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Critical Challenges.
Practical Solutions.

Energy & Environmental Research Center (EERC)

DEVELOPMENT OF INTELLIGENT MONITORING SYSTEM (IMS) MODULES FOR THE AQUISTORE CO_2 STORAGE PROJECT

Nicholas Azzolina

Principal Hydrogeologist and Statistician

U.S. Department of Energy

National Energy Technology Laboratory

Mastering the Subsurface Through Technology Innovation, Partnerships and Collaboration:
Carbon Storage and Oil and Natural Gas Technologies Review Meeting

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PRESENTATION OUTLINE

- Project objectives
- Technical status
  - Data workflow
  - IMS modules
  - IMS graphical user interface (GUI)
- Accomplishments to date
- Lessons learned
- Synergy opportunities
- Project summary

PROJECT OBJECTIVES

- Develop new workflows, algorithms, and a user interface which will automate the integration of CO_2 storage site-monitoring and simulation data as part of an IMS.
- Integrate continuous monitoring measurements (such as pressure, temperature, and injection rate), periodic monitoring measurements (such as seismic, well logs, and gravity surveys), and reservoir simulations with algorithms for visualization and real-time decision-making support.
- Develop a GUI that will allow a carbon capture and storage (CCS) site operator to more efficiently monitor and manage CO_2 injection and subsurface conditions.

