Hydrogen Storage Engineering
CENTER OF EXCELLENCE

Donald L. Anton
Director

SRNL
SAVANNAH RIVER NATIONAL LABORATORY

May 19, 2009

Project ID#ST_14_Anton

This presentation does not contain any proprietary, confidential or otherwise restricted information

Overview

Timeline

- Start: February 1, 2009
- End: January 31, 2014
- 3% Complete (as of 3/31/09)

Barriers

A. System Weight and Volume
B. System Cost
C. Efficiency
D. Durability
E. Charging/Discharging Rates
G. Materials of Construction
H. Balance of Plant (BOP) Components
J. Thermal Management
K. System Life-Cycle Assessment
L. High Pressure Conformality
S. By-Product/Spent Material Removal

Budget

- Total Project Funding:
  - DOE Share: $39,936,000
  - Contractor Share: $4,106,000
  - FY '09 Funding: $7,000,000
- Prog. Mgmt. Funding
  - FY '08: $0
  - FY '09: $611,000

Partners

SRNL Savannah River National Laboratory
Pacific Northwest National Laboratory
Los Alamos National Laboratory
United Technologies Research Center
JPL
NREL National Renewable Energy Laboratory
BASF The Chemical Company
OSU Oregon State University
HRI UQTR
California Institute of Technology
Lincoln Composites A Member of Hexagon Composites Group
HSM Systems
Ford
GM

Center Goals

- **Primary goals:**
  - Quantify the requirements for condensed phase hydrogen storage systems for light duty vehicle applications.
  - Coordinate with all other DOE hydrogen storage programs to compile their media and systems requirements and data.
  - Demonstrate the technologies required to achieve the DOE hydrogen storage 2015 goals.
- **Secondary goal:**
  - Dissemination of new design tools, methodologies, and components required to develop condensed phase hydrogen storage systems.

Technical Objectives

- Using systems engineering concepts, **design innovative system architectures** with the potential to meet DOE performance and cost targets.
- Develop **system models** that lend insight into overall fuel cycle efficiency.
- Compile all relevant **materials data** for candidate storage media and define future data requirements.
- Develop engineering and design models to further the understanding of on-board storage **energy management requirements**.
- Develop **innovative on-board system concepts** for metal hydride, chemical, and sorption materials-based storage technologies.
- Design components and experimental test fixtures to **evaluate the innovative storage devices** and subsystem design concepts, validate model predictions, and improve both component design and predictive capability.
- Design, fabricate, test, and decommission the **subscale prototype systems** of each materials-based technology (metal hydrides, sorption and chemical hydrogen storage materials).

Management Objectives

- Effectively integrate the partner's required key technical activities
- Facilitate their collaboration.
- Interface with external stake holders to communicate progress and transfer technology.

Technical Area Matrix

Hydride Type		
Metal Hydride	Sorption	Chemical
Performance Analysis		
Integrated Power Plant/Storage System Modeling		
Enabling Technologies		
Materials Operating Requirements		
Transport Phenomenon		
Subscale Prototype Construction, Testing and Evaluation		

Hydrogen Storage systems have numerous elements of their design common between hydride types. In order to maximize return on investment and minimize risk, teams of experts on individual technical topics will be assembled to address these technical areas across hydride system types.

Six **Technical Areas** have been identified and spanning hydride types. These areas are defined as:

1. **Performance Analysis** will determine hydrogen storage system requirements
2. **System Modeling** will predict performance
3. **Enabling Technologies** will mitigate technical weaknesses of the hydrides
4. **Materials Requirements** will establish materials operating characteristics
5. **Transport Phenomena** will optimize thermal and mass transfer concepts
6. **Prototype Evaluation** will design, construct and test prototype systems

Technical Team Matrix

To address the risks, the Technology Areas are composed of a series of Technology Teams expert in their area of knowledge

