Hydrogen Storage Engineering
CENTER OF EXCELLENCE

Key Technologies, Thermal Management, and Prototype Testing for Advanced Solid-State Hydrogen Storage Systems

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Jet Propulsion Laboratory
California Institute of Technology

U.S. Department of Energy
Energy Efficiency and Renewable Energy

Project ID
ST045

Overview:
Project Details

Timeline

- Project start date: February, 2009
- Project end date: January, 2014
- % complete: 20% (Duration)

Budget

- Expected total project funding:
  - $3.195M (DOE)
  - $0.03M (Caltech)
- Funding received in FY09:
  - $100K (DOE)
- Funding received for FY10:
  - $350K (DOE)

Barriers/System Targets (2015)

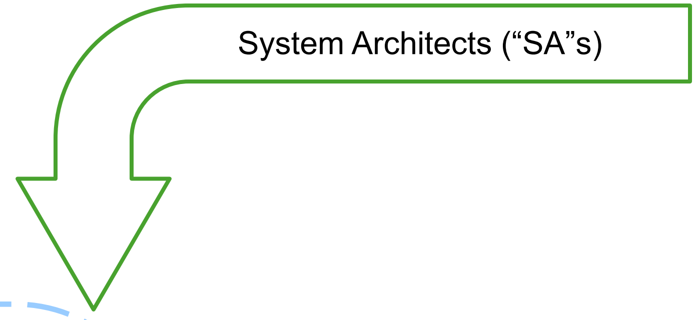
- A. System Weight and Volume
  - 5.5 %wt_{sys}, 55 gH_2/kg_{sys}, 40 gH_2/L_{sys}
- C. Efficiency
  - 90% on-board/60% off-board
- D. Durability/Operability
  - <1% degradation @ 1500 cycles, etc.
- E. Charging/Discharging Rates
  - 3.3 min fill, 0.02 g/kW-s minimum full flow
- G. Materials of Construction
- H. Balance-of-Plant Components
- I. Dispensing Technology
- J. Thermal Management

Partners

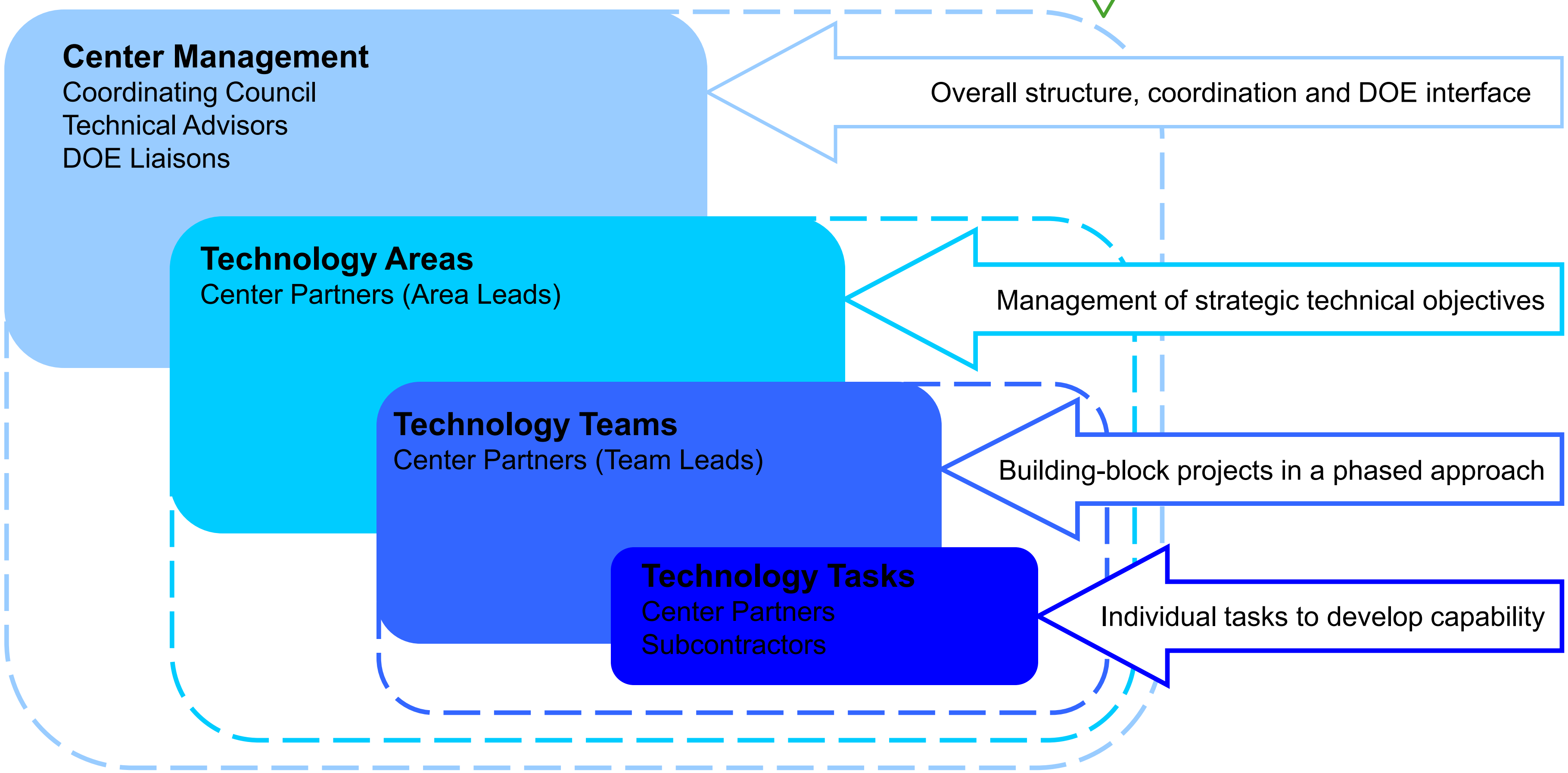
- Caltech (subcontract)