TECHNICAL STATUS

2) IMS Module Development

2.1) Workflow Design

2.2) Data-Preprocessing Design

2.3) Seismic Data Integration

2.4) History Match Automation

2.5) Integration and Automation Testing

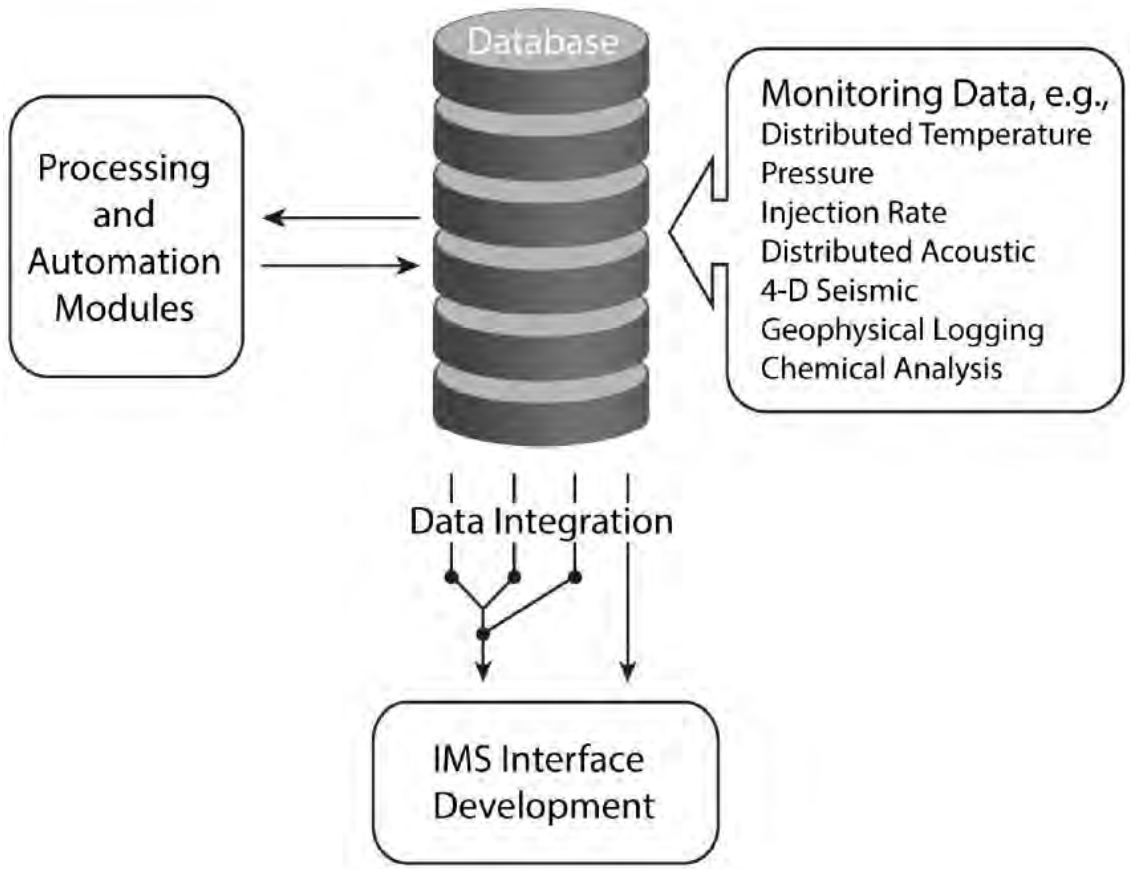
3) IMS Architecture Development

3.1) Database Development

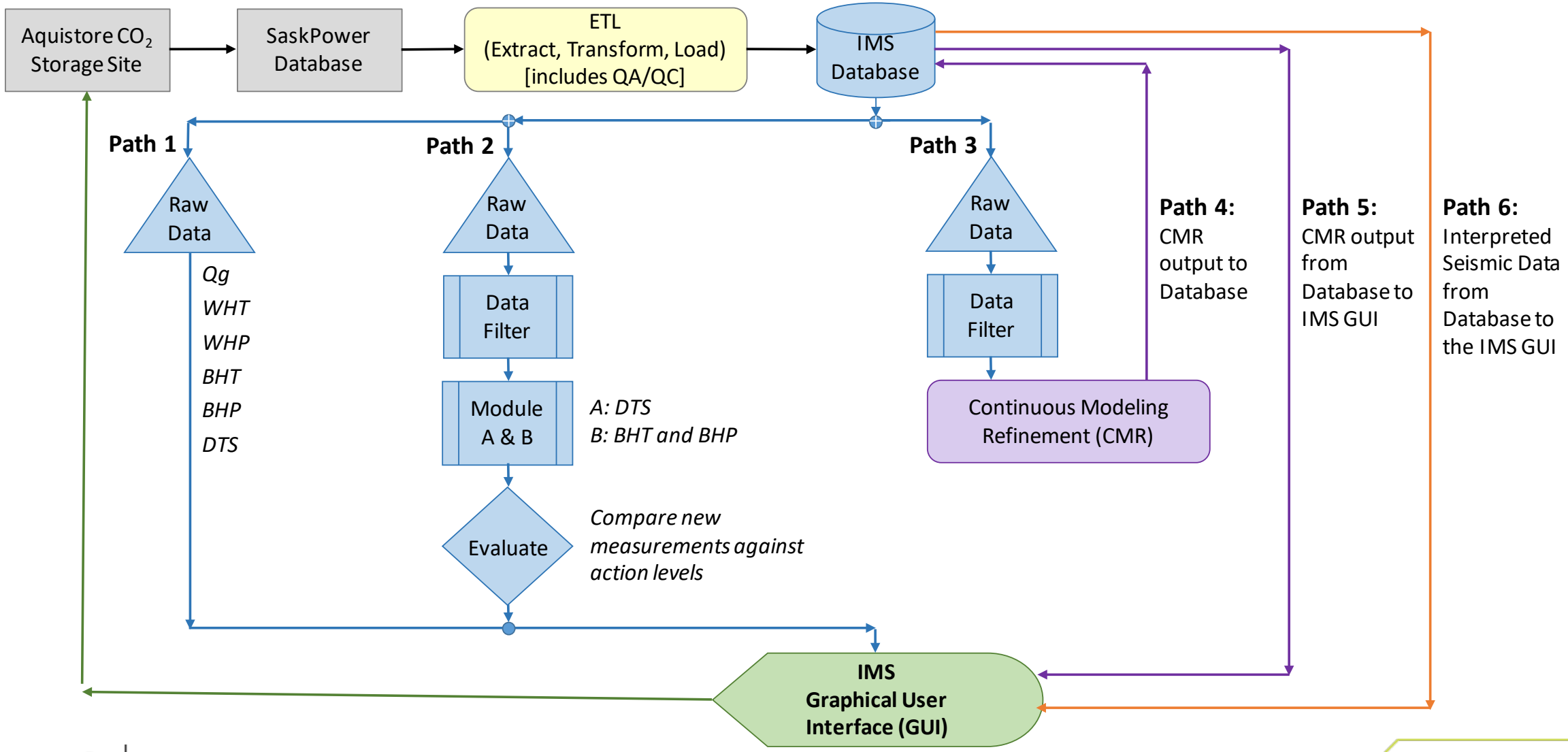
