



Idaho National Laboratory

2005 DOE Hydrogen Program: NHI System Interface and Support Systems

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Project ID
#PD31

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Overview

Timeline

- **Start: Jan 2004**
- **End: 2017+**
- **Project provides ongoing support to DOE NHI**

Budget

- **Total project funding**
 - **Projected DOE funding is \$37M through 2014**
 - **Cost sharing may be pursued by 2010**
- **FY04: \$1.86M**
- **FY05: \$2.79M**

Barriers

- **High temperature structural materials identification & development**
- **High temperature heat transfer fluids**
- **High temperature heat exchanger designs and components**
- **System modeling**
- **Reactor/process interaction analysis**
- **Codes, standards, safety**

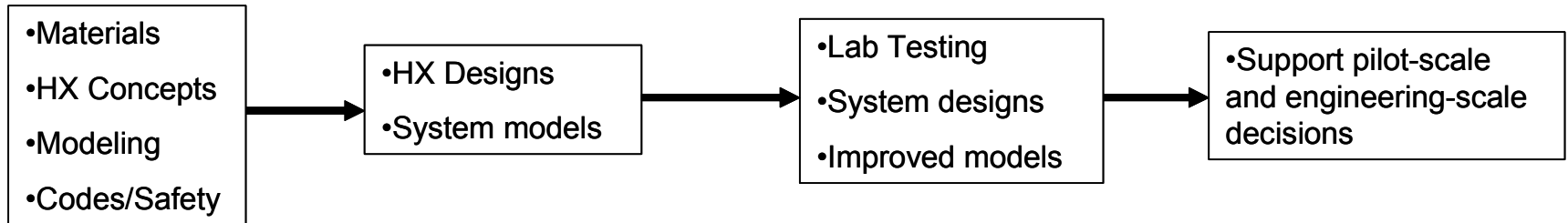
Partners

- **Currently INL, ORNL, SNL, UNLV RF (Ceramatec, GA, MIT, UCB, others)**

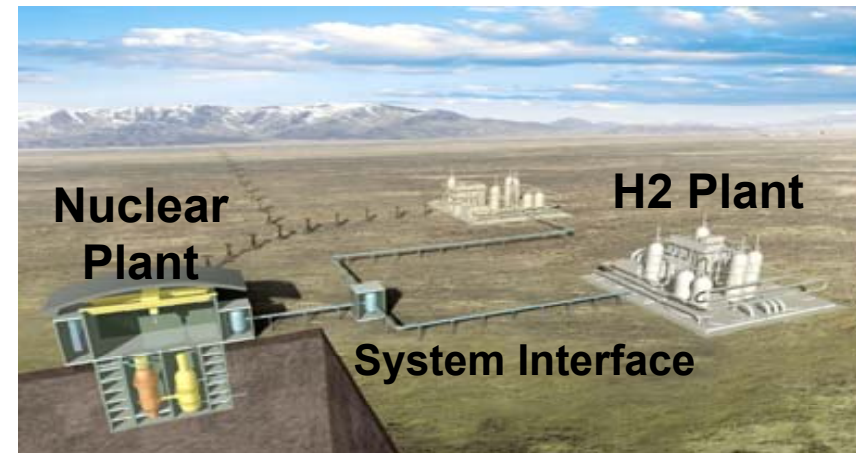
Objectives

- **Project Objectives**
 - **To assist DOE in the development of a high-temperature heat transfer network to enable the linkage of a high temperature nuclear reactor to a nuclear hydrogen production plant (System Interface)**
 - **Support development of hydrogen plant ancillary systems and infrastructure for pilot-scale and engineering-scale nuclear hydrogen production plants (Support Systems)**
- **FY 2005 Objectives**
 - **Determine regulatory/safety factors relevant to determining nuclear plant/hydrogen plant spacing**
 - **Perform analysis of heat transfer fluids and system characteristics**
 - **Determine specific heat exchanger requirements, determine candidate materials, and develop preliminary concepts for system interface heat exchangers**

Approach (1)



- **Initially, parallel paths**
 - **Materials and heat transfer fluid analysis**
 - **Conceptual designs**
 - **Modeling**
 - **Codes/safety**
- **Narrowed focus as project advances**
 - **Development and testing of hardware**
- **Ultimately, project must support pilot-scale and engineering-scale design decisions**



