Image Courtesy of Ruby Mountain Inc.

Image Above: Midnight drilling of RMI 56-5 at McGregor Range on Fort Bliss. The RMI 56-5 drilling effort found the hottest water to date on McGregor Range in 2013.
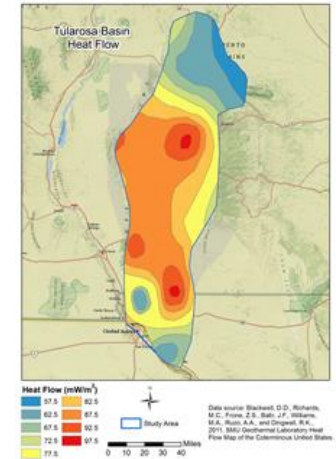
The Convergence of Heat, Groundwater & Fracture Permeability:
Innovative Play Fairway Modelling Applied to the Tularosa Basin

Project Officer: Michael Weathers   May 12, 2015

Principal Investigator: Gregory D. Nash, Ph.D. & Carlon Bennett, Project Manager for RMI

Organizations: Ruby Mountain Inc. (RMI) and Energy & Geoscience Institute (EGI)

Track Name: Hydrothermal/Play Fairway Analysis

Objective: The Tularosa Basin Project is developing PFA models to identify geothermal plays using <u>innovative geothermal adaptation of petroleum industry logic and data driven methods</u> coupled with a <u>novel reward/failure ratio map</u> and ancillary data to support play ranking and entry.

Challenges, Barriers and Knowledge Gaps:

<u>Challenging Tularosa Basin Site Selection</u>
The underexplored basin is a challenging, yet ideal test bed to evaluate effectiveness of the team's data collection techniques as well as the effectiveness of our innovative PFA <u>where the identified geothermal resources have a significant potential to be developed.</u>

<u>Stakeholder Involvement = Data Collection Success!</u>
- Exhaustive literature search of published data conducted
- Primary, secondary and tertiary data sources identified and contact list developed early
- Outreach to military: Data collection & interest in geothermal resource development extremely effective.
- Data sharing agreements executed with key stakholders/military as needed
- Personalized outreach to key stakeholders resulted in greater data collection than expected. Lots of unpublished data discovered!

Impact on Costs, Performance and Markets: The PFA models developed can significantly improve the effectiveness of play ID and entry and prioritize exploration.