Overview:
HSECoE Organizational Approach

- The organization of HSECoE is built around a modular, hierarchical concept based on Technology Areas/Teams/Tasks + System Architects



- This organization will help HSECoE meet objectives by:
  - Maintaining effective tasking within a diverse team
  - Managing technology development in an emerging field



Overview:
JPL's Roles in HSECoE

Hydrogen Storage Engineering Center of Excellence
D. Anton, SRNL
T. Motyka, SRNL

Materials Operating Requirements
D. Herling, PNNL
- Materials Centers of Excellence Collaboration – SRNL, LANL, NREL
- Reactivity & Compatibility – UTRC
- Adsorption Properties – UQTR
- Metal Hydride Properties – SRNL
- Chemical Hydride Properties - LANL

Transport Phenomena
B. Hardy, SRNL
- Bulk Materials Handling – PNNL
- Mass Transport – SRNL
- Thermal Transport – SRNL
- Media Structure - GM

Enabling Technologies
J. Reiter, JPL
- **Thermal Insulation – JPL**
- Hydrogen Purity – UTRC
- Sensors – LANL
- Thermal Devices - OSU
- Pressure Vessels - PNNL

Performance Analysis
M. Thornton, NREL
- Vehicle Requirements– NREL
- Tank-to-Wheels Analysis – NREL
- Forecourt Requirements - UTRC
- Manufacturing & Cost Analysis - PNNL

Integrated Power Plant / Storage System Modeling
D. Mosher, UTRC
- Off-Board Rechargeable - UTRC
- On-Board Rechargeable – GM
- Power Plant – Ford

Subscale Prototype Construction, Testing & Evaluation
T. Semelsberger, LANL
- Risk Assessment & Mitigation – UTRC
- System Design Concepts and Integration - LANL
- Design Optimization & Subscale Systems – LANL, SRNL, UQTR
- Fabricate Subscale Systems Components – SRNL, LANL
- Assemble & Evaluate subscale Systems – LANL, JPL, UQTR

System Architects
- Metal Hydrides– SRNL
- **Cryoadsorbents– JPL**
- Chemical Hydrides– LANL

- **Technology Area Lead**
- **Technology Team Lead**
- **Technology Task Support**

Relevance:
Milestones and Task Breakdown

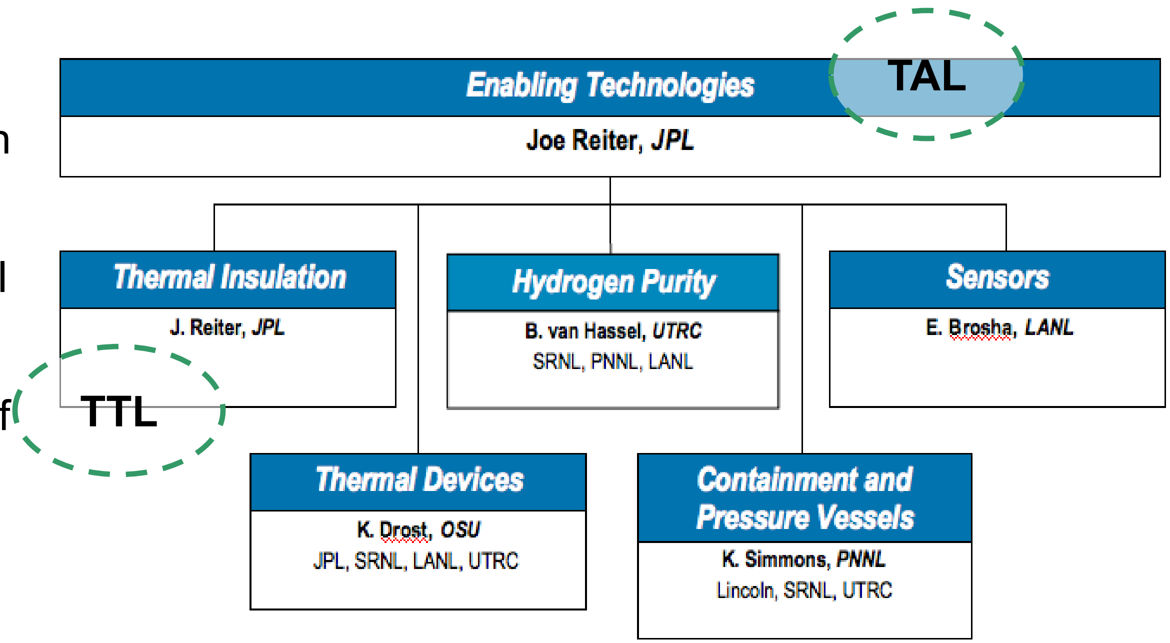
- Management Tasks in support of Center
  - Enabling Technologies TAL
  - Cryo-adsorbent System Architect
- Technical Tasks
  - Task 1: Thermal insulation research and development (Technology Team Lead)
  - Task 2: Insulation material testing and validation
  - Task 3: Metal hydride prototype testing and evaluation
- Milestones (FY2010-2011)
  - 3/2010: Insulating Materials database created, finish primary literature search (Complete)
  - 6/2010: Insulating Materials database initial population complete, available to Center & DOE
  - 10/2010: Initial materials testing (thermal performance) results available
  - 2/2011: Thermal insulation material/approach “upselect” provided to Center TALs/SAs
- The purpose and focus of the JPL effort is *technology management*
  - Assessment of current state-of-art / fitness evaluations of existing technologies
  - Identification of technology gaps re: system requirements and operational demands
  - Assessment of impact of technology gaps on system developability
  - Up-selection of candidate approaches to device design and implementation for gap mitigation
  - Technology development, hardware design and analysis for up-selected technologies
  - Continuing assessment and feedback of emerging technologies

