In-Situ MVA of CO2 Sequestration Using Smart Field Technology

Shahab D. Mohaghegh
Petroleum & Natural Gas Engineering
West Virginia University

DOE Project Manager: Justin Glier

Outline

- Project Objective
- Relevance
- Available Monitoring Methods
- Smart Fields
- In-situ Monitoring, Verification and Accounting in smart fields.
- Project task breakdown
- Current stage of the project

Project Objective

- Detecting the location and amount of leakage from the CO_2 storage sites at the reservoir level.

- Use smart oil field technology to accomplish the above task.
  - Permanent Downhohe Gauges (PDG)
  - Pattern Recognition capabilities of Artificial Intelligence & Data Mining (AI&DM).

Relevance

- Leakage (most probably) will occur from very small conduits (wellbore – inches) within very large fields (hundreds to hundreds of thousands of acres).

- Being able to identify the approximate location and amount of a potential leak (preferably before it shows up on the surface at large scales) can be useful for intervention.

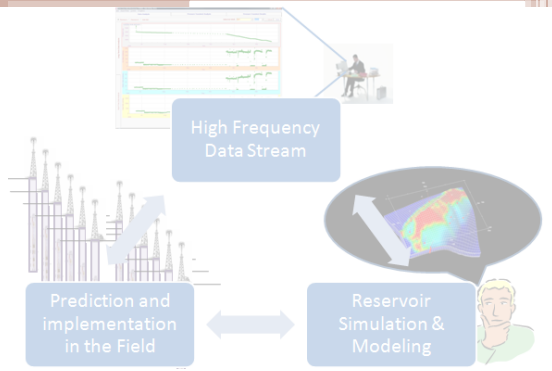
Monitoring Methods

- Near Surface Monitoring
  - Time-laps gravity survey
  - Vegetative stress
  - Groundwater monitoring
  - Soil and vadoze zone gas monitoring
  - Remote sensing
  - Land/Surface deformation