3.2) Data Integration

3.3) IMS Interface Development

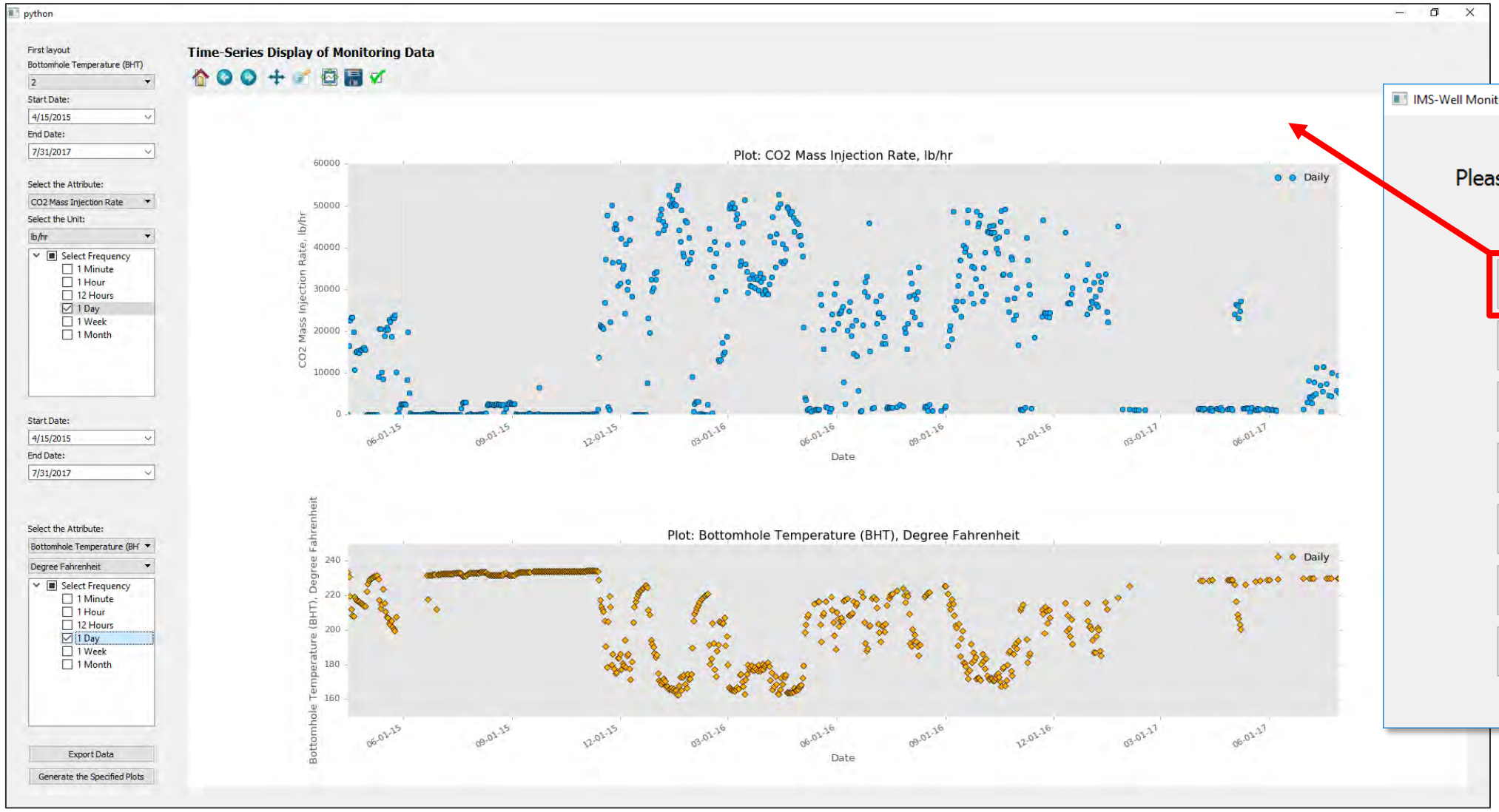
3.4) Process and System Testing

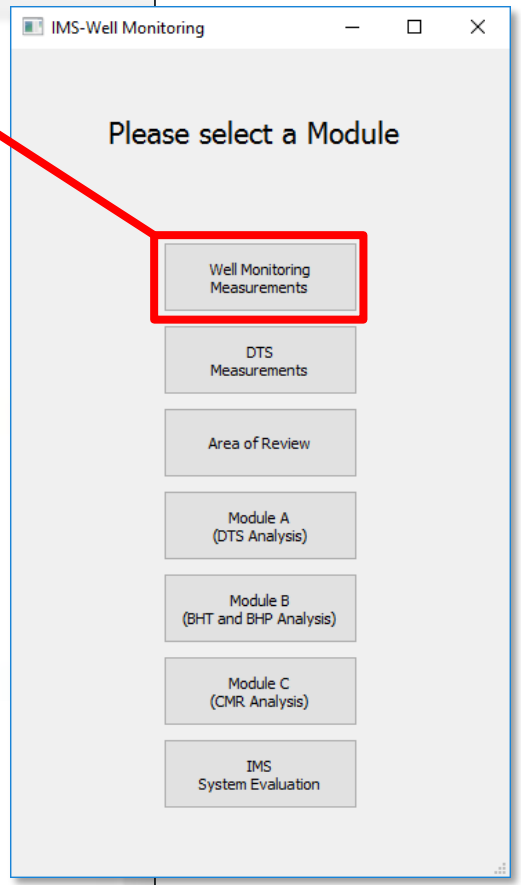


IMS DATA WORKFLOW



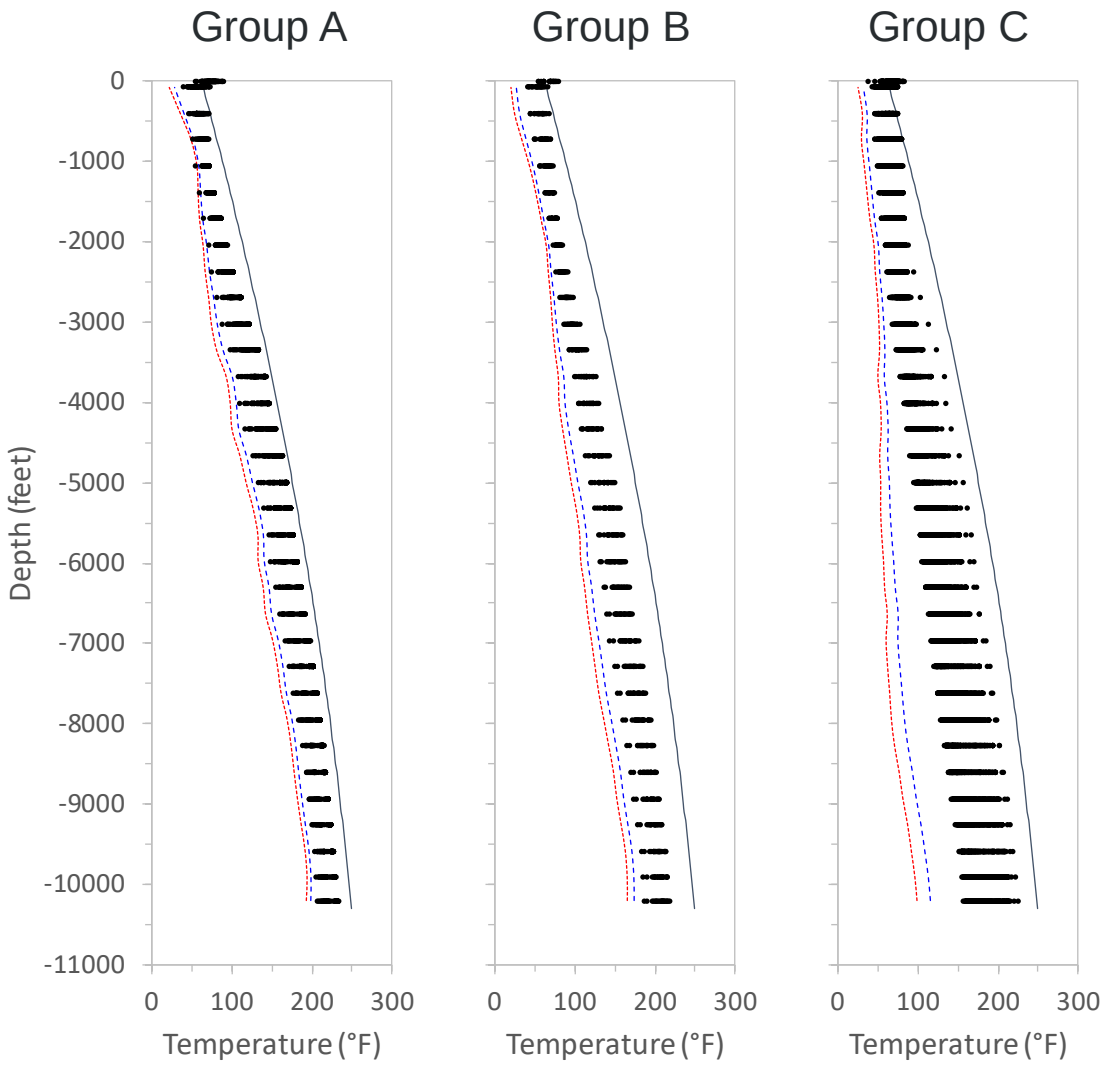
IMS PATH 1: RAW INJECTION WELL DATA



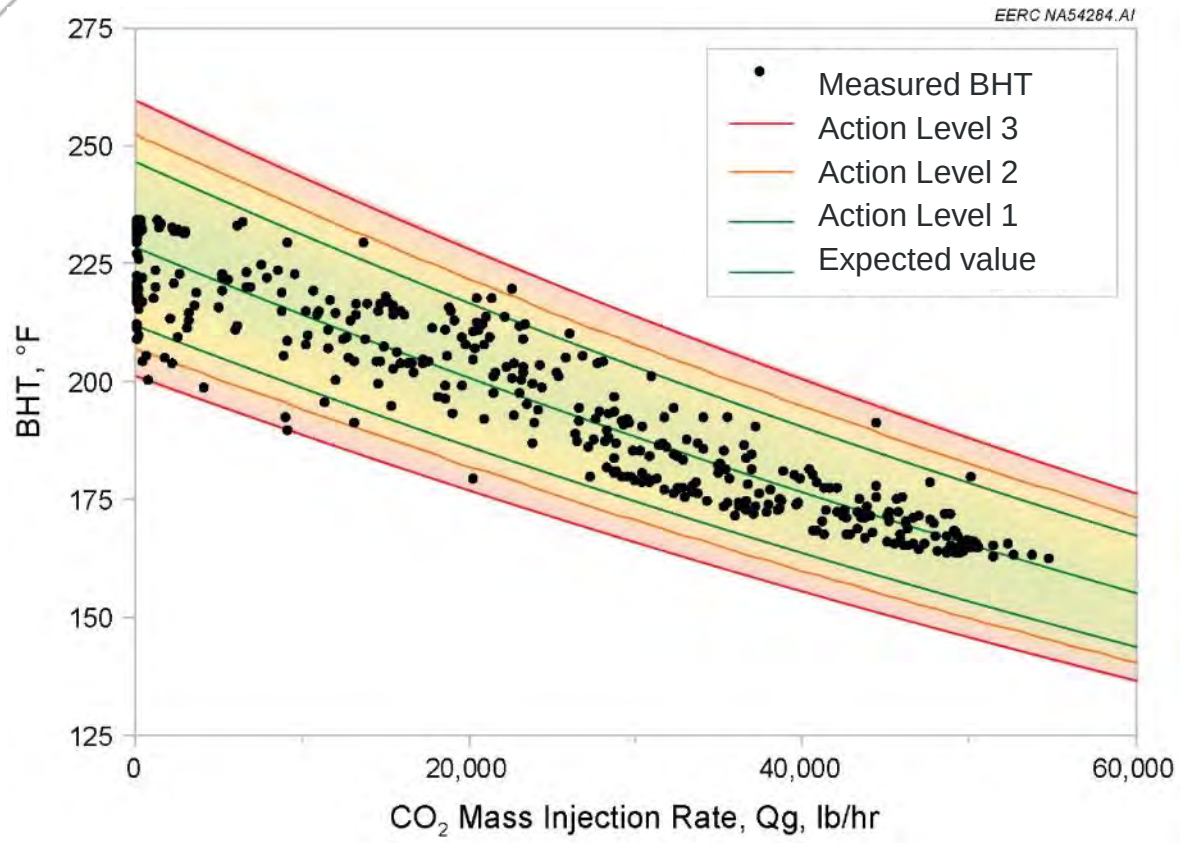