Approach:
JPL Management Tasks in Support of HSECoE

- JPL is the Technology Area Lead (*TAL*) for HSECoE's "Enabling Technologies" strategic technology area *(TA)*
  - This effort is dedicated to facilitating the evaluation of key technologies that serve as particular challenges to prototype development
  - As for other Technology Areas within HSECoE, the work will be managed via the Technology Team Leads (*TTLs*) that will directly interface at the task-level in each case
  - Within each Team, any number of individual tasks may be required to reach objectives

- JPL is also performing research within the "Thermal Insulation" task group, developing approaches for passive thermal management of the storage vessel, thermal devices, and balance-of-plant components of the prototype system

- *See "JPL Task Area 1"*

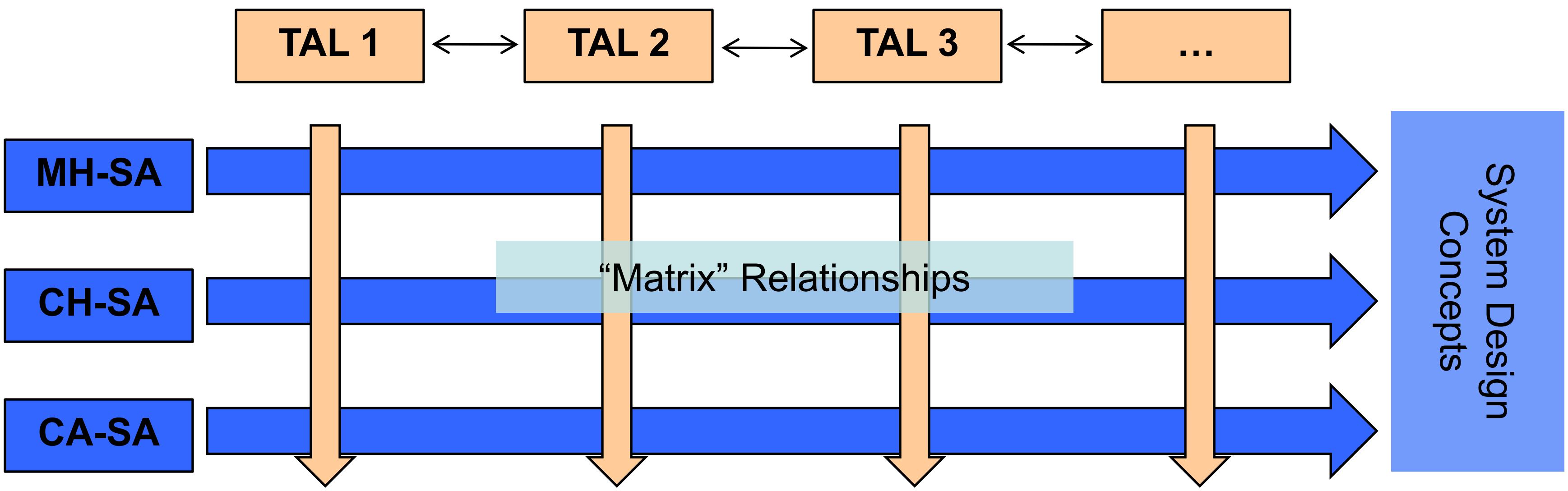


Approach:

JPL Management Tasks in Support of HSECoE

- Beginning FY2010, JPL is working in a System Architect (SA) role for the cryosorption storage demonstrator system design process
  - coordination of engineering efforts from Center partners
  - will interact directly with HSECoE TALs, providing oversight and guidance toward the design-build process of the demonstrator
  - utilizing Caltech subcontract (C. Ahn) as a resource in this role, as well as coordinating with GM (D. Kumar) to provide oversight

- SAs play a crucial role in maintaining the flow of data through the Center from TALs (data acquisition) to design teams and component/system builders (engineering); organization of the task structure is a main focus in FY2010



Approach:
Task Area 1: Thermal Insulation R&D

Objectives of literature/industry Technology Survey ("Phase 1"):

- Survey thermal insulation *material approaches* currently available from market sources and some near-term developable technologies
- Create and maintain database of materials and techniques
- Develop and apply parametric ranking approach to material database
- Make recommendations and provide design support for optimum performance for each type of storage system (MH, CH, CA)

Enabling Technologies

J. Reiter, JPL

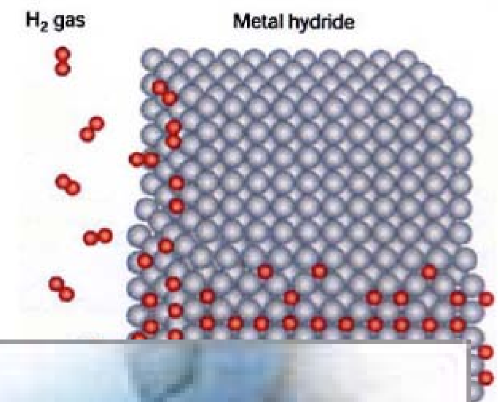
- Thermal Insulation – JPL
- Hydrogen Purity – UTRC
- Sensors – LANL
- Thermal Devices - OSU
- Pressure Vessels - PNNL

Why worry about passive thermal management?

