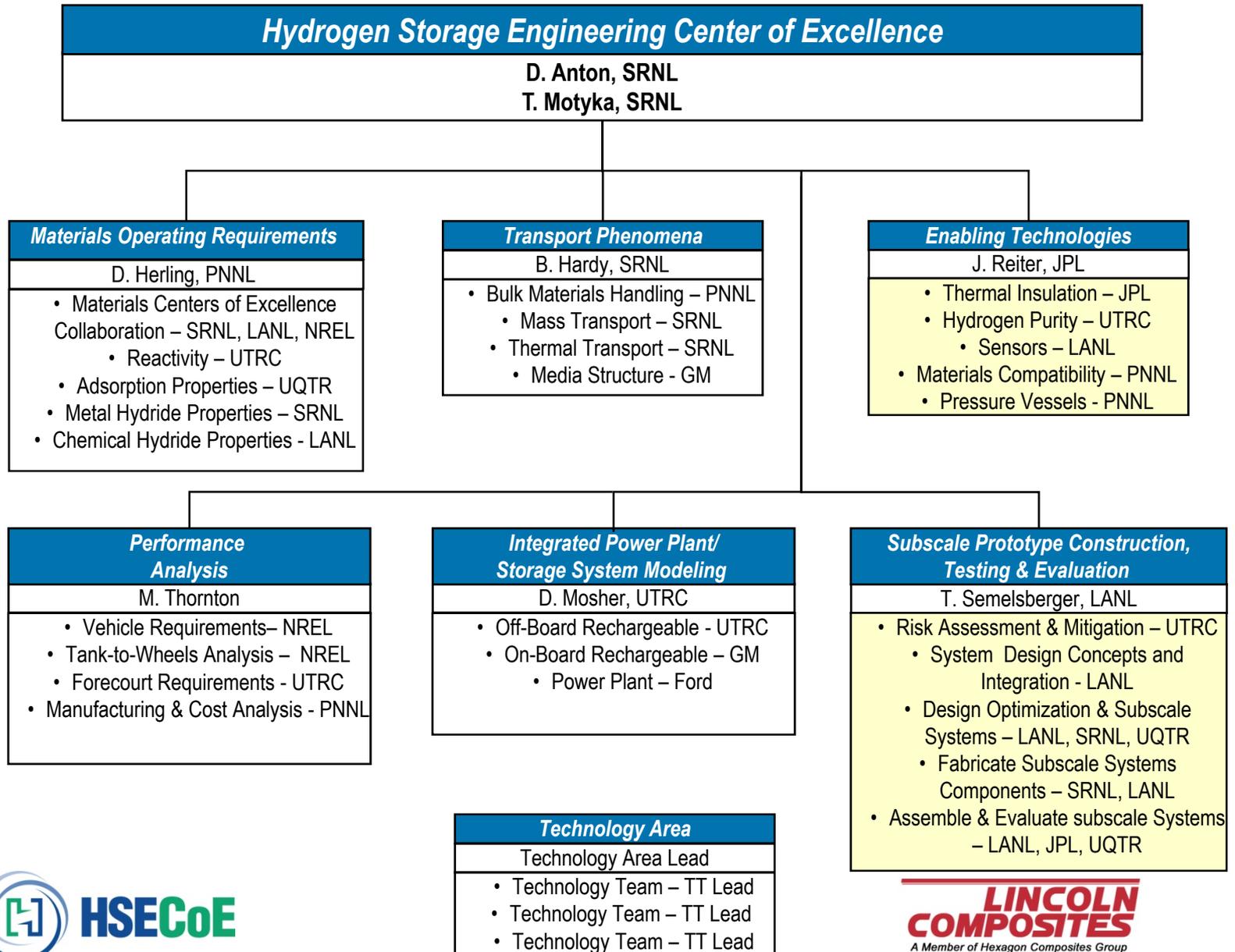
# Progress – Potential Improvements

- Stronger boss materials, allowing thinner sections
  - Reduced cost and weight, increased volume
  - *Alternate boss materials are being evaluated*
    - *AA7075 has significantly higher yield and tensile strength than AA6061*
    - *316SS has higher tensile strength and temperature capability than AA6061*
- Manufacturing processes that increase throughput
  - Decreased overhead costs

