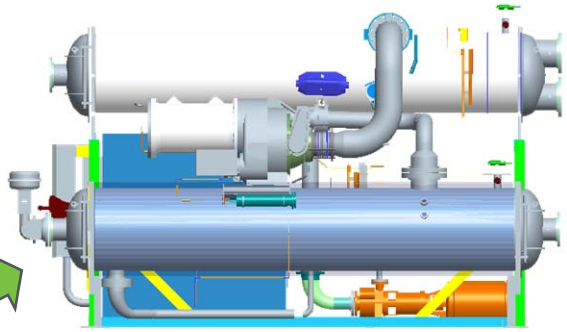
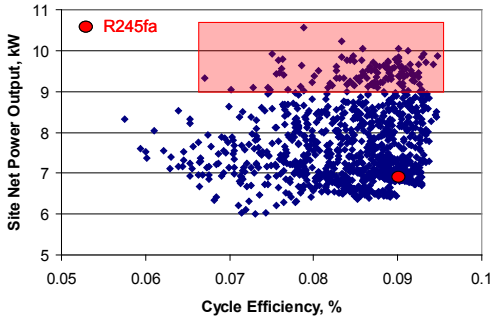
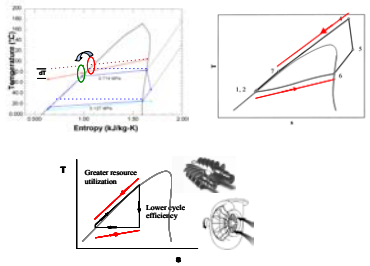
Demonstration



Optimization



Concepts



Tailored Working Fluids for Enhanced Binary Geothermal Power Plants

May 19, 2010

Dr. Ahmad M. Mahmoud
United Technologies Research Center

Specialized Materials and Fluids and Power Plants

Overview

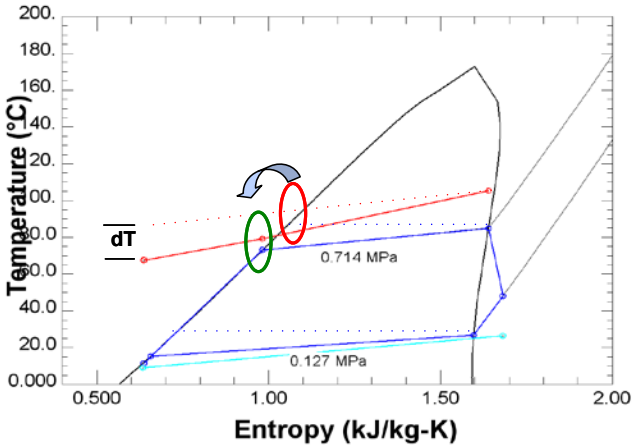
- Timeline
  - Project started on December 29, 2009, ends April 21, 2012
  - Approximately 10% complete
- Budget:
  - Total project cost $2,270,382
  - DOE share $1,816,306
  - Awardee share $ 454,076
  - Funding for FY10 $1,179,000
- Barrier

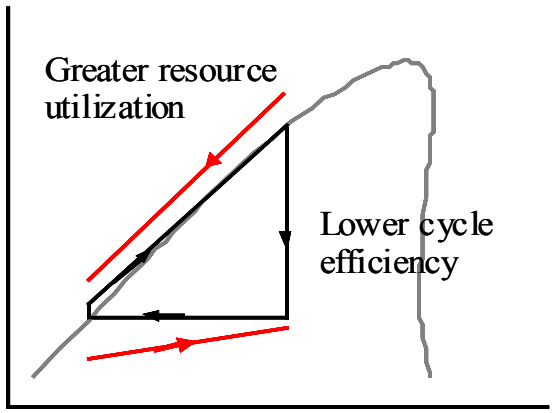
  Low temperature geothermal technology R&D and demonstration
- Partners
  - Georgia Institute of Technology
  - National Institute of Standards and Technology

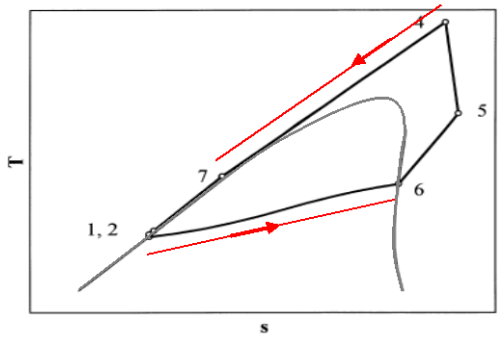
Relevance/Impact of Research

Objective: Down-select of Working Fluid Selection, System and Component-level Designs