Hydride Type		
Metal Hydride	Sorption	Chemical
Performance Analysis		
Vehicle Requirements		
Tank-To Wheels		
Forecourt Requirements		
Manufacturing & Cost Analysis		
Integrated Power Plant/Storage System Modeling		
Power Plant Modeling		
On-Board Rechargeable System Integration		
Off-Board Rechargeable System Integration		
Enabling Technologies		
Hydrogen Purity		
Thermal Devices		
Thermal Insulation		
Sensors		
Containment & Pressure Vessels		
Materials Operating Requirements		
MCoE Collaboration		
Reactivity		
Materials Compatibility		
Kinetics		
Transport Phenomenon		
Thermal Transport		
Media Structure and Enhancement		
Bulk Materials Handling		
Hydrogen Mass Transport		
Go/No-Go Decision		
Subscale Prototype Construction, Testing and Evaluation		
Component Integration		
Risk Assessment/Mitigation		
Design and Optimization		
Fabricate Subscale System Components		
Assemble & Evaluate Subscale System		

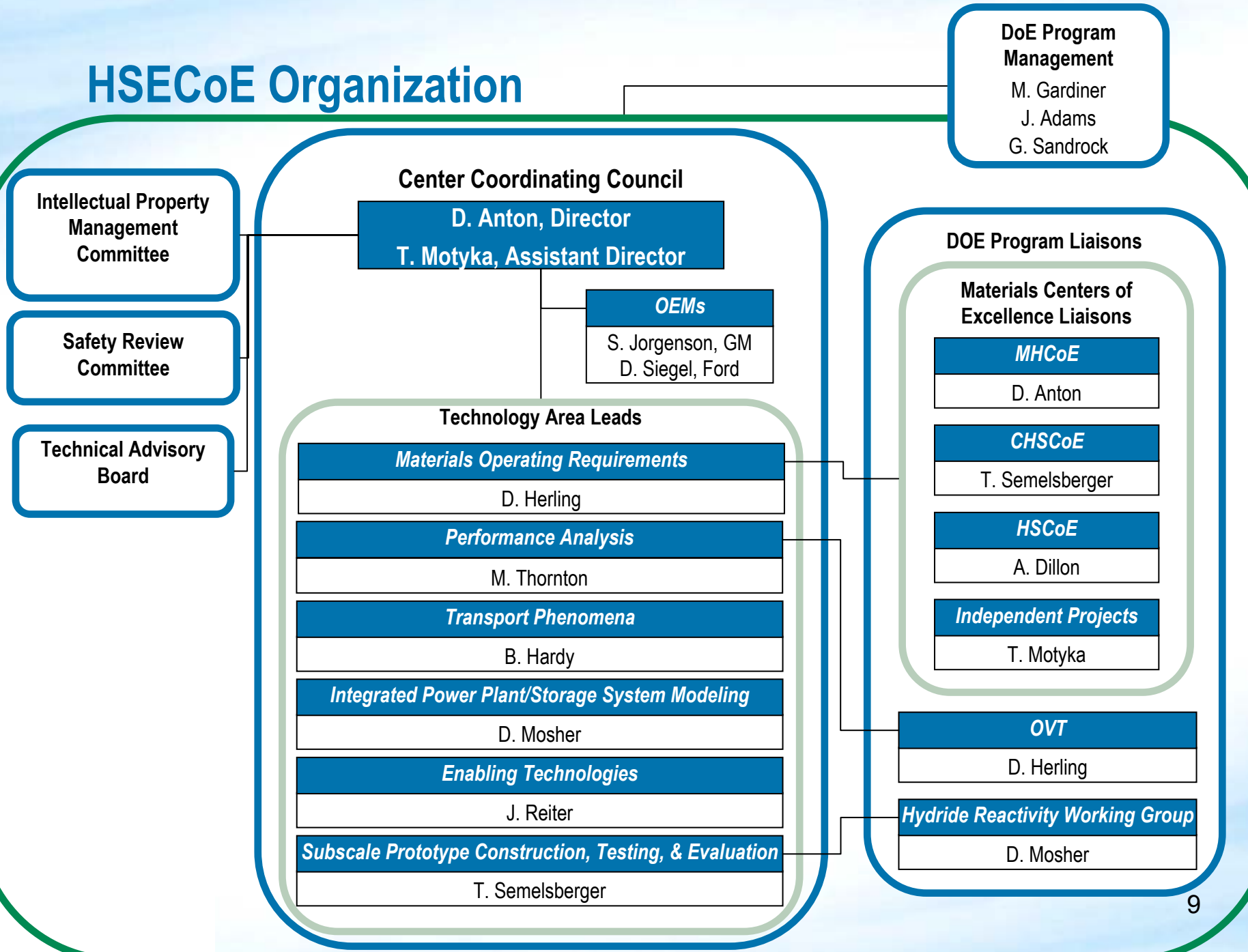
Technical Task Matrix

(Typical)