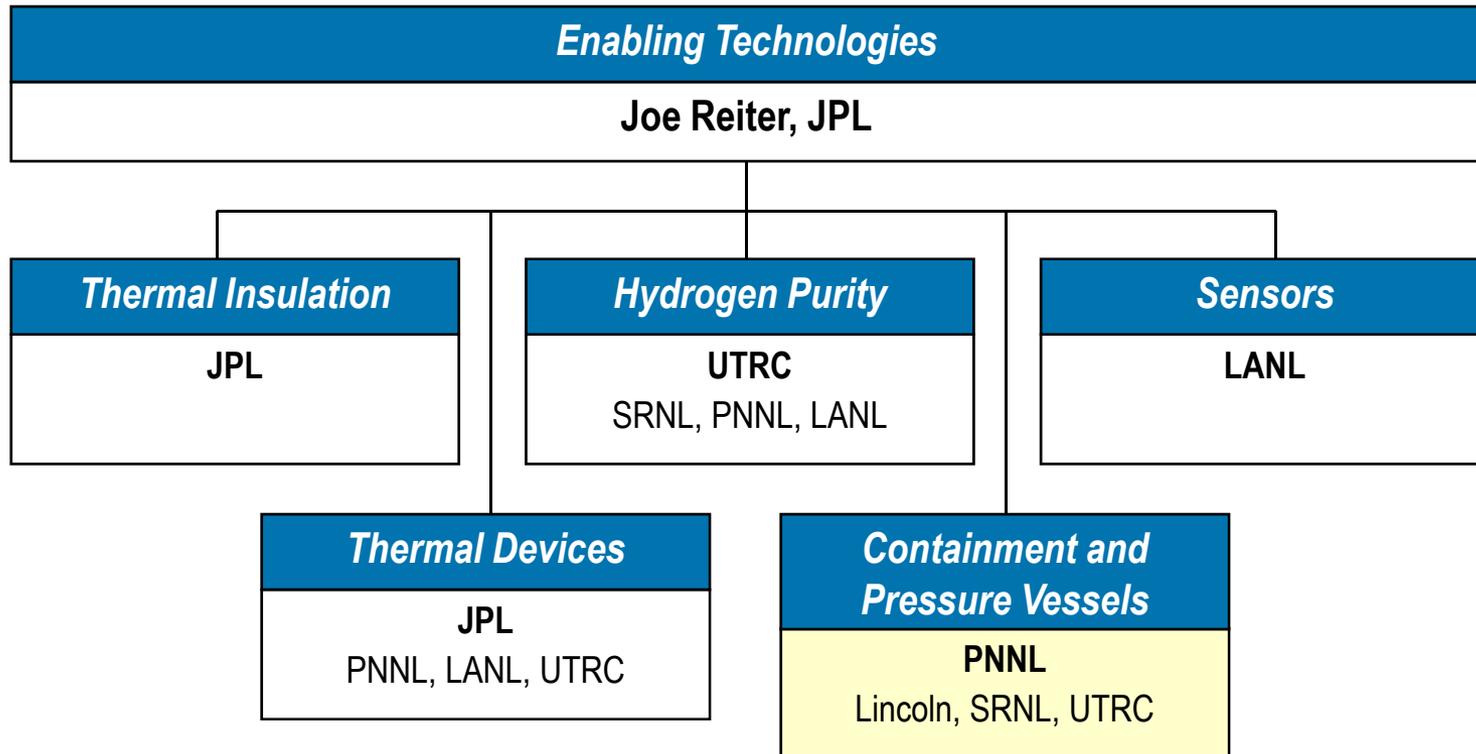
# Accomplishments

- Kick-off meeting in December 2008, Washington DC
- IP agreement signed January 2009
- Face to Face Meeting February 23-25, 2009, Golden, CO
- Safety plan completed May 1, 2009