Regional Impacts
- First-ever basin-wide geothermal assessment
- Ranking of specific geothermal plays and points of entry - most on military installations
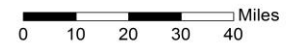
Implications for GTO
- Identification of new geothermal resources
- Reduced exploration risk for industry
- Development and validation of a reusable methodology
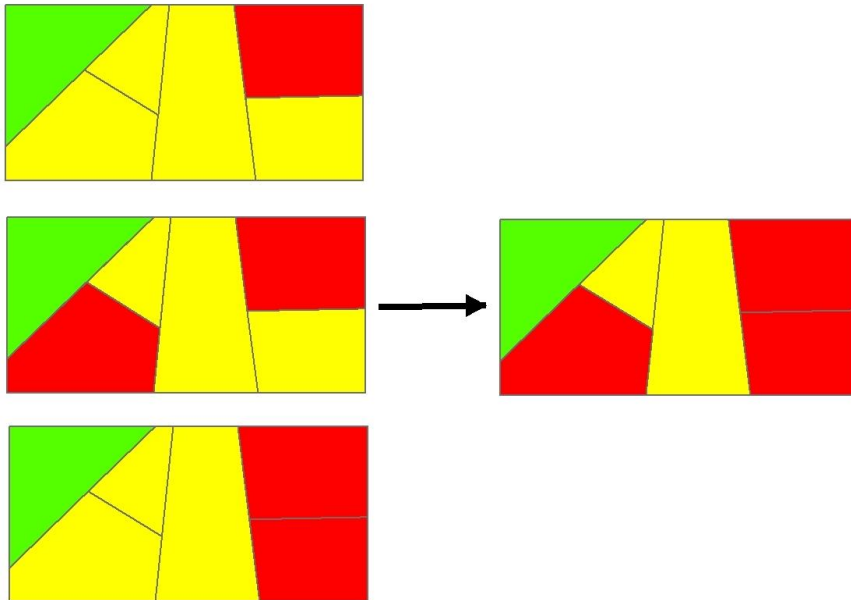- Supports DoD "Net Zero" Energy and national energy security goals (up to 20 MW need in study area)
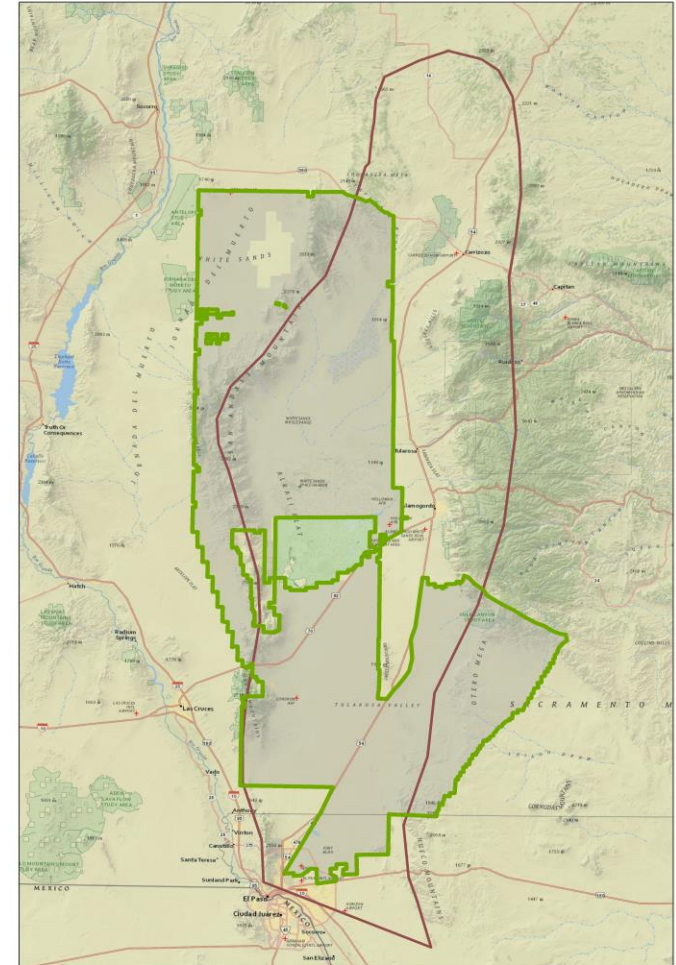
Legend
- Military Reserves
- Study Area

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<u>Our Approach is Unique</u>

- We are using two strategies for PFA

    - (1) **Adaptation** of classic petroleum industry PFA based on three composite risk segment maps (CRS)

Petroleum Industry CRS = Source, Charge, and Seal

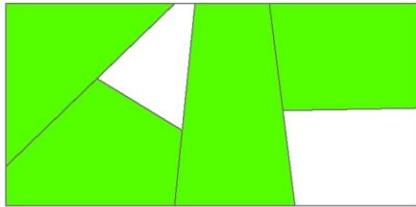Geothermal CRS = Heat, Fluid, and Fault Related Fractures

High Risk

Moderate Risk

Low Risk

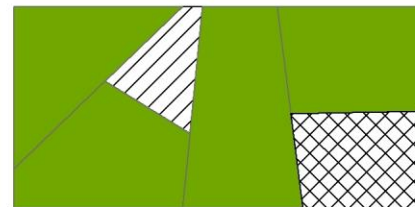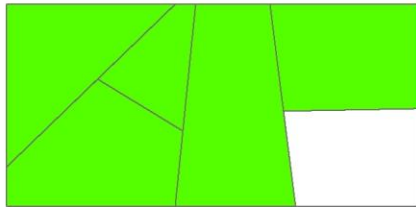**U.S. DEPARTMENT OF ENERGY** | Energy Efficiency & Renewable Energy

PFA uncertainty based upon data availability
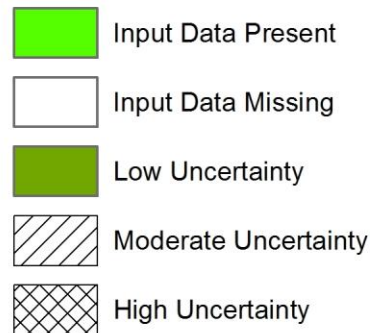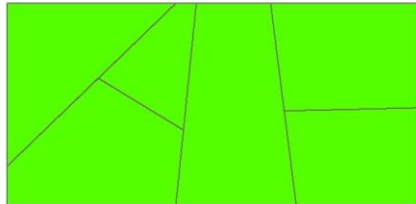