Monitoring Methods

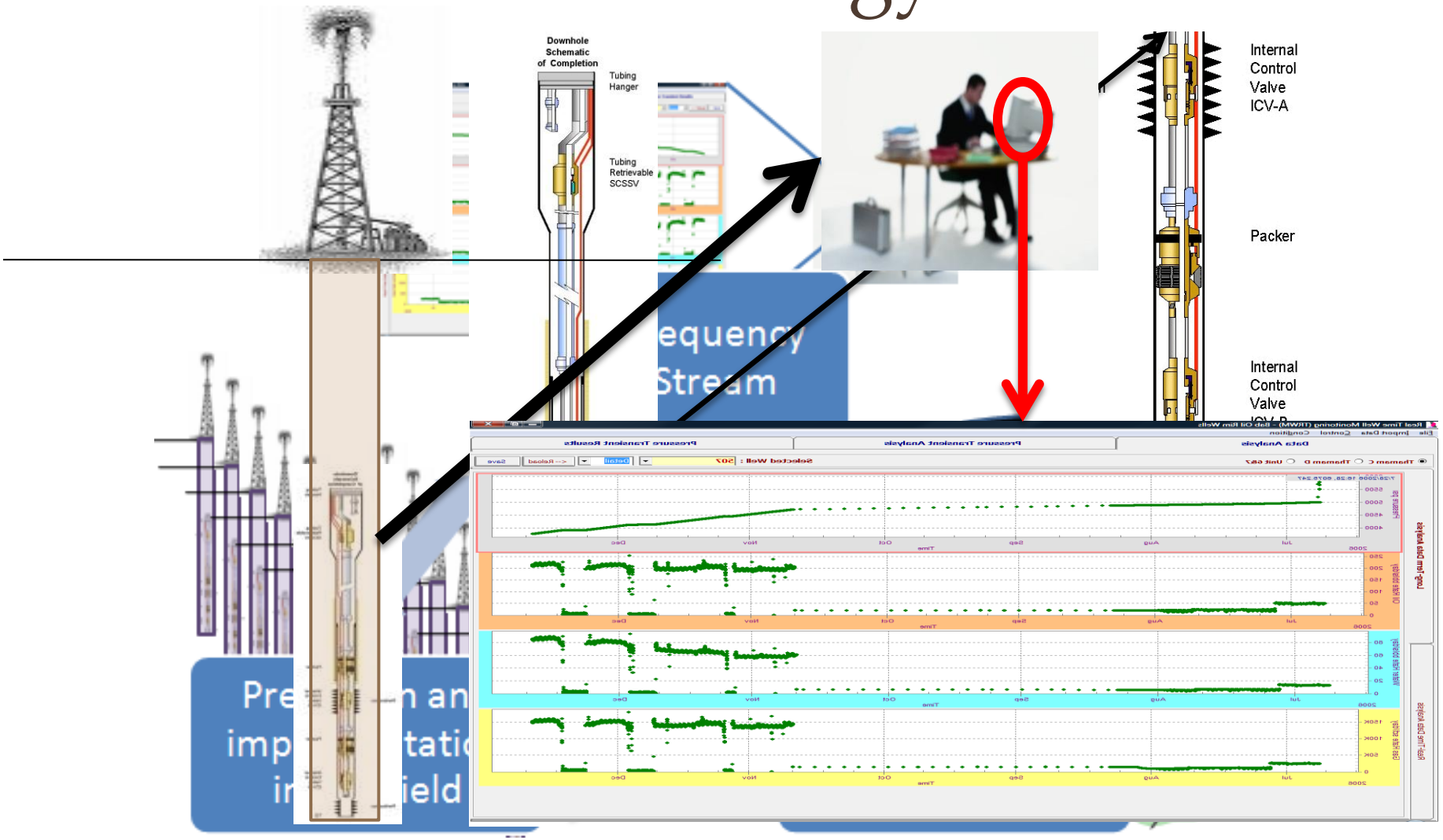
- Sub Surface Monitoring
  - VSP : Vertical Seismic Profiles
  - Passive Seismic monitoring
  - Wire-line logging
  - Pressure Monitoring
  - Gravity Survey
    - CO_2 movement in and above storage formation
    - Mass balance in subsurface
  - Time-lapse 3D Seismic Survey
    - Distribution of CO_2
    - Leakage through faults and fractures
  - Cross-well Survey and seismic imaging
  - Introduced and natural tracers
    - Movement of CO_2 in the storage formation
    - Quantifying solubility trapping
    - Tracing leakage

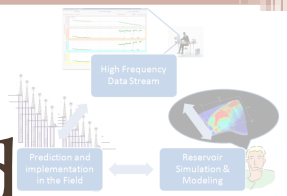
Smart Field Technology



- Smart field technology includes Permanent Downhole Gauges (PDG).
- PDGs monitor the pressure changes in the formation and transmit high frequency-high resolution data streams to the surface, in real-time.
- Pressure changes in the reservoir are indications of fluid flow in the formation which during the **post-injection** time-frame are indicators of a potential leakage in the system.

Smart Field Technology

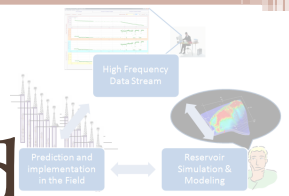




In-Situ Monitoring, Verification and Accounting in Smart fields

- Pressure changes detected by multiple PDGs carries information regarding the location and amount (rate) of the leakage.

- The complex and highly convoluted real-time data transmitted by multiple PDGs is cleansed, summarized, processed and modeled.



In-Situ Monitoring, Verification and Accounting in Smart fields

- Deconvolution of the signals will help identify the approximate location and amount (rate) of the leakage.

- Pattern recognition capabilities of Artificial Intelligence and Data Mining (AI&DM) technology is used as a tool for deconvolution of the high-frequency pressure signals.