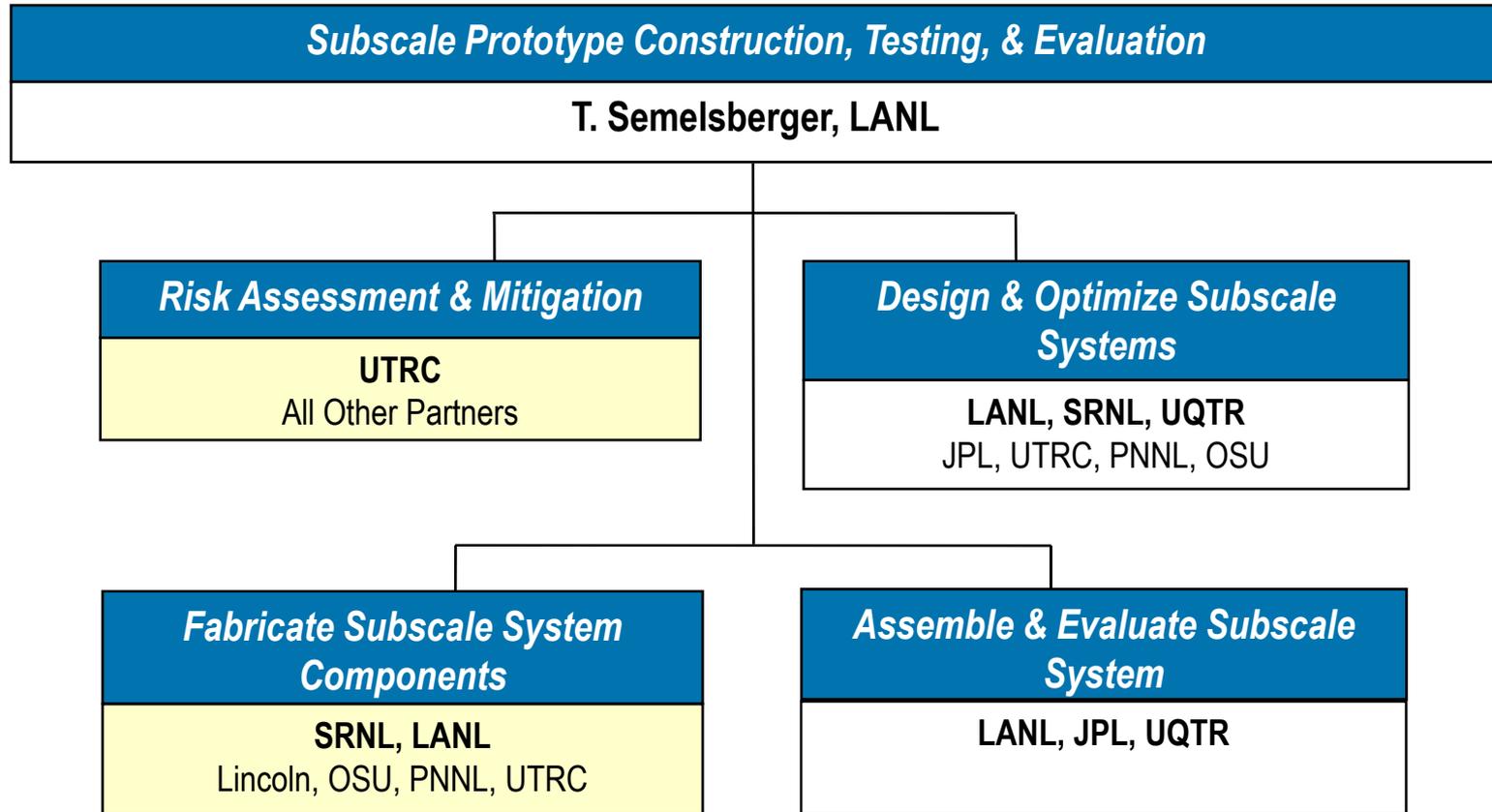
# Collaborations



# Collaborations



# Collaborations



# Future Work

- Continue progress on evaluating potential improvements
- Down select most promising engineering concepts.
- Evaluate design against DOE 2010 and 2015 Hydrogen Storage Go / No Go Criteria
- Phase 2 – continuation of container development in support of system requirements
- Phase 3 – fabrication of subscale containers to support assembly of prototype systems for evaluation

# Summary

- Lincoln Composites has initiated work under the DOE contract funding the HSECoE
- Design, material and process improvements have been identified that show potential to meet DOE 2010 and 2015 goals for the storage system
- Work is progressing on schedule with expectation of meeting go/no-go criteria to proceed to Phase 2
  - 4 of the DOE 2010 numerical system storage targets must be fully met
  - The status of the remaining numerical targets must be at least 40% of the target or higher