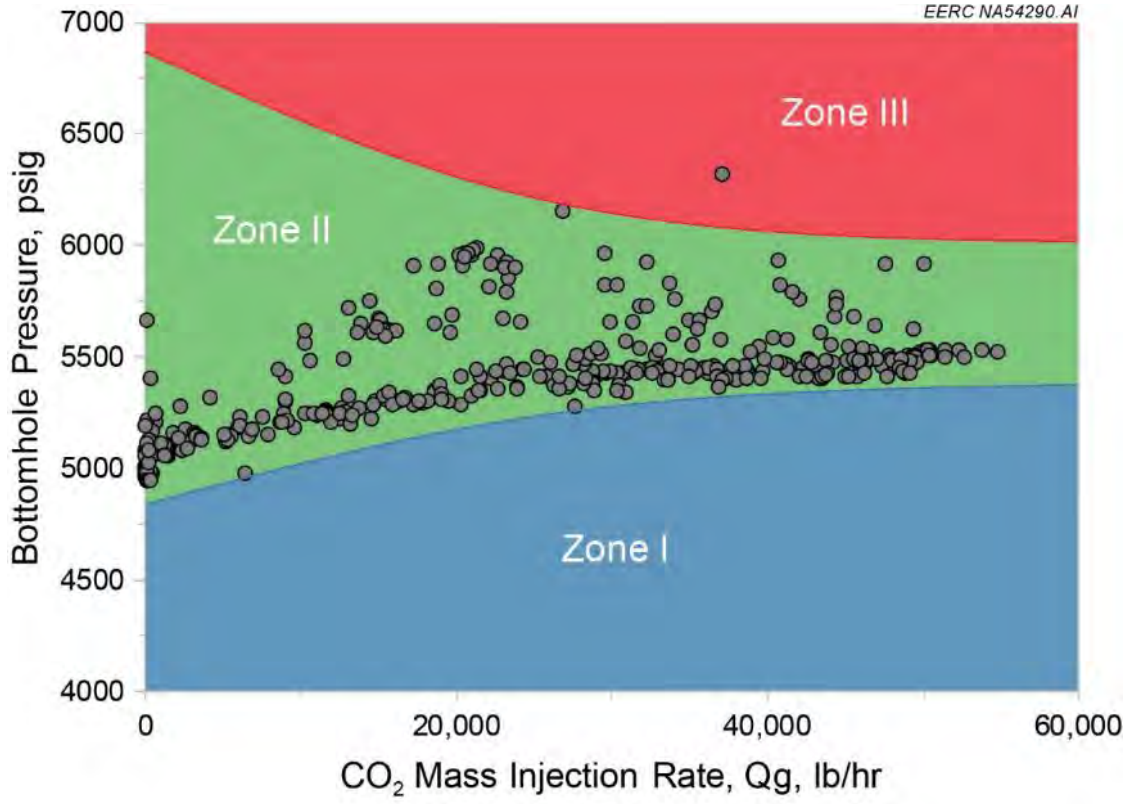
IMS PATH 2: MODULE A – DTS TEMPERATURE PROFILES

- Developed statistical action levels for
  - Module A: DTS temperature profiles
  - Module B: BHT and BHP measurements
- ***Action levels*** are threshold values that are used to detect exceedances of normal operating limits.