Heat CRS Input: Geothermometers

PFA spatial uncertainty will also be addressed in the final PFA models
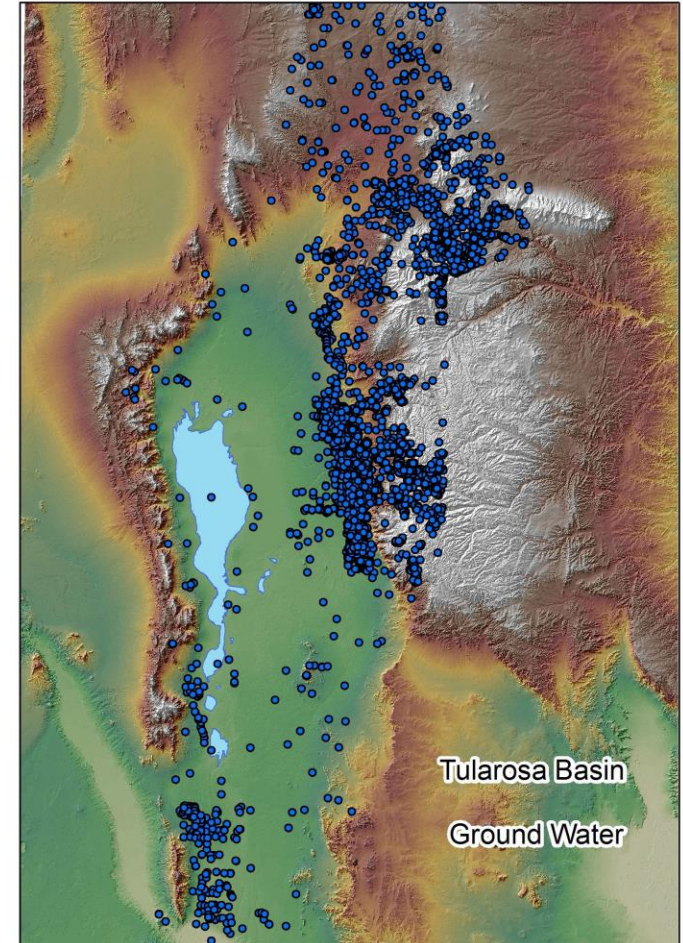
Heat CRS Input: Heat Flow

Heat CRS Input: Temperature Gradient

Input Data Present

Input Data Missing

Low Uncertainty

Moderate Uncertainty

High Uncertainty

Scientific/Technical Approach

- (2) Data driven model development: weights of evidence

  - CRS maps are developed using training sites

  - Local training sites (known geothermal systems) are sparse

    - Training sites from outside of the Tularosa Basin will be used to augment
    - If infeasible, knowledge based layers of evidence will augment the model

- Results of the two models will be compared and contrasted to determine which provides the most useful information (never done before)

- Cost benefit analysis will be performed for identified plays

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Project Design

- Data, data, and more data
  - Good spatially-dispersed data is the most critical component of this project

  - Heat of the Earth, fault-fracture permeability, and fluid for heat transfer

  - Incorporate data into a GIS database for processing
   - Process into raster and vector formats for PFA

Tularosa Basin

Ground Water

● Wells penetrating ground water

▢ Paleolake Ortero

Miles
0 10 20 30 40

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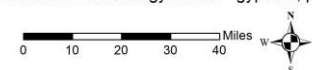- ## Project design (cont.)
  - PFA: Two methods tested and Contrasted
    - Petroleum industry standard (knowledge-based)
    - Weights of evidence (data-driven stochastic)
      - Used for mineral exploration
      - Found by Moghaddam et al. (2013) [1] to be a superior data-driven method
        » Hybrid to be created if training sites are too limited (novel approach)
  - Success/Failure map development
    - Visualization of cost/benefit
      - Couples a heat-in-place model with
        a business model for each play identified
  - Ancillary data for GIS overlays
    - ASTER analysis (10 images)
      - Nighttime ground temperatures
      - Mineralogy (hard or soft, EGS implication)
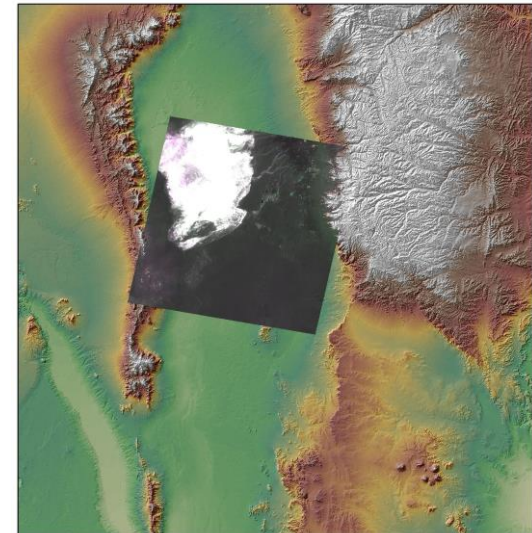
Example ASTER mineralogy: white = gypsum, pink = clay