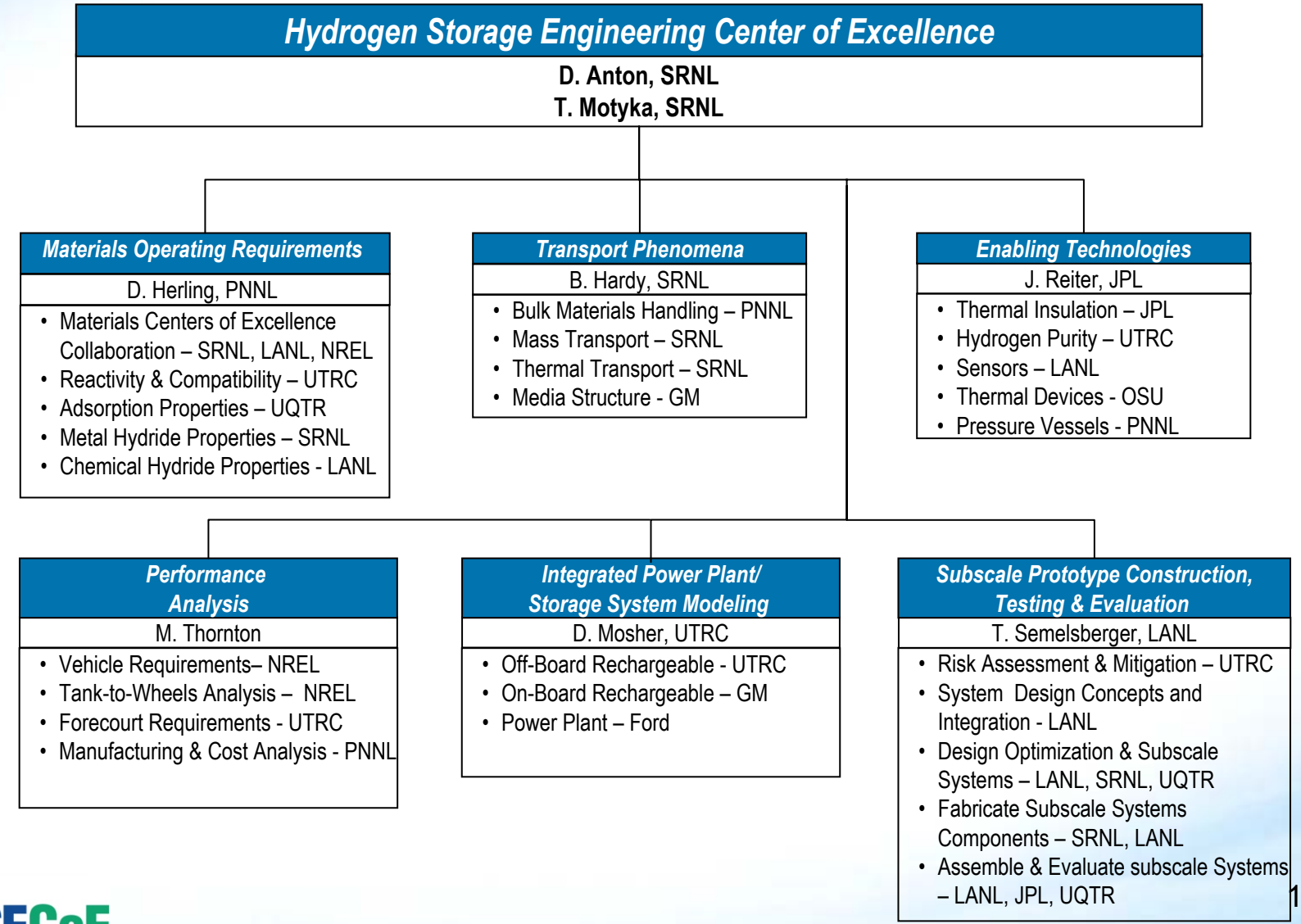
- The Technology Teams will work on specific Technology Tasks required for each hydride type. These tasks will sum to the required development necessary to design, build and test subscale prototype systems.
- Technical Team descriptions will be elucidated in partner's posters.