- Costs of reservoir characterization, drilling and pumping resource are significant
- Maximize net-site power output for given temperature and flow
- Drop the resource temperature before reinjection
- Need to develop enhanced energy conversion systems with high resource utilization







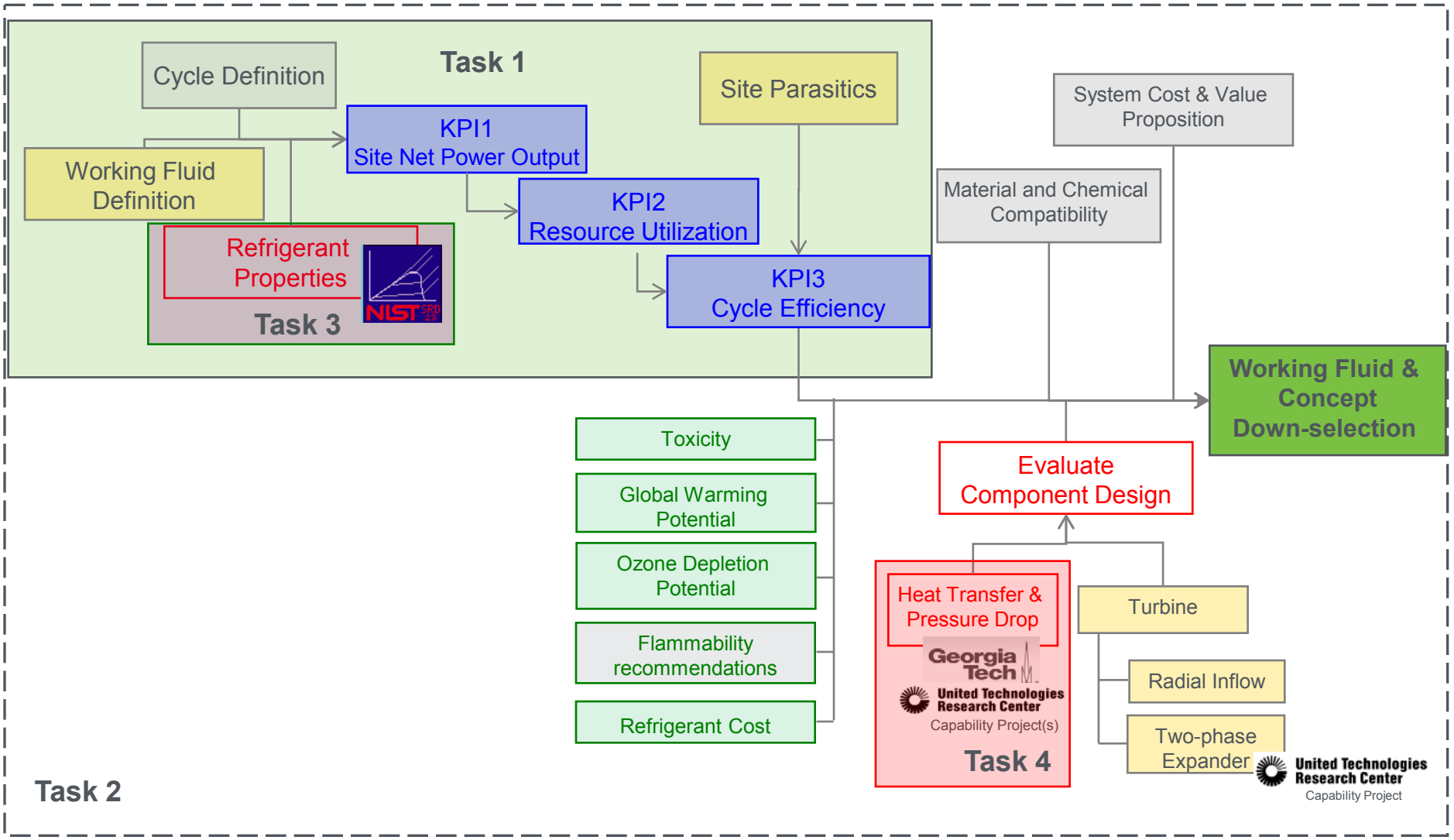
Relevance/Impact of Research(Cont'd)

Objective: To improve the utilization of available energy in geothermal resources and increase the energy conversion efficiency of systems employed by a) tailoring the subcritical and/or supercritical glide of enhanced working fluids to best match thermal resources, and b) identifying appropriate thermal system and component designs for the down-selected working fluids.