[1]Moghaddam, M. K., Y. Noorollahi, F. Samadzadegan, M. A. Sharifi, and R. Itoi, 2013: Spatial data analysis for exploration of regional scale geothermal resources, *Geothermics*, Elsevier, p. 69–83.

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- Project design (cont.)
  - Milestones are well planned and organized. Milestones 1-3 have been met and project is ahead of schedule.

  - Scientific rigor lies in (1) PFA geothermal adaptation, (2) development of best practices in GIS data processing to facilitate accurate PFA and (3) comparison/contrast of knowledge-based and data-driven techniques <u>which has never been done before.</u>

  - The current key issues are adding additional data to the database, creating two final PFA models, and developing the success/failure ratio map (cost/benefit).

  - The approach has been executed to the level that petroleum industry PFA logic has been tested and a <u>preliminary basin-wide PFA has been completed</u>.

- ## Data Collection (Milestone 1 Completed)

  – ### Exhaustive literature review

  – ### Data extracted from digital databases

  – ### Stakeholders meetings yielded significant data results

  – ### Data collected to date:

  Heat flow, temperature gradients, water chemistry, volcanic ages, Quaternary faults, Bouguer gravity data, total magnetic intensity, ASTER multispectral imagery, 10m DEM, shaded relief, earthquakes, top of ground water, wells, Pleistocene Lake Ortero shoreline, digital geologic map.

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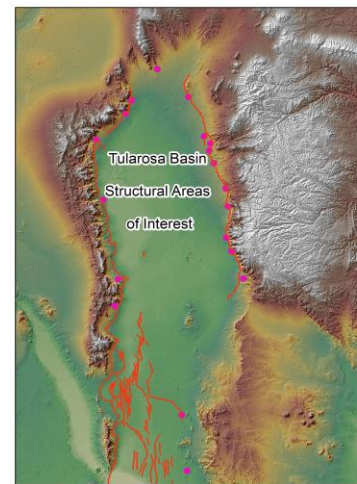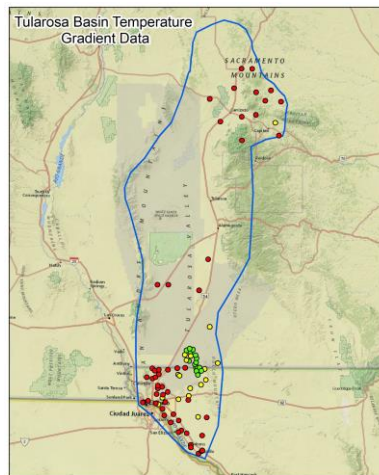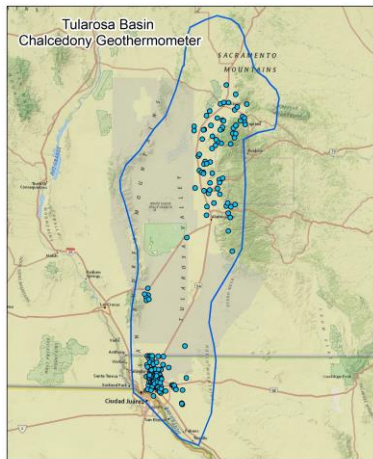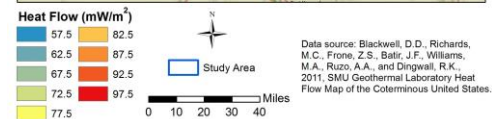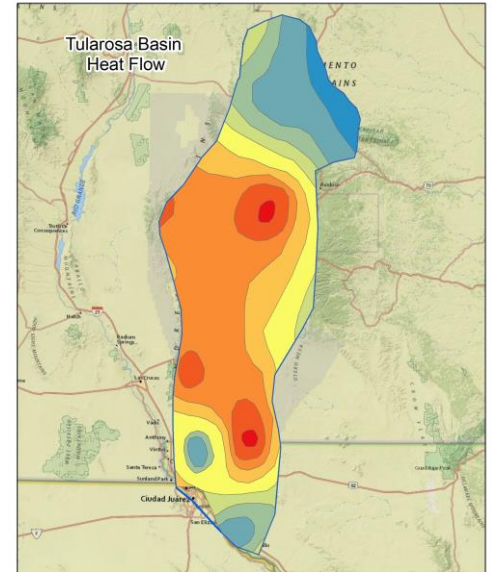
- **GIS Data Integration (Milestone 2 Completed)**
    - All data integrated into the GIS database