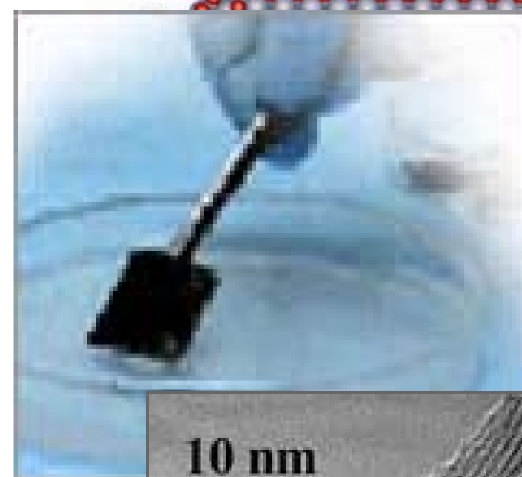
While obvious that cryogenic systems must rely on passive thermal control due to the need to retain sensible heat (latency, dormancy), it is somewhat less obvious that elevated-temperature systems (MH, CH) would also benefit from such passive control (onboard efficiency, etc.)

Technical Accomplishments:
Task Area 1: Thermal Insulation R&D

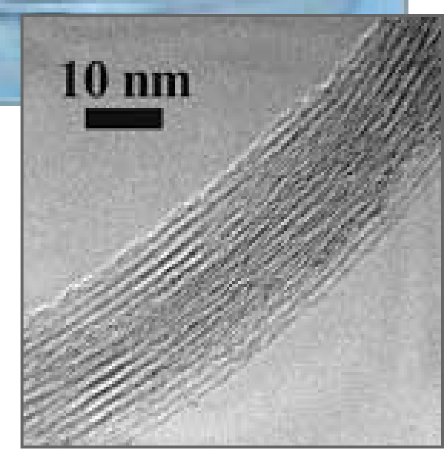
- Across the categories of storage materials, and 3 different types of thermal insulation requirement were defined (via DOE Targets)



- Metal Hydride temperature range requirements
  - "Hot" Case
  - Operating ambient temp -40 °C (from Ultimate Targets)
  - material operating temperature RT < T < 200 °C



- Chemical Hydride temperature range requirements
  - "Complex Components" Case
  - Operating ambient temp -40 °C (from Ultimate Targets)
  - material operating temperature RT < T < 100 °C

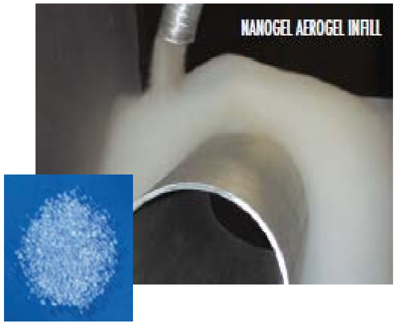


- Adsorption temperature range requirements
  - "Cold" Case
  - Operating ambient temp 60 °C (from Ultimate Targets)
  - material operating temperature -196 °C (~ -160 °C) < T < RT

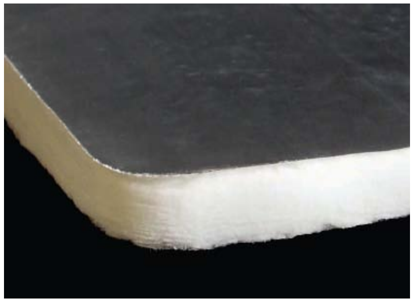
http://www1.eere.energy.gov/hydrogenandfuelcells/storage/carbon_materials.html
http://www1.eere.energy.gov/hydrogenandfuelcells/storage/chem_storage.html
http://bnl.gov

Technical Accomplishments:
Task Area 1: Thermal Insulation R&D

- Literature/industry survey of available technologies, categorized across material type and insulative approach:
  - Loose-Fill Material Material that are either produced or broken down into small particles, so that they can conform to any space without disturbing any structure
    - Perlite, Nanogel infill, 3M Glass Microspheres
    - 18 mW/m•k (25 ^{0}C) - 47 mW/m•k (21 ^{0}C), -101 – 100°C
  - Thermal Blanket (rolls) Material Material that consist of flexible fibers in sheets, blankets or roll forms and can be trimmed to fit
    - Cryogel Z, Nanogel Thermal Wrap, Ultra-flexible fiberglass
    - 15.5 mW/m•k (50 ^{0}C) – 37.5mW/m•k (24 ^{0}C), -270 – 537°C
  - Semi-Rigid/Molded Material Material that can be molded into a given shape
    - Trymer Polyisocyanurate, Nanogel Expansion Pack, Semi-rigid cork
    - 18 mW/m•k (25 ^{0}C) - 37.5 mW/m•k (20 ^{0}C), -200 – 200°C
  - Misc Materials All other Materials not covered under previous categories (e.g., sprayed foam)