Approach (2)

- **Multi-laboratory effort involving national laboratories, universities, and private companies**
 - **INL, ORNL, Sandia**
 - **UNLV Research Foundation**
 - **Ceramatec**
 - **General Atomics**
 - **MIT**
 - **UC-Berkeley**
 - **Expansion to other laboratories in future as needed to support the project**

Technical Accomplishments (1)

- **Infrastructure**
 - Defined infrastructure requirements for pilot-scale hydrogen production plants (Mar 2004)
- **Balance of Plant**
 - Defined initial balance-of-plant requirements for nuclear hydrogen plants (Jun 2004)
- **System Interface – most efforts concentrated here**
 - Identification of technical requirements and relevant technical issues
 - High temperature materials investigations and development
 - Heat transfer fluid and systems effects investigations
 - High temperature heat exchanger development

Technical Accomplishments (2)

- **System Interface technical requirements and issues identified (INL, MIT, UC-Berkeley, MIT, Sept 2004)**
 - **Broadly covers materials, mechanical construction, operation, and safety needs and issues**
- **Initial study of nuclear plant/hydrogen plant spacing requirements performed (INL, Mar 2005)**
 - **Probabilistic Safety Assessment (PSA) tools used**
 - **ALOHA code for chemical dispersion events**
 - **SAPHIRE code to perform probabilistic risk analyses**
 - **Factors considered**
 - **Probability of nuclear core damage less than 10^{-6}**
 - **Past history of hydrogen events at commercial BWR's, PWR's**
 - **Possible effects of hydrogen explosions, chemical leaks on nuclear plant**
 - **Results**
 - **Spacing between 60 m and 120 m is possible, depending upon placement of blast barriers, control room placement, etc.**

Technical Accomplishments (3)

- **Initiated study of the influence of heat transfer fluid choice (helium, molten salt) and nuclear reactor power conversion configuration (direct, indirect, variations) on thermal-hydraulics, mechanical stresses, structural materials choices for system interface (INL)**
- **Study of nickel-based high temperature alloys for application to heat exchangers (UNLV, MIT, UC-Berkeley, GA)**
 - Initiated SCC testing of Waspaloy under slow-strain-rate conditions in presence of S-I fluids and cathodic and anodic potential fields
 - Preparing to test Incoloy 800H, Zr-705, Nb-1Zr, Nb-7.5Ta under constant load conditions
- **High temperature heat exchanger design modeling for secondary and process heat exchangers (UNLV)**
 - Performed CFD modeling of compact design involving grid spacing studies, channel dimension parametrics, mechanical stress analysis, temperature profile analysis (FLUENT)
 - Incorporating H_2SO_4 decomposition behavior into process heat exchanger modeling to monitor effects on temperature and stress.

Technical Accomplishments (4)

- **Development of Incoloy 800H + Pt and Inconel 617 + Pt added alloys for catalytic heat exchangers (MIT)**
 - Created buttons of 800H and 617 + Pt added material and converting buttons to wrought shapes for testing
 - Constructed catalyst test system to test catalytic activity
- **Corrosion studies of materials in liquid HI-I₂-H₂O at 400-450 °C for application to S-I process (GA)**
 - 22 metallic and non-metallic materials tested using exposed coupons (Nb and SiC-C composites among clear winners)
 - Test apparatus installed to study effects of materials processing on corrosion rates
- **Identification of non-metallic materials, manufacturing techniques, and heat exchanger designs for high-temp operation (Ceramatec)**
 - Non-metallic material choices identified
 - SiC, MoSi₂, Ti₃SiC₂, Si₃N₄, Al₂O₃, SiAlON, Cordierite (Mg₂Al₄Si₅O₁₈)
 - Identification of critical issues performed
 - Manufacturability/cost, corrosion and thermal shock resistance, thermal conductivity, reliability, strength, creep resistance

Future Work (1)

- **Remainder of FY05**
 - **Materials & Heat Transfer Fluids**
 - Complete thermal-hydraulic analysis of heat transfer fluids and effects on materials choices, temperature profiles, etc.
 - Analysis of hydrogen plant heat exchanger and heat transfer loop requirements, including materials needs
 - Continue corrosion testing of materials candidates for S-I process
 - Continue mechanical properties measurements of metallic alloys
 - Complete work on non-metallic materials, manufacturing methods
 - **HX Concepts**
 - Complete initial design of sulfuric acid decomposition heat exchanger
 - Perform catalyst testing of Alloy 617/800+Pt catalyst
 - **Modeling**
 - Continued modeling work on baseline heat exchangers