- **Data Processing and Analysis (Milestone 3 Completed)**
    - Preliminary Composite Risk Segments (CRS)
        – Heat of the Earth (heat flow, temperature gradients & geothermometers, potential fault-fracture permeability, fluid for heat transfer

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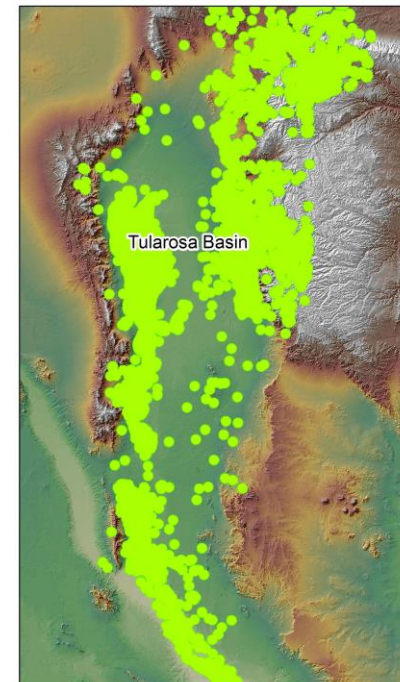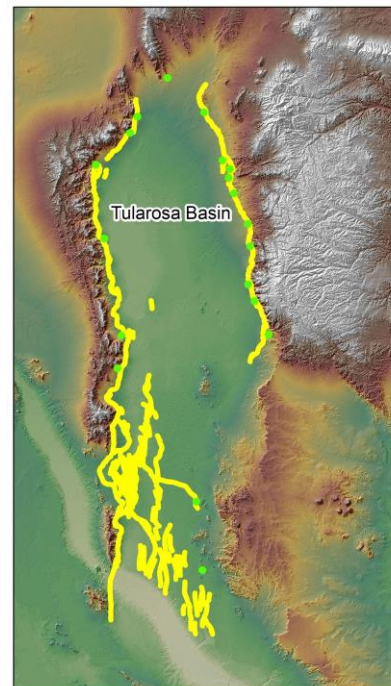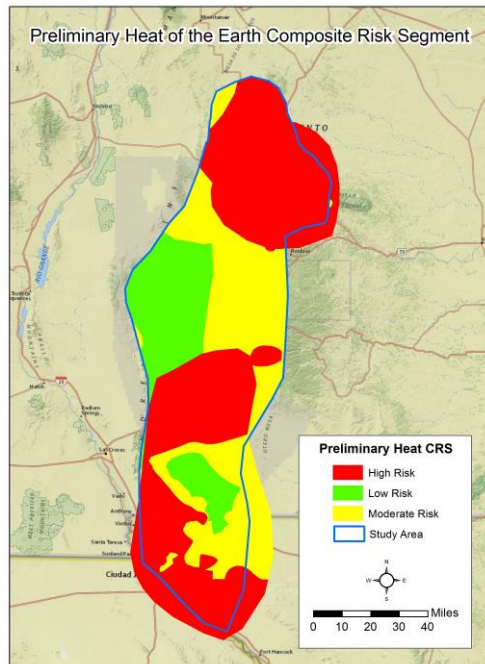
- ## Preliminary basin-wide PFA completed

  - Tested petroleum industry methodology

  - Five plays identified to date

    – 3 at White Sands Missile Range

    – 2 on Fort Bliss

    – Bliss' Davis Dome area with high certainty

    – Facilitated initiation of first success/failure study

  – Additional recently acquired temperature gradient and water chemistry data from Fort Bliss, White Sands, Holloman AFB and Alamogordo Utilities