http://www.cabot-corp.com/Aerogel/Building-Insulation/Products


http://www.aerogel.com/products/pdf/Cryogel_Z_DS.pdf


http://www.atlantech1.com/productlines/TrymerPipe.aspx

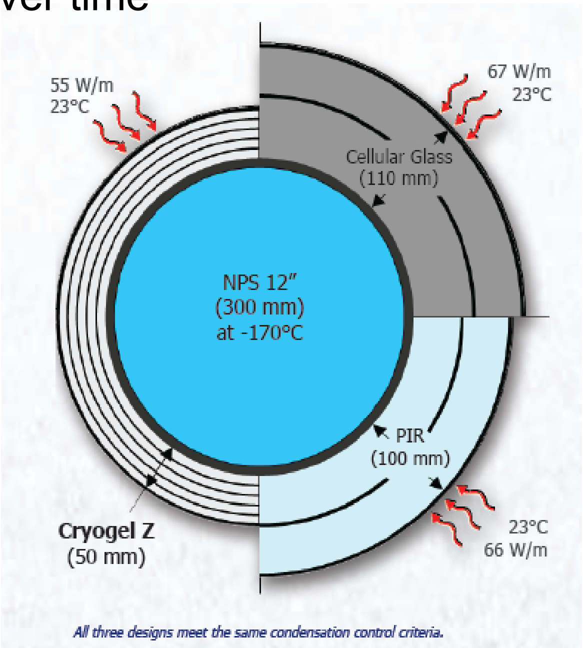
Technical Accomplishments:
Task Area 1: Thermal Insulation R&D

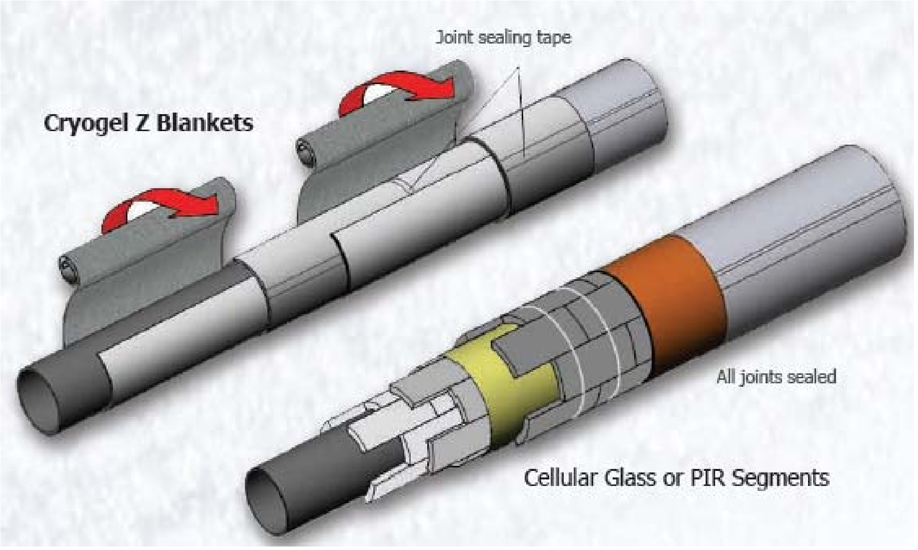
Sample approach to comparative weighting of database materials:

•Cryogel Z has a lower Thermal Conductivity compared to PIR

•All Aerogel material cost more then all the other insulations surveyed

•Evacuated Perlite has low Thermal Conductivity but has degradation issue over time





http://www.aerogel.com/Aspen_Aerogels_Cryogel_Z.pdf

•Nanogel Expansion Pack will need to be covered along with fiberglass, cork and several others

•Perlite and Nanogel beads have very low density and low thermal conductivity

Technical Accomplishments:

Task Area 1: Thermal Insulation R&D

Material/Products	Company	Temperature Range C (oustide temp -30/50)		K Value (mW/m-K)	Density	Cost	units/size
Blankets							
CryogelZ	Aspen Aerogel	-270	90	15	8.0 lb/ft^3	$150.00	5mm 60"x59"
Pryogel XT	Aspen Aerogel	-40	650	21	11 lb/ft^3	$150.00	5mm 60"x59"
Pryogel XTF (fire protect)	Aspen Aerogel	-40	650	21	11 lb/ft^3	$250.00	10mm 60"x59"
Pryogel 2250	Aspen Aerogel	-270	250	15.5	10.7 lb/ft^3	$150.00	2mm 60"x59"
SpaceLoft Subsea	Aspen Aerogel	-200	200	13.9	8 lb/ft^3	$150.00	5mm 60"x59"
JPL Aerogel	JPL	cryo	1600	9 (1 atm @23 C)	N/A	N/A	N/A
composite silica aerogel, titania and silica powder	JPL	cryo	1600	4 (23 C)	N/A	N/A	N/A
Nanogel Thermal Wrap	Cabot	-200	125	21 (12.5 C)	4.68 lb/ft3	$150.00	8 mm X1m X1m
Nanogel Compression Pack	Cabot	-200	200	~18 (25 C)	~6.24 lb/ft3	custom	
The Nanogel Expansion Pack	Cabot	-200	200	~18 (25 C)	~6.24 lb/ft3	custom	
Thermablok Blanket	Thermablok	-200	200	13.6 (25 C)	9.4 lb/ft^3	$4.99	125'x57"x0.4" (593.75 sq ft)
Semi-Rigid/ Molded							
Trymer Polyisocyanurate (PIR)	Atlantech Distribution / made by Dow Chemical	-183	148	27.38 (24 C)	1.65 lbs./ft^3	$24.96	15" pinpe size x 1" thick in 3" sections 3 per ft
Semi-Rigid Cork Insulation	McMaster-Carr	-200	130	37.5 (20 C)	7-8 lbs/ft^3	$7.68	12"x36"x1" sheets
Semi-Rigid PVC Foam Insulation	McMaster-Carr	-198	71	24.5 (24 C)	3 lbs/ft^3	$68.66	32"x48"x1"
Rigid Fiberglass Insulation	McMaster-Carr	-17.78	232	31.7 (24 C)	3 lbs/ft^3	$12.43	24"x48"x1"
Ultra-Flexible Fiberglass Insulation	McMaster-Carr	-17.78	538	37.5 (24 C)	2.4 lbs/ft^3	$14.10	24"x96"x1"
Rigid Mineral Wool Insulation	McMaster-Carr	-17.78	649	33.1 (24 C)	6.8-8.6 lbs/ft^3	$8.50	1"x1"x3"
Semi-Rigid Mineral Wool Insulation	McMaster-Carr	-17.78	649	34.6 (24 C)	8 lbs/ft^3	$6.19	24"x48"x1"
nsulation Extra-High Temperature Sheets	McMaster-Carr	-17.78	1051.7	40.35 (800 C)	19 lbs/ft^3	$171.97	24"x40"x1"
Loose-Fill							
Glass Bubbles K1	3M	cryo	<600	47 (21 C)	7.8 lb/ft3	$5.00	.25 lbs
Glass Bubbles K15	3M	cryo	<600	55 (21 C)	9.36 lb/ft3	$5.00	.25 lbs
Cryogenic Perlite	Perolite Products, Inc	below -100	800	40-60 (24 C)	2-25 lb/ft3	$5.50	4 cubic feet bag
Evacuated Perlite	l Tech or Exfoliators PTY LTD or incon c	below -100	800	.7 (-107 C)	8-9.5 lbs./ft^3	$5.50	4 cubic feet bag
Non-Evacuated Perlite	Perl Tech or Exfoliators PTY LTD	below -100	800	37 (24 C)	2- 6.24 lbs./ft^3	$5.50	4 cubic feet bag
Provosil / Perlite Fill	Redco II	-240	1093	29 (-101 C)	2 to 20 lbs./ft^3	$13.00	4 cubic feet bag
Nanogel Translucent Aerogel	Cabot	-200	250	18 (25 C)	5.6 – 6.2 lb/ft3	$49.95	1 gallon (.5 lbs)
Nanogel IR Opacified Beads	Cabot	-200	250	10-15 (-88 C)	6.24 lb/ft3	$65-100	per kg
Nanogel Fine Particle Aerogel	Cabot	-200	250	18 (25 C)	2.5 – 6.2 lb/ft3	$65-100	per kg
MISC							
Void-Filling Foam Insulation	McMaster-Carr	-128.9	93.3	23.1(24 C)	1.75 lbs/ft^3	$34.15	12 sq. ft 1" thick

Raw data as well as parametric results are provided to Center partners via *Sharepoint* site

Proposed Future Work:
Task Area 1: Thermal Insulation R&D

- **Database Ranking and Data Mining**: We are moving forward with a parametric ranking study of passive thermal management techniques, exercising a spreadsheet-based model framework for evaluating the database of available technologies
  - this model framework should be capable of an ongoing evaluation of new technologies and approaches as they emerge

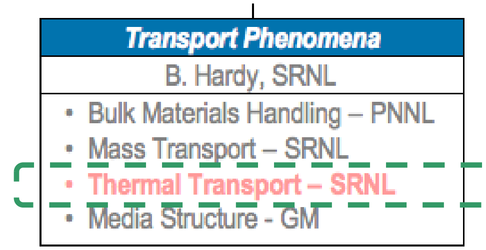
- **Insulation Study "Phase 2"**: Near-term efforts on vacuum-gap vessels for cryogenic systems; planned collaborations and technical interchange possible with industry, following the example of the "baseline" LLNL Gen 3 cryo-tank design
  - Develop a "tank-level" prediction of thermal insulation performance (work with partners in ET TAL) for each type of storage system
  - provide insulation "upselect" to Center

- **Advanced Thermal Management**: Special focus on JPL in-house thermal technologies for use in storage systems
  - Hydrogen/helium/etc. "active gas gap heat switches" for variable heat conduction
  - Aerogel insulation (bulk) for passive control of tank temperature

This Future Work is targeted to assist the Phase 1/2 Go/No-Go point in early 2011, and will help inform system performance metrics on an ongoing basis

Approach:

JPL Task Area 2 - Thermal Testing & Validation



- Beginning in Q3FY2010, JPL will utilize current in-house capabilities to support overall Center activities to evaluate and predict the performance of passive thermal management techniques

- Main focus is on model/sub-model validation via bench-testing of “thermal management materials” with relevant heat loads and temperatures
  - Can provide validation paths for models developed either at JPL or by other Center Partners; can also provide feedback for Materials Compatibility and/or Safety

- If necessary, we are baselining a model platform with custom capabilities as well as basic “1-D worksheet” models for performance prediction
  - Model platform originally developed during engineering activities within the Metal Hydrides Center of Excellence (MHCoE)
  - Will work with SRNL TAL to partition task on an as-needed basis

- This is a gated activity; results will inform the Center Go/No-Go set for Q2 FY2011 milestone, but efforts can continue for materials that remain viable

Technical Accomplishments:
JPL Task Area 2 - Thermal Testing & Validation

- Only just underway!
- Setup of the materials testing lab has started at JPL (5/2010)
  - co-located with other ongoing hydrogen R&D efforts (MHCoE, etc.)

- Some materials in the Thermal Insulation Materials Database are already in-hand and ready for instrumented studies (*k, Cp, f(T)*, etc.)