Future Work (2)

- **FY06**

- Complete interface heat exchanger design and high temperature materials testing for baseline processes
- Construct and initiate testing of lab-scale high temperature hydrogen process materials and test loops
- Complete initial design studies for H₂-plant BOP
- Complete initial reactor-process isolation assessment
- Complete assessment of applicable codes and standards

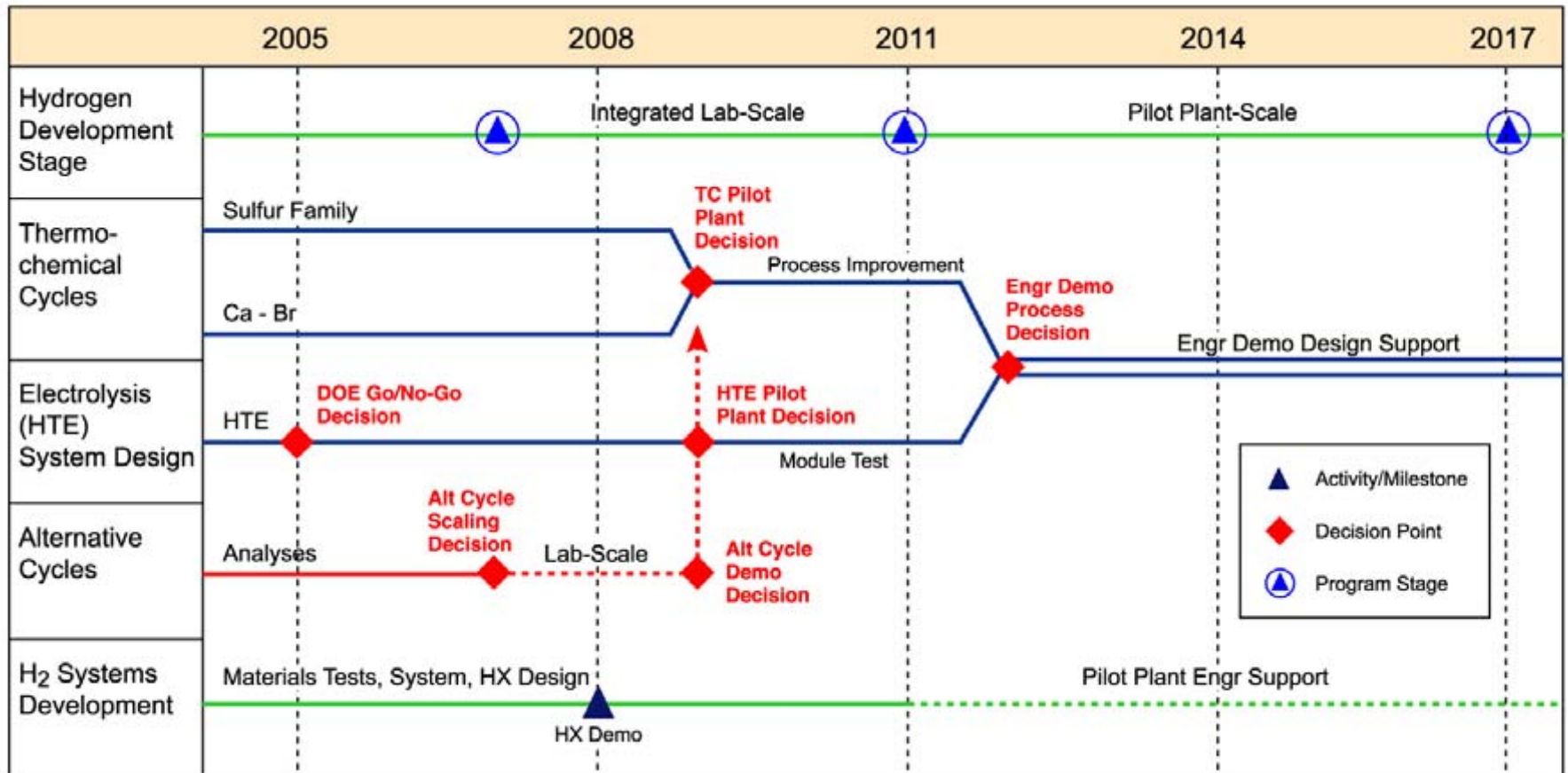
- **FY07**

- Coordinate pilot-scale component designs and testing
- Perform lab-scale experiments on heat exchangers & components
- Complete pilot-scale BOP design for baseline H₂ processes
- Initiate permitting activities for pilot-scale experiments