IMS PATH 2: MODULE B – BHT AND BHP



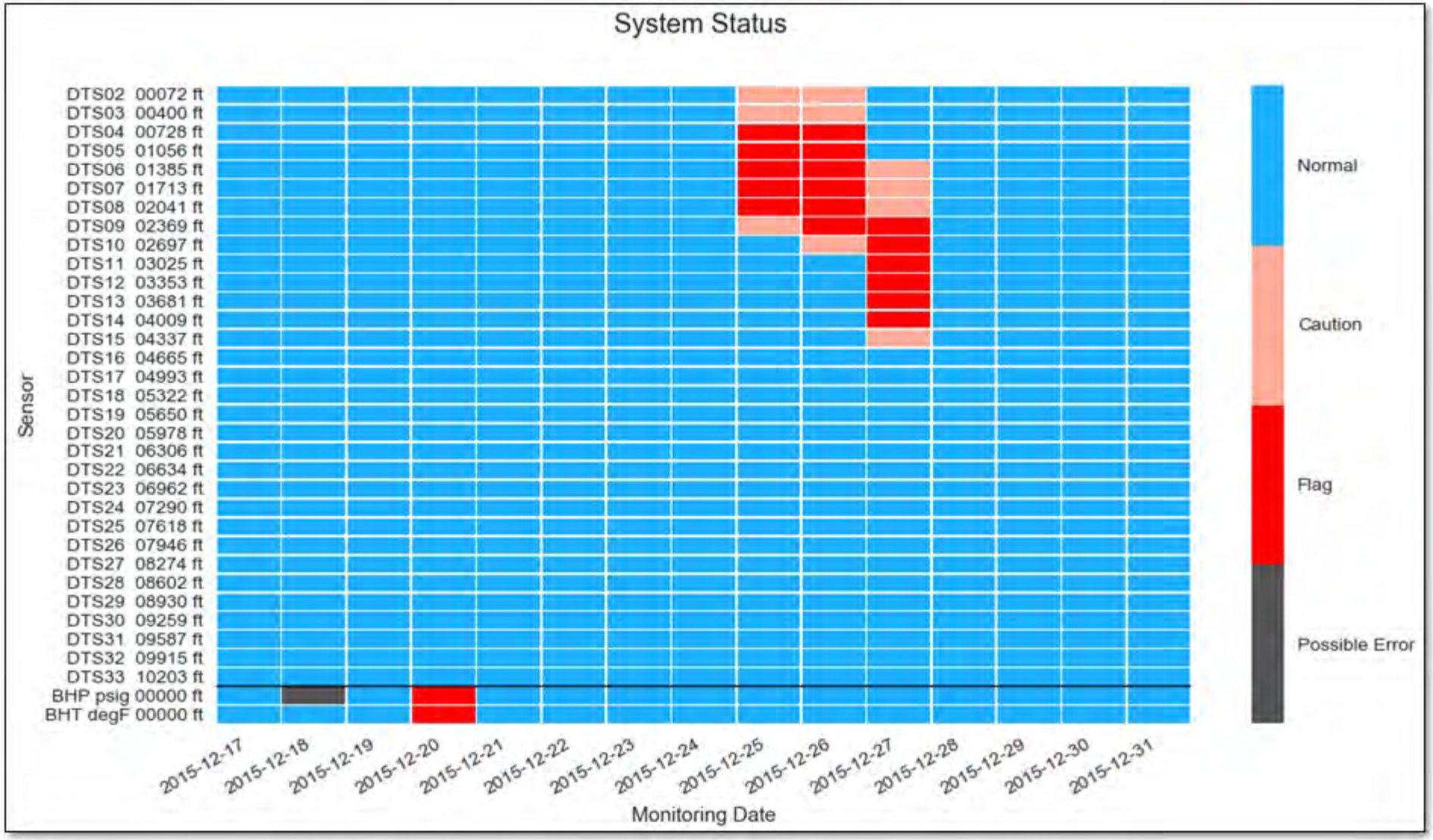


IMS PATH 3: MODULE C – CMR

- Seismic data are collected periodically, and therefore represent lower acquisition frequency (LAF) data.
- Treatment of these LAF-data occurs through a separate CMR module.
- The CMR module utilizes a two-step procedure using a reduced surrogate model and full simulation model to generate one of four potential outcomes.

Action Level Rank	Description	Details
1	Low	Rapid convergence
2	Low to Medium	Additional iterations required
3	Medium to High	Significant additional iterations required
4	High	Failure to converge

SYSTEM EVALUATION MODULE



ACCOMPLISHMENTS TO DATE

Completed

- M01: Project kickoff meeting
- M02: Initial database schema
- M03: Data preprocessing design
- M04: 3-D seismic algorithm
- M05: Draft data integration algorithm
- M06: Initial GUI design
- M07: Shot record plume tracking tested
- M08: Design of history match automation
- M09: Updated database schema
- M10: GUI coding
- M11: Initial automation testing

Completed (cont.)