Proposed Future Work:
Task Area 2: Thermal Testing & Validation

- **Thermal Performance Testing**: We are bringing on-line a benchtop testing facility, designed to obtain specific performance data for selected materials to test against database information
  - continue to obtain material samples, perform benchtop verification of bulk material properties
    - thermal conductivity (*k*) vs. operating temperature
    - specific heat (*Cp*) vs. operating temperature
    - some limited cycling durability/performance breakdown effects
  - the results of this effort will naturally feed into the Center's general modeling capabilities; some "on-demand" testing will be available, in order to plug gaps in model frameworks

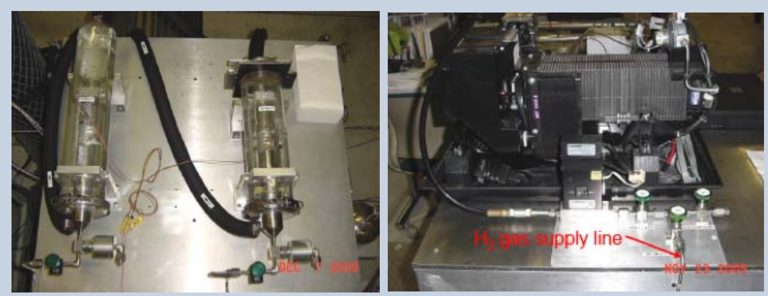
Approach:
JPL Task Area 3: Prototype Testing and Evaluation

- This activity is JPL's primary role in Phase 2/3 and supports the entire Center
  - Presupposes the selection of a metal-hydride based prototype demonstrator, although some contributions may be made in the event a sorption system is still selected
- Utilizes a currently active fabrication/testing/characterization laboratory at JPL with available space for ~2 test-stands
  - Hydrogen Storage Engineering Laboratory (HSEL)
- Tasks aligned under this objective are currently scoped to run from Q2FY2012 through Q4FY2013; i.e., 1.5y +
- Selected subtasks:
  - Develop test procedures and test safety plan
  - Build test stand, develop test software
  - Assemble system/fill/closeout hydride storage vessels
  - Integrate system with test facility
  - Analyze and disseminate data
  - Disposition storage prototype at conclusion of testing

Subscale Prototype Construction, Testing & Evaluation

T. Semelsberger, LANL

- Risk Assessment & Mitigation – UTRC
- System Design Concepts and Integration - LANL
- Design Optimization & Subscale Systems – LANL, SRNL, UQTR
- Fabricate Subscale Systems Components – SRNL, LANL
- Assemble & Evaluate subscale Systems – LANL, JPL, UQTR



Testing an integrated MH-bed/PEM-FC hybrid power system on a facility within JPL's Hydrogen Storage Engineering Lab (HSEL)

Collaborations

- System Architecture
  - D. Kumar (GM): CA system models, performance metrics, flowsheets
  - C. Ahn (Caltech): CA materials performance,
  - R. Chahine (UQTR): CA vessel design approach, testing/performance, material densification
- Technology Area discussions/regular technical interchanges
  - B. van Hassel (UTRC): H2 Purity TTL/material impurity production
  - K. Simmons (PNNL): Pressure Vessels TTL/tank design and costing, trade studies
  - N. Newhouse (Lincoln): tank design criteria
  - K. Drost (OSU): Thermal Devices TTL/high heat flux combustors/exchanger performance
  - E. Brosha, T. Semelsberger (LANL): Sensors TTL/fuel sensor development and test results

Summary

- **Technology management tasks**: Outside of the lab, effort is focused on a smooth technical interchange among Center partners at the TAL/TTL level.
  - Coordinating the *Enabling Technologies TA* is important to maintaining an “upward” flow of results and data to enhance system development
  - The new *System Architect* role will provide a path to satisfying technical targets and navigating overall system performance

- **JPL is producing a database resource**: The compilation of research into the “bleeding edge” of insulating materials and approaches will result in a persistent technical resource for the Center and DOE
  - the database will be combined with the results of materials performance testing, providing validated results for modeling efforts and guidance for design/build

- **Materials testing effort is gearing up**: Experimental data will enhance identification of target/milestone achievement, especially for cryo-dormancy and “cold start” system requirements. Work will support Phase 1/2 Go/No-Go decisions as well as provide a resource past the G/NG gate

FY2010/FY2011 will be an extremely busy period!

Supplemental Slides

SA/TAL Responsibility Matrix

- Matrix aligns System Targets with TAL elements responsible for producing estimates and system analyses (high-level org.)

	Parameter		units	2010	2015	Resp. TA
1	Gravimetric	Density	KgH_2/ Kg system	0.045	0.055	PA
2	Volumetric	Density	KgH_2/liter	0.028	0.04	PA
3	Cost		$/KWh net	4	2	PA
4	Operability	Min./Max. Op. T	°C	-30/50	-40/60	IPP/SSM
5		Min./Max, Deliv. T	°C	-40/85	-40/85	IPP/SSM
6		Cycle Life	N	1000	1500	MOR
7		Min. Deliv. P	bar	4	3	IPP/SSM
8		Max Deliv. P	bar	100	100	IPP/SSM
9	Rates	Fill Time	Min.	4.2	3.3	TP
10		Min. Flow	g/s•KW	0.02	0.02	IPP/SSM
11		Start time 20°C	sec.	5	5	IPP/SSM
12		Start Time -20°C	sec.	15	15	IPP/SSM
13		Trans. Resp. 10%-90%	sec.	0.75	0.75	IPP/SSM
14	Fuel Purity		%	99.99	99.99	ET
15	EH&S	H2 Loss	gH_2/hr•KgH_2	0.1	0.05	ET