Hydride Type		
Metal Hydride	**Sorption**	**Chemical**
Transport Phenomenon		
Thermal Transport		
Model HX for Component		Model HX for reactor
Design/Evaluate HX Components		Design HX Components
Validate Models		Validate Models
Media Structure and Enhancement		
Bulk Materials Handling		
Model Mass Flow for System		Model Mass Flow for Reactor
Design/Evaluate Mass Flow Components		Design/Evaluate Mass Flow Components
Validate Models		Validate Models
Hydrogen Mass Transport		
Model Mass Flow for System		Model Mass Flow for Reactor
Design/Evaluate Mass Flow Components		Design/Evaluate Mass Flow Components
Validate Models		Validate Models

HSECoE Organization

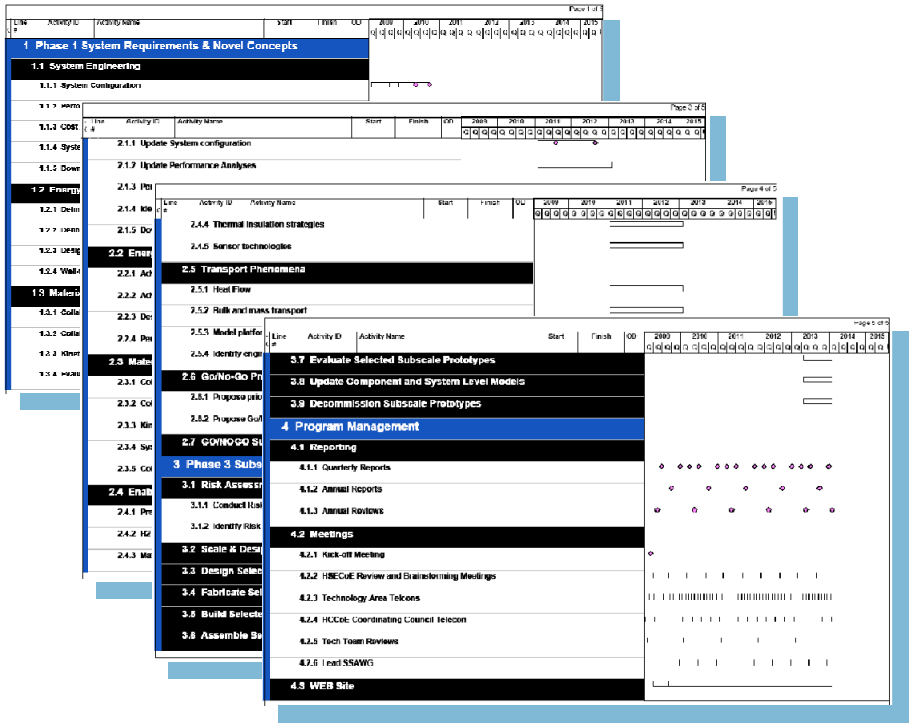


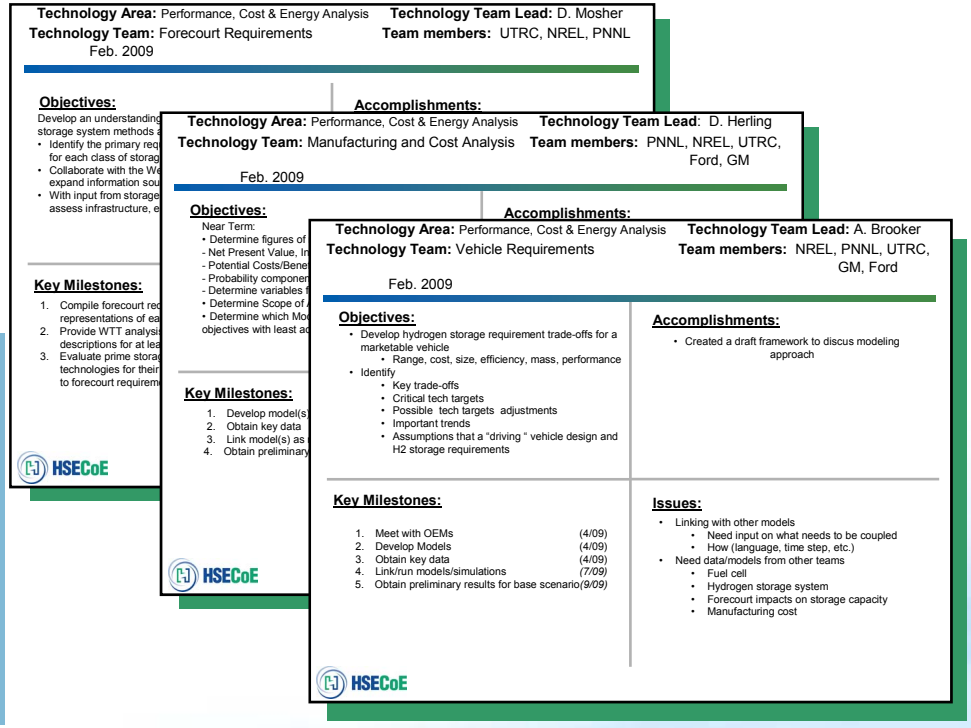
Technical Area Organization



Program Management

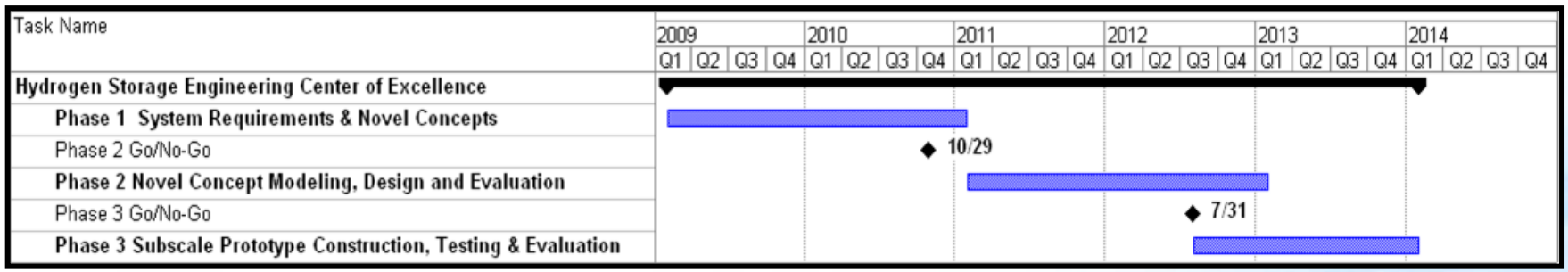
- **Total Program Gantt Chart tracked including deliverables, reports, & milestones using Primavera updated quarterly.**
- **Technical Area and Technical Team progress reported utilizing Quad Chart format quarterly.**





Important Dates

- Duration: 5 years
  - Phase 1 Start: Feb. 1, 2009
  - Phase 2 Go/No-Go Determination: Oct. 31, 2010
  - Phase 2 Start: Feb. 1, 2011
  - Phase 3 Go/No-Go Determination: July 31, 2012
  - Phase 3 Start: Aug. 1, 2012
  - Completion Date: Jan. 31, 2014



HSECoE

HSECoE Go/No-Go Decisions

Phase I / Phase II Go/No-Go Decision Q3 Y2:	Provide a system model for each material sub-class (metal hydrides, adsorption, chemical storage) which shows: • 4 of the DOE 2010 numerical system storage targets are fully met • The status of the remaining numerical targets must be at least 40% of the target or higher
Phase II / PhaseIII Go/No-Go Decision Q2 Y4:	Provide at least one full scale system design concept (5kg H_2 stored) where: • 6 of the DOE 2015 numerical targets are fully met • The status of the remaining numerical targets must be at least 50% of the target or higher

These Go/No-Go decisions require the HSECoE to consider and approach each of the DOE goals individually, and <u>not</u> concentrate only on one or two.