Project Tasks

- Task 1- Program management and reporting:
  - An advisory committee to be formed to provide industrial insight to the project.
    - Battelle
    - Consol
    - Schlumberger
    - Advance Resources International
    - U.S. Department of Energy, NETL

Project Tasks

- Task 2- Site Selection:
  - 2.1: Developing Site Selection Criteria
  - 2.2: Selecting a Site

Project Tasks

- Task 3- Data Collection, Base Model Construction:
  - 3.1: Selection of Reservoir Modeling Software
  - 3.2: Data Collection
  - 3.3: Developing Geological Model
  - 3.4: Upscaling the Geological Model
  - 3.5: Developing the Base Model

Project Tasks

- Task 4- CO_2 Injection & History Matching:
  - 4.1: Data Collection on CO_2 Injection
  - 4.2: History Matching CO_2 Injection

Project Tasks

- Task 5- Simulating CO_2 Leakage:
  - 5.1: Modeling CO_2 leakage (abandoned wells – unknown locations)
  - 5.2: Modeling high frequency data stream and its transmission to the remote office.

Project Tasks

- Task 6- Handling High Frequency Data:
  - 6.1: Developing techniques for real-time, high-frequency data processing:
    - Data Cleansing
    - Data Summarization
  - 6.2: Data preparation for modeling and pattern recognition.

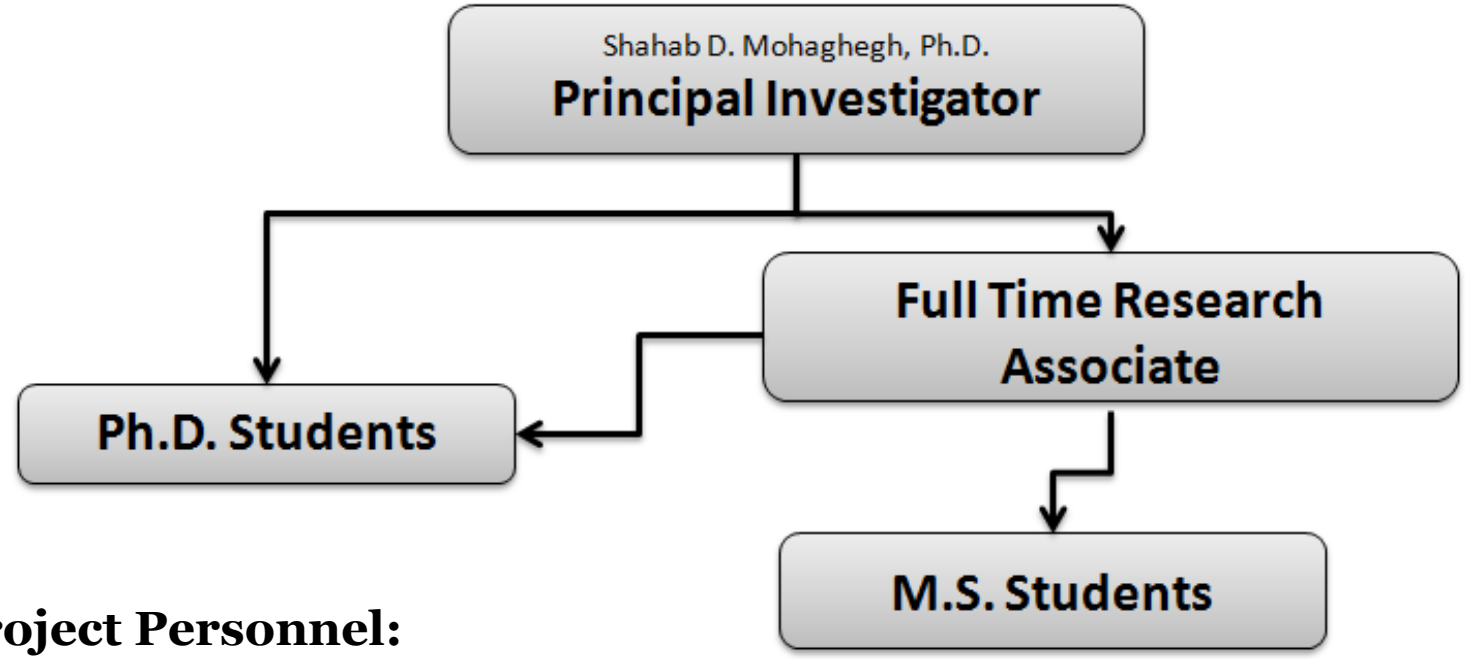
Project Tasks

- Task 7- Pattern Recognition Analysis:
  - 7.1: Key Performance Indicators (KPI).
  - 7.2: Data partitioning
  - 7.3: Neural Network architecture design
  - 7.4: Neural Network training and calibration
  - 7.5: Neural Network validation
  - 7.6: Neural Network model analysis

Project Tasks

- Task 8- CO_2 Leak Detection in Homogeneous Reservoir.
- Task 9- CO_2 Leak Detection in Heterogeneous Reservoir (the selected test site).
- Task 10- Building an Interface.