Loose-Fill Insulation

Perlite

•Naturally occurring volcanic glass

•Currently used in LN2 storage tanks, LN2 transport vehicles and LH2/LOX storage tanks at NASA KSC

•K-value of 29 mW/m-K (-101 ^{o}C)

http://www.perlite.net

http://www.cabot-corp.com/Aerogel/Building-Insulation/Products

Nanogel Infill

•Part of the silica aerogels family, Material is made up of small particles of aerogel, which consist largely of air (95%), Particle sizes from 10µm to 4mm

•Currently used in building insulation, insulated pipeline systems, transport and stationary tanks and LNG vessels

•K-value of 18 mW/m•k (25 ^{o}C)

3M Glass Bubbles

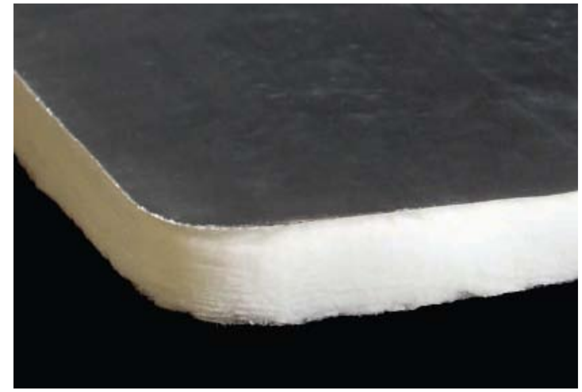
•Strong, lightweight, hollow glass spheres (soda-lime-borosilicate)

•Currently being considered as replacement for perlite in storage tanks at NASA KSC

•K-value of 47 mW/m•k (21 ^{o}C)

http://solutions.3m.com/wps/portal/3M/en_US/Mining/Home/Pages/Applications/GlassBubbles/

Thermal Blanket Insulation



http://www.aerogel.com/products/pdf/Cryogel_Z_DS.pdf

Cryogel Z

- Flexible silica aerogel blanket with reinforcing fibers; currently used in LNG Gasification Piping and Equip, LNG Field Joints, and LNG Cryogenic Bellows
- K-value of 15.5 mW/m•k (50 ^{o}C)
- Temperature range of -270 ^{o}C to 90 ^{o}C

http://www.cabot-corp.com/wcm/download/en-us/ae/Oil%20&%20Gas%20brochure%209_09.pdf

Nanogel Thermal Wrap

- Silica aerogel granules in fiber matrix, flexible at cryogenic temperatures with high tensile strength; currently used in insulation for pipe systems, and on subsea oil and gas fields
- K-value of 21 mW/m•k (12.5 ^{o}C)
- Temperature range of -200 ^{o}C to 125 ^{o}C

Ultra-Flexible Fiberglass Sheets

- Currently used in insulation industrial furnaces
- K-value of 37.5mW/m•k (24 ^{o}C)
- Temperature range of -17 ^{o}C to 537 ^{o}C

http://www.ehow.com/how_4932219_install-fiberglass-blanket-insulation.html

Semi-Rigid Molded Insulation

Trymer Polyisocyanurate (PIR)

•Closed-cell Polysiocyanurate pipe insulation, similar to polyurethane (PUR); currently used in industrial pipe insulation, commercial chilled water insulation aı a/c systems

•K-value of 27.4 mW/m•k (24 ^{o}C)

•Temperature range of -183 ^{o}C to 148 ^{o}C

http://www.atlantech1.com/productlines/TrymerPipe.aspx

http://www.cabot-corp.com/wcm/download/en-us/ae/Oil%20&%20Gas%20brochure%209_09.pdf

Nanogel Expansion Pack

•Made from Silica Aerogel, this system consist of flat packs of compressed nanogel and pre-attched to rugged outer sheath; currently used in insulation for subsea pipe-in-pipe systems

•K-value of 18 mW/m•k (25 ^{o}C)

•Temperature range of -200 ^{o}C to 200 ^{o}C

Semi-Rigid Cork

•Moisture-resistant cork sheets; currently used in building insulation and as wall/ceiling tiles

•K-value of 37.5 mW/m•k (20 ^{o}C)

•Temperature range of -200 ^{o}C to 130 ^{o}C

http://www.corkstore.com

Technology Area: Enabling Technologies
Technology Team: Thermal Insulation

Area Lead: J Reiter, *JPL* (818)354-4224
Team Lead: J. Reiter, *JPL* (818)354-4224

December 2009 (v3)

Objectives:

- Identify notional requirements, capabilities, and gaps for passive thermal management in storage systems
- Develop high-level trade space performance models *f*(geometry,material,temperature,time,etc.) as evaluative tool (interface with HSECoE modeling groups)
- Validate trades and novel approaches with strategic experiments on the bench top
- Evaluate, recommend, and incorporate candidate approaches for engineered systems (full- and sub-scale)

Accomplishments:

- Began work under FY2009 funding (awarded 9/2009)
- Identified initial material/approach parameter table

Key Milestones:

1. Complete initial state-of-art survey/lit search (JPL) (2/10) **15%**
2. Report initial weighted trade space model results (JPL) (3/10)
3. Initial model validation experiments for MH system (JPL) (6/10)
4. Initial model validation experiments for CS system (JPL) (9/10)

new, re-defined, ~~complete~~

Issues:

- Need to outline model framework for trade space study (spreadsheet/database/etc.)
- JPL task in the process of rapidly "staffing up"

HSECoE