Phase 1 Deliverables, Milestones and Decisions

- **Deliverable Reports**
  - Automotive & Materials Requirement
  - Materials Data Compilation
  - Subcomponent Design Models/Validation
  - Efficient Hydrogen Storage System Concepts
- **Technical Milestones**
  - Identify vehicle operating requirements
  - Define hydrogen storage system requirements
  - Define materials data requirements
  - Describe required thermal & mass transport methods
- **Go/No-Go Decisions**

  Provide a system model for each material sub-class (metal hydrides, adsorption, chemical storage) which shows:
  - 4 of the DOE 2010 numerical system storage targets are fully met
  - The status of the remaining numerical targets must be at least 40% of the target or higher

Phase 2 Deliverables, Milestones and Decisions

- **Deliverable Reports**
  - Advanced vehicle power plant requirements
  - Detailed materials data base
  - Validated subcomponent models
  - Provisional subscale concepts & designs
- **Technical Milestones**
  - Identify vehicle architectures
  - Assess materials characteristics
  - Identification of necessary heat & mass transport methods
  - Identification of enabling technical components
- **Go/No-Go Decisions**

  Provide at least one full scale system design concept (5kg H_2 stored) where:
  - 6 of the DOE 2015 numerical targets are fully met
  - The status of the remaining numerical targets must be at least 50% of the target or higher