Innovation:

- Comprehensive multi-faceted technical approach
  - Cycle Analysis
  - System and Component Designs
  - Fluid Optimization
  - Fluid Property Portions
- Fundamental Measurements and Analysis
  - Thermodynamic & Thermophysical Properties
  - Flow Boiling and Condensation Heat Transfer & Pressure Drop
- Next-generation component designs

Scientific/Technical Approach



Accomplishments, Expected Outcomes and Progress

Expected Outcomes:

- Validated system and component-level design tools
- Robust screening and down-select methodology with cross-cutting potential
- Optimized Heat Exchanger and Turbine design for down-selected working fluids
- Thermodynamic and thermophysical property data and modeling for down-selected fluids
- Flow boiling and condensation heat transfer and pressure drop data, correlations and analytical models
- Proof-of-concept demonstration for an efficient two-phase expander

- Potential impact: For the same resource conditions, the overall energy conversion of binary geothermal power plants will increase by at least 40%

Project Management - Schedule

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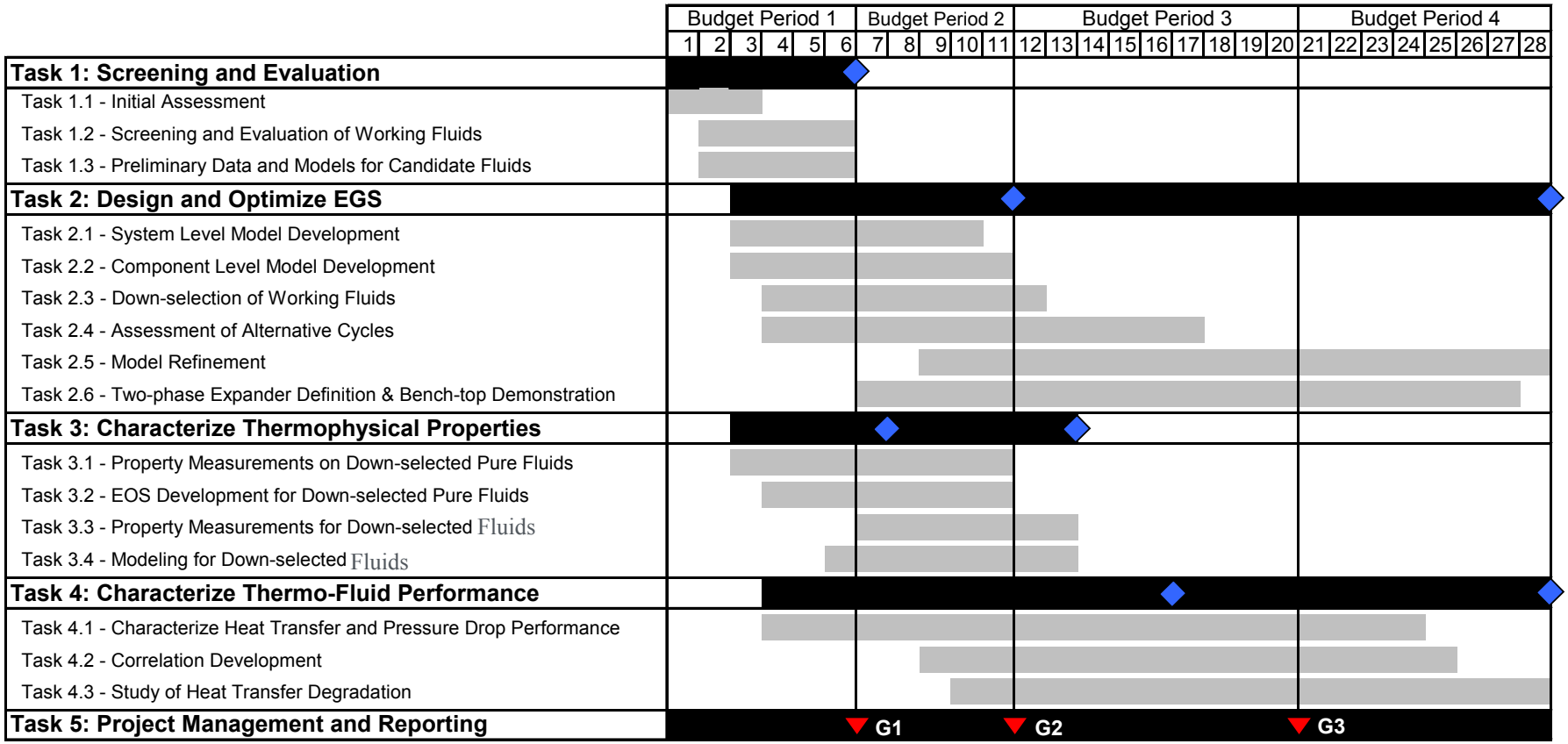
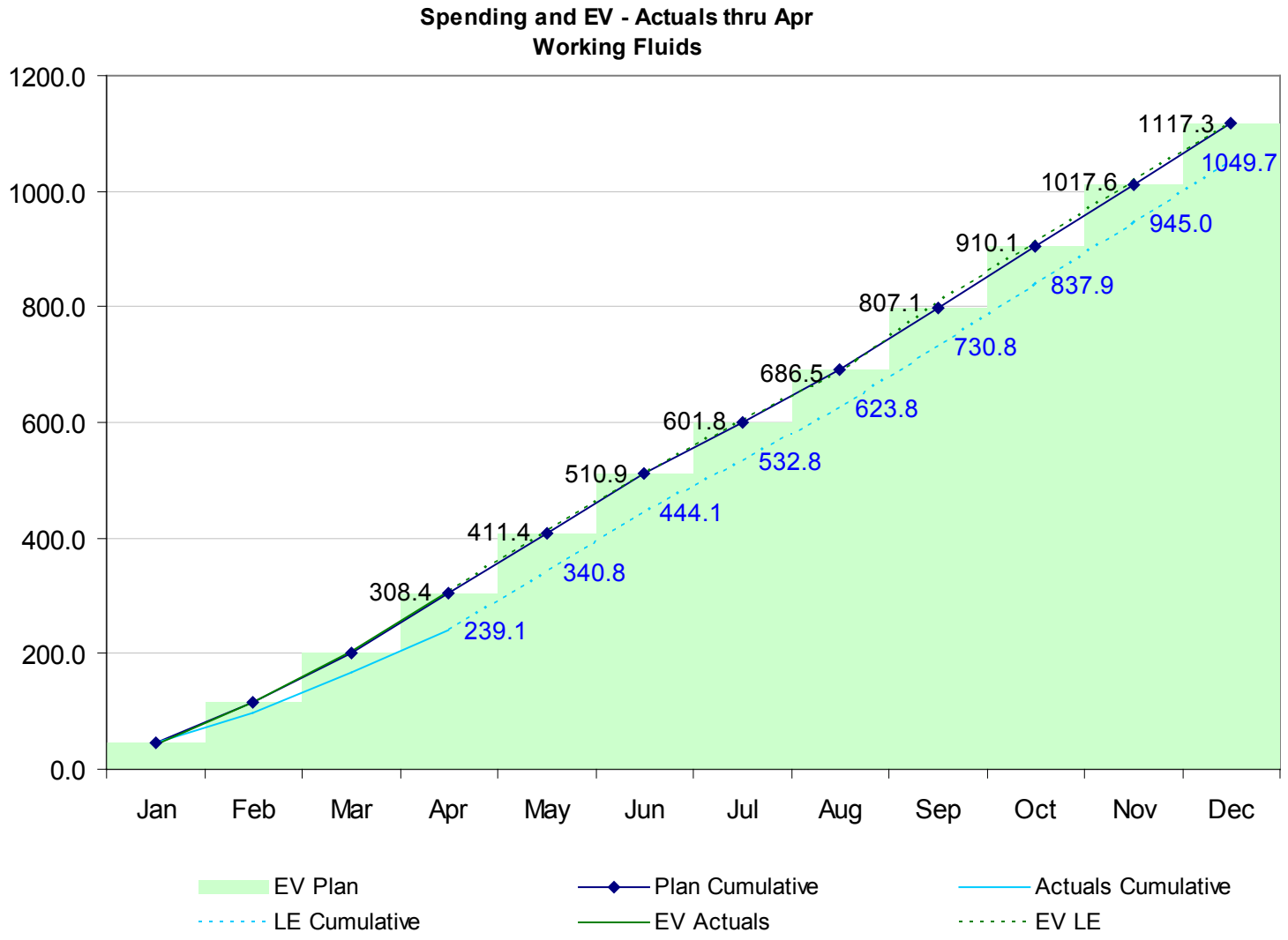


Technical Review

Go/No-Go Decision Point

EOS: Equations of State

Project Management - FY2010 Spend Plan



Future Directions

Complete upcoming key milestones (2010):

- Complete development of system- and component-level models
- Finalize down-select of enhanced working fluids for characterization of thermodynamic properties, thermophysical properties, heat transfer and pressure drop performance tasks
- Complete two-phase expander concept down-select and initiate plan for execution of the proof-of-concept demonstration

Explore technology insertion potential for enhanced working fluids and enhanced component-level technologies not only in the geothermal ORC applications and in other DOE applications.

Ensure UTC business units are associated with the project to ensure successful technology transfer and commercialization.

Summary

- Project Objective is to improve the utilization of available energy in geothermal resources and increase the energy conversion efficiency of systems employed.
- UTRC will lead the proposed innovative multi-faceted approach and will leverage world-class capabilities of NIST and Georgia Tech to provide feedback
- Project has been initiated and executed according to the management plan and is on schedule and within budget.
- Technology insertion potential is large for geothermal ORC as well as other DOE technology areas