    - Methodology now in place

    - New data can be quickly added to the GIS and updated models created
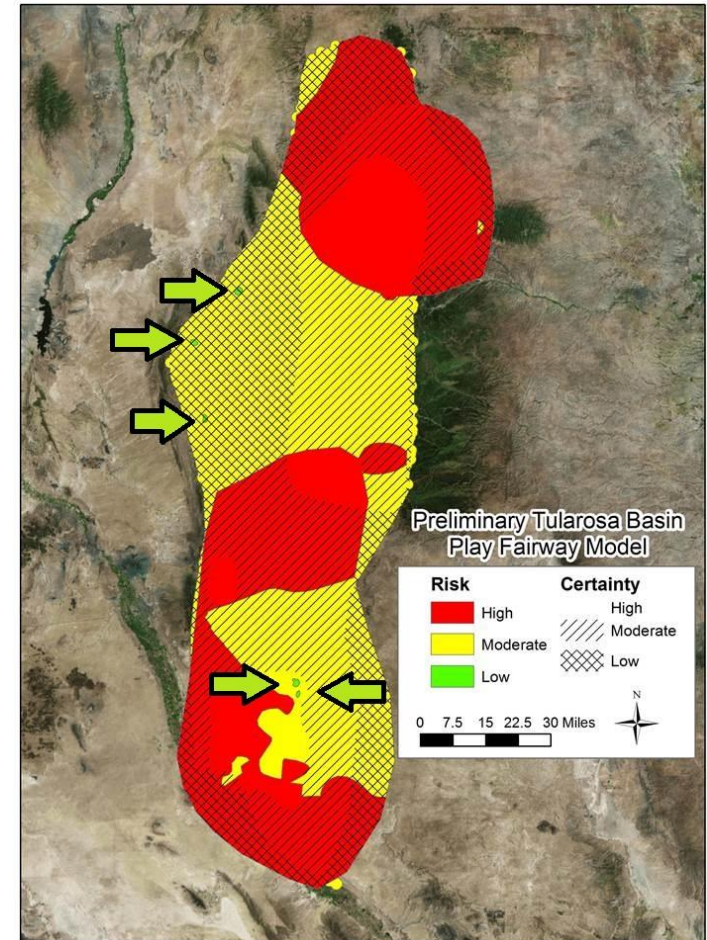
Image Above: Five "Low Risk" Plays identified on military lands in preliminary model. More data coming.

Accomplishments, Results and Progress

Original Planned Milestone/ Technical Accomplishment	Actual Milestone/Technical Accomplishment	Date Completed
1. Data collection	Completion of initial data collection	Dec. 31, 2014
2. GIS data integration	Completion of GIS data integration	February 15, 2015
3. Data processing and analysis	Completion of data processing and analysis for preliminary model development	March 20, 2015

Future Directions

- A complete water chemistry analysis

- More structural analyses to raise certainty of structural areas of interest
  - Review paleotectonics
  - Distribution of stress
  - Additional geophysical data interpretation
  - Geomorphometrics

- Weights of Evidence PFA will be completed

- Final petroleum industry type PFA will be completed
  - Results will be compared and contrasted

- Success/Failure modeling for each identified play
  - Success/failure map and generalized economic analysis will be produced for GIS overlay

- Market transformation will be initiated by:
  - GRC paper and presentation (paper submitted for the 2015 Annual Meeting);
  - Presentation of final PFA models to ALL key stakeholders en masse (military, utilities, municipalities & academia); and,
  - Final model results posted on EGI's "Ask EGI" website with distribution to 65 energy companies.

Future Directions

- In future phases, further market transformation can be completed by concentrated outreach to DoD end user community and industry:

  – Follow-up meetings with key DoD Energy Managers and DoD officials

  – Targeted outreach to industry

  – Publication of results in high-visibility, scientific, peer-reviewed journals

  – Publication of results via DOE/DoD Outreach Network

  – Presentations at appropriate technical conferences including: Defense Energy Summit and Innovation Showcase, the National Defense Industry Association Conference, Army Net Zero Conferences and other market transformation symposia

  – Additional areas being identified to further our PFA methodology

Mandatory Summary Slide

✓ Data collection efforts exceeded expectations

✓ Individual outreach to key stakeholders yielding significant results

✓ Project team has determined there is a regional interest in geothermal development & significant interest in project

✓ Extensive geothermal exploration database developed

✓ All project activity is on, or ahead of, schedule

✓ Project is exceeding cost sharing targets

✓ The knowledge-based PFA methodology has been developed and applied to the Tularosa Basin

✓ Additional incoming data will upgrade the certainty of model results

Chance of project success is extremely high -
Preliminary PFA model already showing promise.