- M12: Full system testing
- D01: Updated project management plan
- D02: Data submission to EDX (#1 and #2)
- D03: Shot record plume tracking
- D04: Data integration and risk profiling

In Progress

- M13: Process and system testing
- D02: Data submission to EDX (#3)
- D05: Final technical report

LESSONS LEARNED

- **Research difficulty:**
  - Time delays associated with acquiring repeat logging or seismic measurements
    - Automated history matching may still experience the associated time delay from the periodic data acquisition and time required for processing and interpretation. The permanent seismic array was not functioning as expected during the period of performance.
- **Research difficulty:**
  - Attributing causation given one or more monitoring measurements
    - Populating conditional probability tables for a Bayesian network require extensive simulations of the wellbore and formation, including different failure modes and magnitudes.
- **Research gap:**
  - Modeling of intermittent CO_2 injection cycle and resultant injectivity changes
    - Need to adapt existing analytical and semianalytical models to account for transient effects.

SYNERGY OPPORTUNITIES

- **Potential leverage on advanced techniques for:**
  - Data integration and assimilation.
  - Data analytics and automated learning.
  - Closed-loop reservoir management and robust optimization techniques.
- **Collaboration with other R&D projects**
  - Field testing of emerging technologies
- **Broad applicability for commercial or demonstration projects**
  - Tools and workflows could be applied in any CO_2 storage project to effectively monitor an active injection site in real time.

PROJECT SUMMARY

- **Successfully developed new workflows and algorithms designed to:**
  - Handle real-time monitoring data from the SaskPower database for the Aquistore site.
  - Store and handle information in a secure database.
  - Perform data-preprocessing linked to an automated history match.
  - Integrate continuous and periodic data into automated history match.
  - Utilize the continuous monitoring data to model and predict bottomhole conditions in real time.
  - Establish threshold decision criteria (action levels) for real-time decision support.
- **Next steps:**
  - Complete the process and system testing
  - Finalize the IMS GUI
  - Complete the final technical report

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CONTACT INFORMATION

Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

www.undeerc.org
701.777.5120 (phone)
701.777.5181 (fax)

Nicholas A. Azzolina
Principal Hydrogeologist & Statistician
nazzolina@undeerc.org


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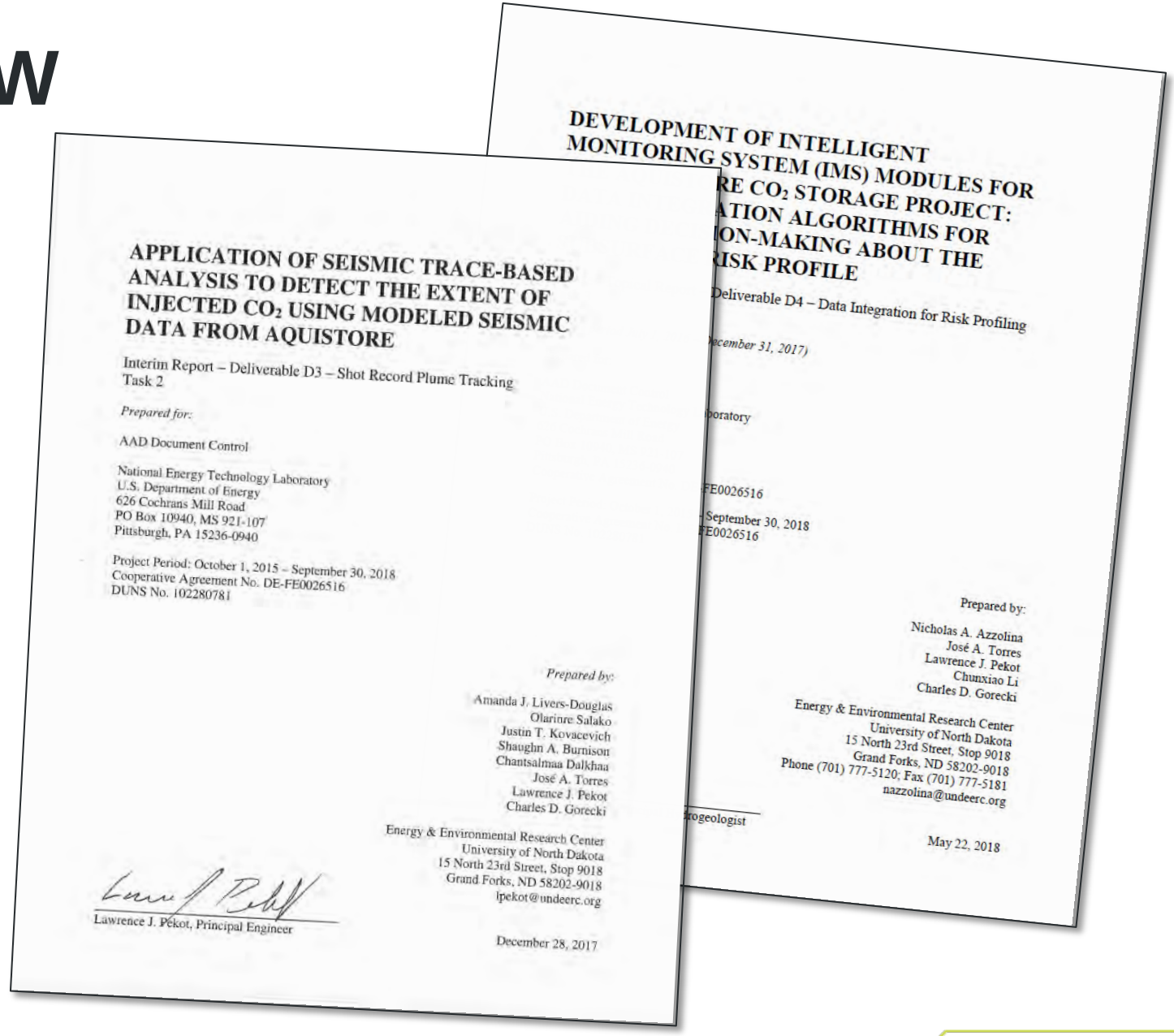
APPENDIX

APPENDIX OVERVIEW

- Benefits to the program
- Project overview
  - Goals
  - Objectives
  - Task structure
  - Milestones and deliverables
  - Success criteria
- Organization chart
- Gantt chart
- Bibliography
- Acknowledgments
- Contact information