- **FY08**

- Complete design and testing activities to support pilot-scale decisions
- Complete design and testing for required BOP components and system
- Complete documentation of systems interface and BOP technologies for pilot-scale experiment decisions

Future Work (3)



03-GA51038-09

Supplemental Slides

Publications and Presentations

- R.P. Anderson, C.V. Park, W.D. Ridgeway, D.M. Ginosar, J.C. Perkowski, R.A. Carrington, S.R. Sherman, M.R. Anderson, J.S. Herring, P.S. Pickard, R.D. Doctor, R.A. Montgomery, M.D. Sandvig, *Infrastructure Requirements for a Nuclear Hydrogen Pilot Plant*, INEEL/EXT-04-01791, Rev. 0, March 2004
- S.R. Sherman, D.B. Barber, J.H. Kolts, *Reactor/Process Interface Requirements*, ANL W7500-0001-ES-00, Rev. 0, July 2004
- D. Vaden, M.F. Simpson, S.R. Sherman, J.H. Kolts, *Balance of Plant Requirements for a Nuclear Hydrogen Production Plant*, ANL W7500-0003-ES-00, Rev. 0, September 2004
- S.R. Sherman, M.F. Simpson, D. Ginosar, T. Lillo, P. Peterson, R. Ballinger, A. Roy, T. Hechanova, J.H. Kolts, *Reactor/Process Interface Heat Exchanger and Intermediate Loop Technical Issues*, ANL W7500-0002-ES-00, Rev. 0, September 2004
- T. Hechanova, *High Temperature Heat Exchanger Project: Quarterly Progress Report, October 1, 2004 through December 31, 2004*, University of Nevada Las Vegas Research Foundation, funded under Financial Assistance DE-FG-04-01AL67358, Amendment 007, U.S. Department of Energy
- C. Smith, S. Beck, B. Galyean, *An Engineering Analysis for Separation Requirements of a Hydrogen Production Plant and a High-Temperature Nuclear Reactor*, INL/EXT-05-00137, Rev. 0, March 2005.

Hydrogen Safety (1)

The most significant hydrogen hazard associated with this project is:

- Through 2006
 - Most significant hydrogen hazard will be associated with handling pressurized cylinders of hydrogen for the purposes of testing materials for hydrogen embrittlement and hydrogen permeability. There is a risk of hydrogen fire in the case of a leak, since these tests may occur at temperatures that are above the auto-ignition temperature of hydrogen in air (571 °C).
- From 2007 through 2009
 - Most significant hazard will be associated with the production of hydrogen in laboratory-scale hydrogen production facilities at volumes reaching 1000 liters/hour. If leaks or equipment failures occur, there is a risk of hydrogen fire, since some of these tests may occur at temperatures that are above the auto-ignition temperature of hydrogen in air (571 °C).

Hydrogen Safety (2)

Our approach to deal with this hazard is:

- Procedural Controls
 - Procedures and experimental practices will conform to all institution-specific safety requirements and guidelines at the location where the experiment or test is being carried out
 - Thorough hazard assessments (and corrective actions) will be conducted for all experiments
 - Experimenters and technicians will have Stop-Work Authority
 - Persons performing the experiment have right to stop the conduct of any experiment if they believe a situation, procedural step, etc. is unsafe
- Engineering Controls
 - Experiments will be performed behind engineering barriers (fume hood sash, ventilated enclosure, etc.)
 - Areas around experimental equipment will be well ventilated to disperse hydrogen leaks, and the areas will be monitored for significant hydrogen concentrations
 - All equipment will be leak-tested to prevent air in-leakage
 - Fail-safe control schemes will be used to shut down equipment or experiments under potentially hazardous conditions.