Project Personnel



Project Personnel:
Shahab D. Mohaghegh
Yasaman Khazaeni
Rubai Zhao
Abdullahi Yusuf
Two more graduate students

Milestone Log

	Title	Description	Related task or subtask	Completion Date	Validation Technique and Milestone Progress
Budget Period 1:					
Milestone 1.1	Advisory Board Meeting	Advisory board should get together for a meeting (or conference call) to select a site for the project.	Subtask 2.1	End of First Quarter	Meeting minutes received by Project Manager
Milestone 1.2	Site Selection	A site must be selected for the project.	Subtask 2.2, 2.3	End of Second Quarter	E-mail confirmation of site sent to PM.
Milestone 2.1	Data collection	Completion of geologic and production data collection	Subtask 3.2	End of Third Quarter	Memo regarding data type and extent received by Project Manager
Milestone 2.2	Completion of geological model	Completion of geologic/geo-cellular model	Subtask 3.3	End of Fourth Quarter	Memo received by Project Manager
Milestone 2.3	Completion of the base model	Completion and testing the base flow model	Subtask 3.6	End of Fifth Quarter	Quarterly Technical Report
Milestone 3	CO_2 Injection Modeling	Completion of modeling the CO_2 injection.	Subtask 4.3	End of Sixth Quarter	Technology progress report received by Project Manager (included in Continuation Application).
Budget Period 2:					
Milestone 4.1	CO_2 Leakage Modeling	Model realistic CO_2 leakage from the formation	Subtask 5.1	End of Seventh Quarter	E-mail received by PM
Milestone 4.2	Downhole pressure modeling	Model realistic real-time downhole pressure measurements.	Subtask 5.2, 5.3, 5.4	End of Eighth Quarter	E-mail following successful demonstration of model to PM held at WVU
Milestone 5	Handling High Frequency Data	Developing techniques for handling high frequency data	Subtask 6.1, 6.2, 6.3	End of Ninth Quarter	Topical report received by PM
Milestone 6	Pattern recognition	Completing pattern recognition analysis	Subtask 7.1, 7.2, 7.3, 7.4, 7.5, 7.6	End of Tenth Quarter	Memo regarding recognition analysis received by PM
Milestone 7	Application to Homogeneous system	Completing of analysis and application to Homogeneous system	Task 8	End of Eleventh Quarter	Progress report received by PM
Milestone 8	Application to Heterogeneous system	Completing of analysis and application to Heterogeneous system	Task 9	End of Twelfth Quarter	Topical Report received by PM
Milestone 9	Build Program Interface	Completion of Software Package	Task 10	End of Twelfth Quarter	Software Package delivered to PM

Project Timeline

Task Title	Project Tasks	Budget Period 1						Budget Period 2					
		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
Program Managemetn	Task One												
Site Slection	Task Two												
	2.1												
	2.2												
	2.3												
Base Model Developemnt	Task Three												
	3.1												
	3.2												
	3.3												
	3.4												
	3.5												
	3.6												
History Matching	Task Four												
	4.1												
	4.2												
	4.3												
CO2Leakage Modeling	Task Five												
	5.1												
	5.2												
	5.3												
	5.4												
High Frequency Data Handling	Task Six												
	6.1												
	6.2												
	6.3												
Pattern Recognition Analysis	Task Seven												
	7.1												
	7.2												
	7.3												
	7.4												
	7.5												
	7.6												
Application to Homogenous System	Task Eight												
Application to Heterogenuous Reservoir	Task Nine												
Interface Development	Task Ten												

Current Stage of the Project

- Task 1 - Program management and reporting
  - This task is completed, advisory committee is formed and has had meetings and conference calls during the first quarter of the project.
- Task 2 - Site Selection
  - Two main candidate sites are selected.
    - Citronelle – Rodessa Formation, operated by Denburry.
    - Mattoon – Mt. Simon Formation, operated by FutureGen.