APPLICATION OF SEISMIC TRACE-BASED ANALYSIS TO DETECT THE EXTENT OF INJECTED CO_2 USING MODELED SEISMIC DATA FROM AQUISTORE

Interim Report – Deliverable D3 – Shot Record Plume Tracking
Task 2

Prepared for:

AAD Document Control

National Energy Technology Laboratory
U.S. Department of Energy
626 Cochrans Mill Road
PO Box 10940, MS 921-107
Pittsburgh, PA 15236-0940

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Prepared by:

Amanda J. Livers-Douglas
Olarinre Salako
Justin T. Kovacevich
Shaughn A. Burnison
Chantsalmaa Dalkhaa
José A. Torres
Lawrence J. Pekot
Charles D. Gorecki

Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018
lpekot@undeerc.org

Lawrence J. Pekot, Principal Engineer

December 28, 2017

DEVELOPMENT OF INTELLIGENT MONITORING SYSTEM (IMS) MODULES FOR RE CO_2 STORAGE PROJECT: ATION ALGORITHMS FOR ION-MAKING ABOUT THE RISK PROFILE

Deliverable D4 – Data Integration for Risk Profiling

ecember 31, 2017)

oratory

FE0026516

September 30, 2018
FE0026516

Prepared by:

Nicholas A. Azzolina
José A. Torres
Lawrence J. Pekot
Chunxiao Li
Charles D. Gorecki

Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018
Phone (701) 777-5120; Fax (701) 777-5181
nazzolina@undeerc.org

rogeologist

May 22, 2018

BENEFITS TO THE PROGRAM

- The Energy & Environmental Research Center (EERC) is conducting a 3-year project focused on developing new workflows, algorithms, and a user interface that will automate the integration of CO_2 storage site-monitoring and simulation data as part of an intelligent monitoring system (IMS) for the Aquistore CO_2 Storage Site in Saskatchewan, Canada.
- Compared with traditional manual processing, interpretation, and integration workflows, the IMS will allow a carbon capture and storage (CCS) site operator to more efficiently monitor and manage CO_2 injection and subsurface conditions.
- This technology contributes to the Carbon Storage Program goals of:
  - Developing and validating technologies to ensure for 99% CO_2 storage permanence.
  - Developing technologies to improve reservoir storage efficiency while ensuring containment effectiveness.
  - Developing best practice manuals (BPMs) for monitoring, verification, and accounting (MVA).

PROJECT OVERVIEW – GOALS

Develop and demonstrate software and workflows capable of:

1) Improving short- and long-term prediction of CO_2 saturations and reservoir pressure by using seismic and pressure data to reduce uncertainty of simulation predictions through iterative automated history matching.

2) Providing processing and integration of monitoring data and simulation results to allow the CO_2 storage site operator to more effectively monitor and manage operations and a site's evolving risk profile.

3) Providing decision support for improving storage performance and efficiency and/or reducing project risk through expedited response times and minimization of human error.

PROJECT OVERVIEW – OBJECTIVES

- Develop and demonstrate new real-time-data-capable workflows, algorithms, and a user interface which automate the integration of CO_2 storage site-monitoring and simulation data. The algorithms and workflows developed will integrate continuous monitoring data, periodic monitoring data, and reservoir simulations with algorithms for visualization and real-time decision-making support.
- Develop and test an automated history-matching workflow to improve short- and long-term prediction of the distribution of CO_2 saturations and reservoir pressure.
- Develop and test a technical user interface that will present the results for visualization and real-time decision support.
- Complete the IMS using monitoring data acquired at the Petroleum Technology Research Centre's (PTRC's) Aquistore CO_2 storage site near Estevan, Saskatchewan.

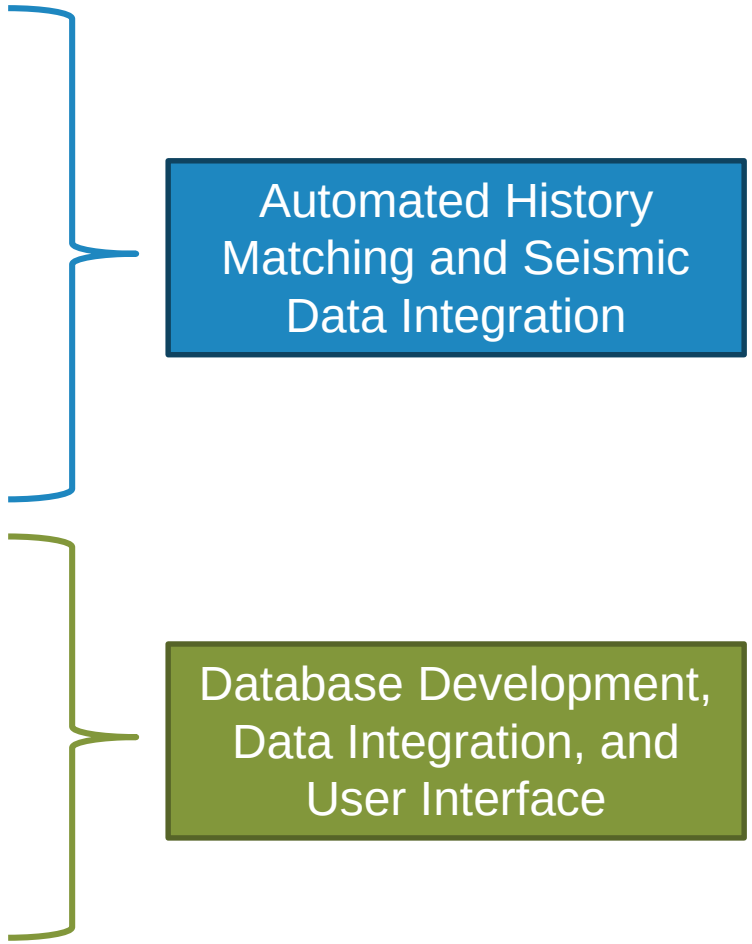
PROJECT OVERVIEW – TASK STRUCTURE

2) IMS Module Development

- 2.1) Workflow Design
- 2.2) Data-Preprocessing Design
- 2.3) Seismic Data Integration
- 2.4) History Match Automation
- 2.5) Integration and Automation Testing