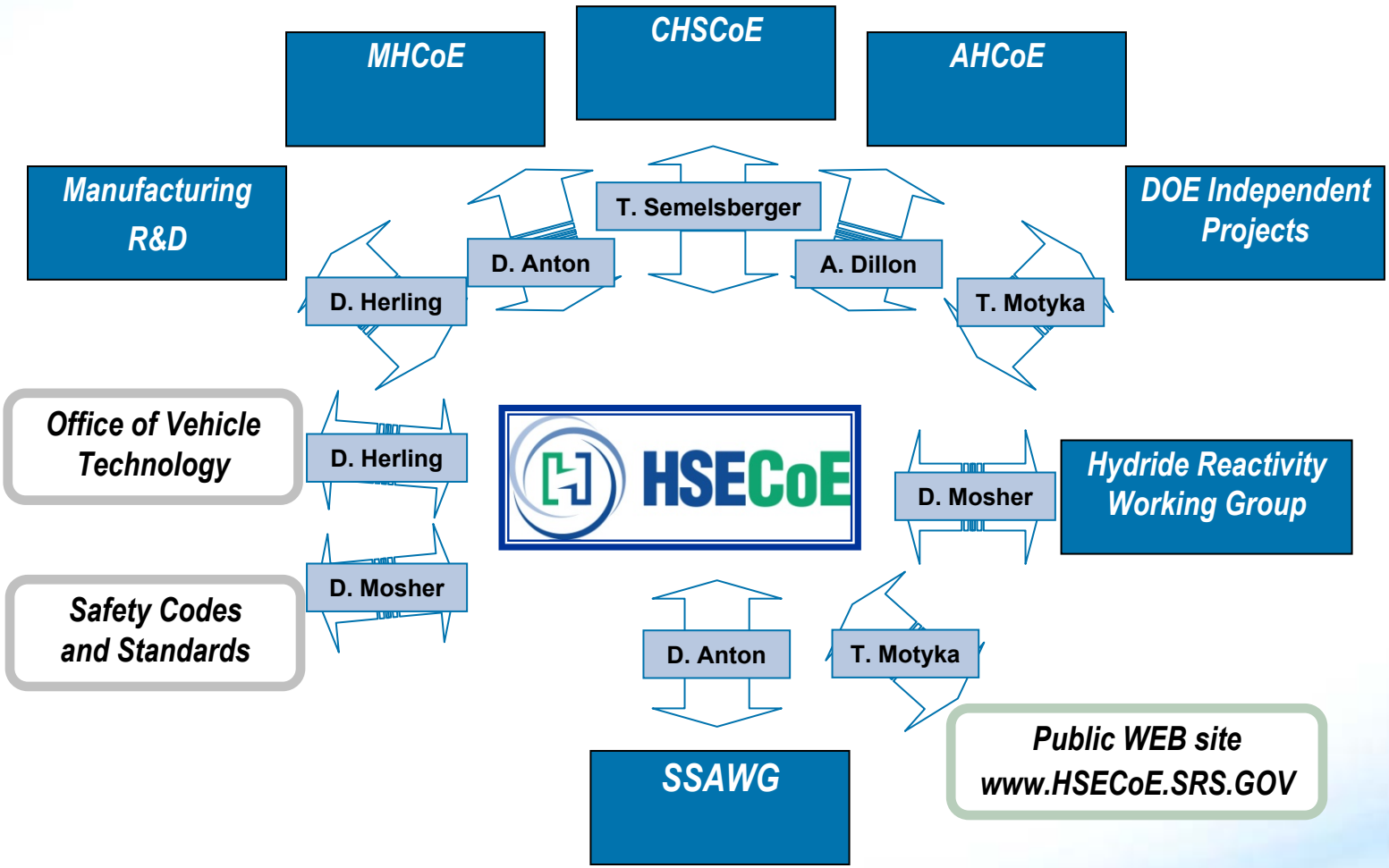
Phase 3 Deliverables and Milestones

- **Deliverables**
  - Hazard risk assessment for selected media
  - Design optimization for each media type down selected
  - Subscale prototype for each media down selected
  - Detailed test plan
  - Subscale test station
  - Reports documenting results of subscale system tests
  - Decommissioning of subscale prototypes
- **Milestone**
  - Design build and evaluate down selected subscale hydrogen storage systems.

Intra-Center Communications

- Intra-Center WEB site utilizing *SharePoint* will be established to facilitate the transfer of data and share results within the Center
- Regular Technology Team telecons
- Monthly Technology Area telecons
- Quarterly Coordinating Council telecons
- Semi-annual HSECoE Face-2-Face meetings to be held at rotating partners locations
- Quarterly technical progress reports
- Annual technical summary reports

Extra-Center Communications



Technical Gap Identification

- **It is recognized that in key technical areas a critical risk may be identified which needs to be addressed with specific WBS tasks.**
  - Technical gap identification will continue throughout the duration of the Center.
  - These gaps will be quantified to the extent possible at F2F meetings.
  - These gaps will be communicated through the WEB site and at AMRs so that potential solutions are considered and proposed from outside the Center to DoE through annual solicitations.
  - These proposed technologies may be incorporated into the Center with the consent of DoE, the HSECoE & the awardee.

IP Plan

- **Objectives**
  - To encourage the beneficial exchange of technical information and promote the creation of intellectual property.
  - To ensure the proprietary rights of all Partners are appropriately protected.
  - To secure Partners of the HSECOE appropriate benefits based on their contributions to Award Work.
  - To promote the rapid dissemination of information and maximize commercial development of inventions for the public good.
- **Establish Intellectual Property Management Committee (IPMC)**
  - Information Sharing
  - Reporting Requirements
  - Intellectual Property Prosecution
  - Licensing/Royalties
  - Addition/Termination of Partners
- **IP Agreement signed by all partners Jan. 31, 2008.**

Safety Plan

- The Assistant Director will form and lead a Safety Review Committee comprised of key Center representatives.
- The Safety Review Committee will coordinate submission and review Safety Plans from each partner and subcontractor within 90 days of program start based on the DOE Safety Planning Guidance for Hydrogen Projects.
- The primary objectives of the Safety Review Committee will be to communicate newly identified safety issues, new practices, near misses and lessons learned obtained from all of the other Centers of Excellence as well as the hydrogen community as a whole.
- Communication will make use of Center face-to-face meetings, telecons, website postings/archives and direct contact as warranted.
- Designated Subject Matter Experts will be available to review partner's operations to adequately identify hazards and recommend appropriate hazard controls, especially for prototype operations involving higher risks.

Accomplishments

Kick-Off meeting held Dec. 10, Washington, D.C.

USCar Tech Team meeting held Dec. 11, Washington, D.C.

IP Agreement signed Jan. 31, 2009

Face to Face Meeting held Feb. 23-25, 2009, Golden, CO

- **Modifications to TA structure**
- **Quad charts completed**
- **1st 100 day plan set**

Team and Center Milestones Go/No-Go negotiated, Feb. 28, 2009

Established External WEB site, April 1, 2009

Safety plan completed May 1, 2009

Face to Face Meeting held May 18, 2009

- **Materials data requirements established**
- **1st draft of media readiness established**

HSECoE

Project Summary

Relevance: Bring all of the technologies being studied for hydrogen storage to demonstration

Approach: Model and optimize the necessary hardware required to build hydrogen storage systems, validate models and design and test prototype hydrogen storage systems.

Technical Accomplishments: Brought team together and negotiated technical team assignments, milestones and deliverables.

Collaborations: HSECoE Team, external DOE stakeholders and international collaboration

Proposed Future Research: Initiate programs in vehicle modeling, system modeling, materials requirements, transport phenomena and enabling technologies.

HSECoE