Current Stage of the Project

- Task 3 - Data Collection and Base Model Construction
  - Available data has been collected for both sites.
    - Citronelle:
      - A base model in CMG/GEM is collected from ARI.
        - one gas injection well,
        - 9000 Acre area
        - 51 layers
        - Homogenous characteristics.
      - A set of formation tops in power point pictures format are also collected from ARI.
      - Production history from 1959 is available in Alabama geological survey for over 600 wells.

Current Stage of the Project

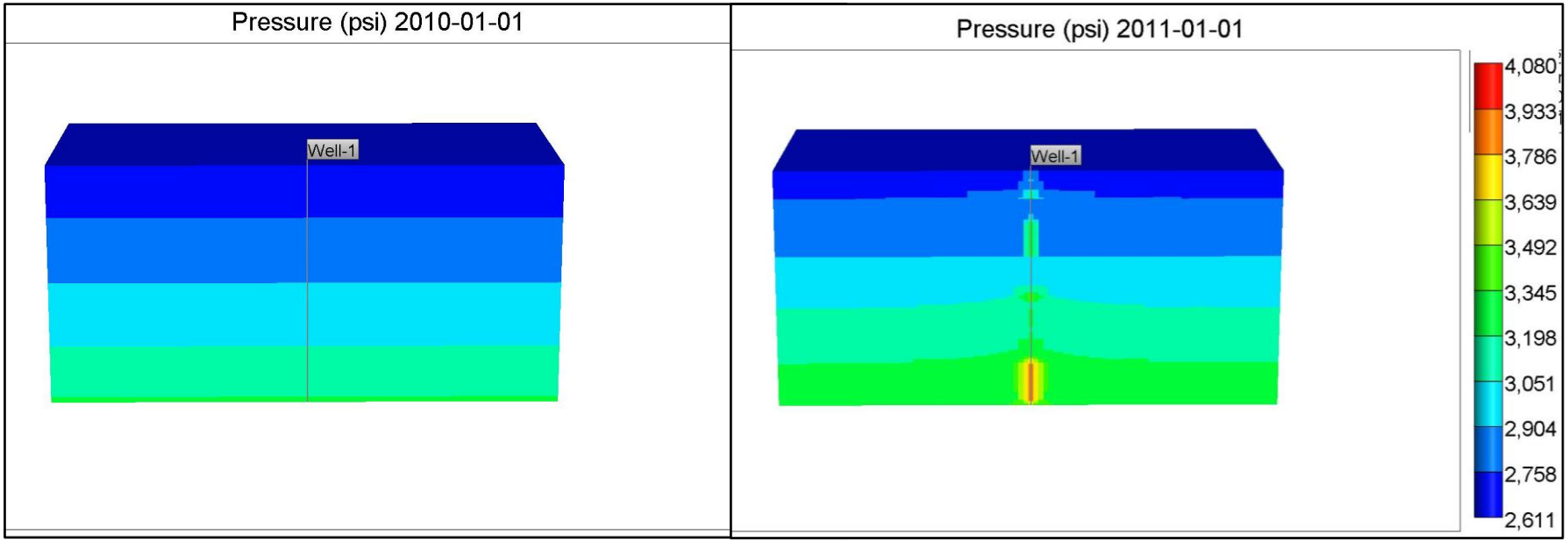
- Task 3 - Data Collection and Base Model Construction
  - Available data has been collected for both sites.
    - Mattoon:
      - Formation top markers and porosity -Permeability log for a 53 layer structure is collected for weabor-horn well which is close to Mattoon site. (Permeability is based on a correlation)
      - This data is mapped and adjusted for the Mattoon site location.

Current Stage of the Project

- Task 3 - Data Collection and Base Model Construction
  - Mattoon
    - A base model is built in CMG/GEM using the available information.
    - CO_2 injection is performed for one year.

Current Stage of the Project

- Task 3 - Data Collection and Base Model Construction
  - Mattoon



Current Stage of the Project

- Task 3 - Data Collection and Base Model Construction
  - Mattoon