3) IMS Architecture Development

- 3.1) Database Development
- 3.2) Data Integration
- 3.3) IMS Interface Development
- 3.4) Process and System Testing



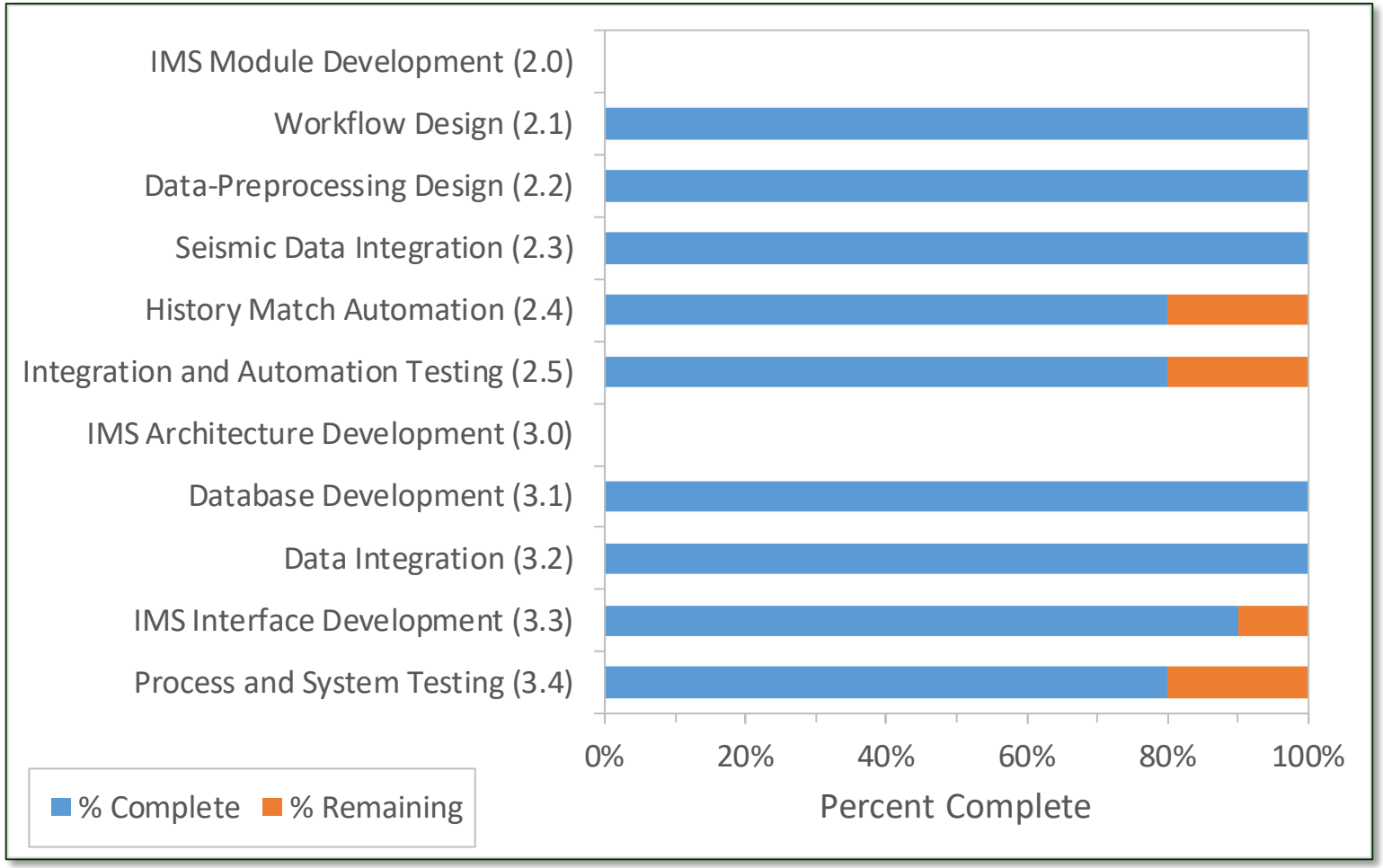
PROJECT OVERVIEW – MILESTONES

Task/ Subtask	Milestone/Deliverable Title	Completion Date	Verification Method	Comments
1.1 – Project Management	M1 – Project Kickoff Meeting Held	12/02/15	Presentation file submitted to DOE	Completed
3.1 – Database Development	M2 – Initial Database Schema	03/31/16	Reported in subsequent quarterly report	Completed
2.2 – Data-Preprocessing Design	M3 – Data-Preprocessing Design	06/30/16	Reported in subsequent quarterly report	Completed
2.3 – Seismic Data Integration	M4 – 3-D Seismic Algorithm	09/30/16	Reported in subsequent quarterly report	Completed
3.2 – Data Integration	M5 – Draft Data Integration Algorithm	12/31/16	Reported in subsequent quarterly report	Completed
3.3 – IMS Interface Development	M6 – Initial GUI Design	02/28/17	Reported in subsequent quarterly report	Completed
2.3 – Seismic Data Integration	M7 – Shot Record Plume Tracking Tested	11/30/17	Reported in subsequent quarterly report	Completed
2.4 – History Match Automation	M8 – Design of History Match Automation	11/30/17	Reported in subsequent quarterly report	Completed
3.1 – Database Development	M9 – Updated Database Schema	09/29/17	Reported in subsequent quarterly report	Completed
3.3 – IMS Interface Development	M10 – GUI Coding Completed	12/31/17	Reported in subsequent quarterly report	Completed
2.5 – Integration and Automation Testing	M11 – Initial Automation Testing Completed	12/31/17	Reported in subsequent quarterly report	Completed
3.4 – Process and System Testing	M12 – Full System Testing Initiated	02/08/18	Reported in subsequent quarterly report	Completed
3.4 – Process and System Testing	M13 – Process and System Testing Completed	08/31/18	Will be reported in final technical report	In progress

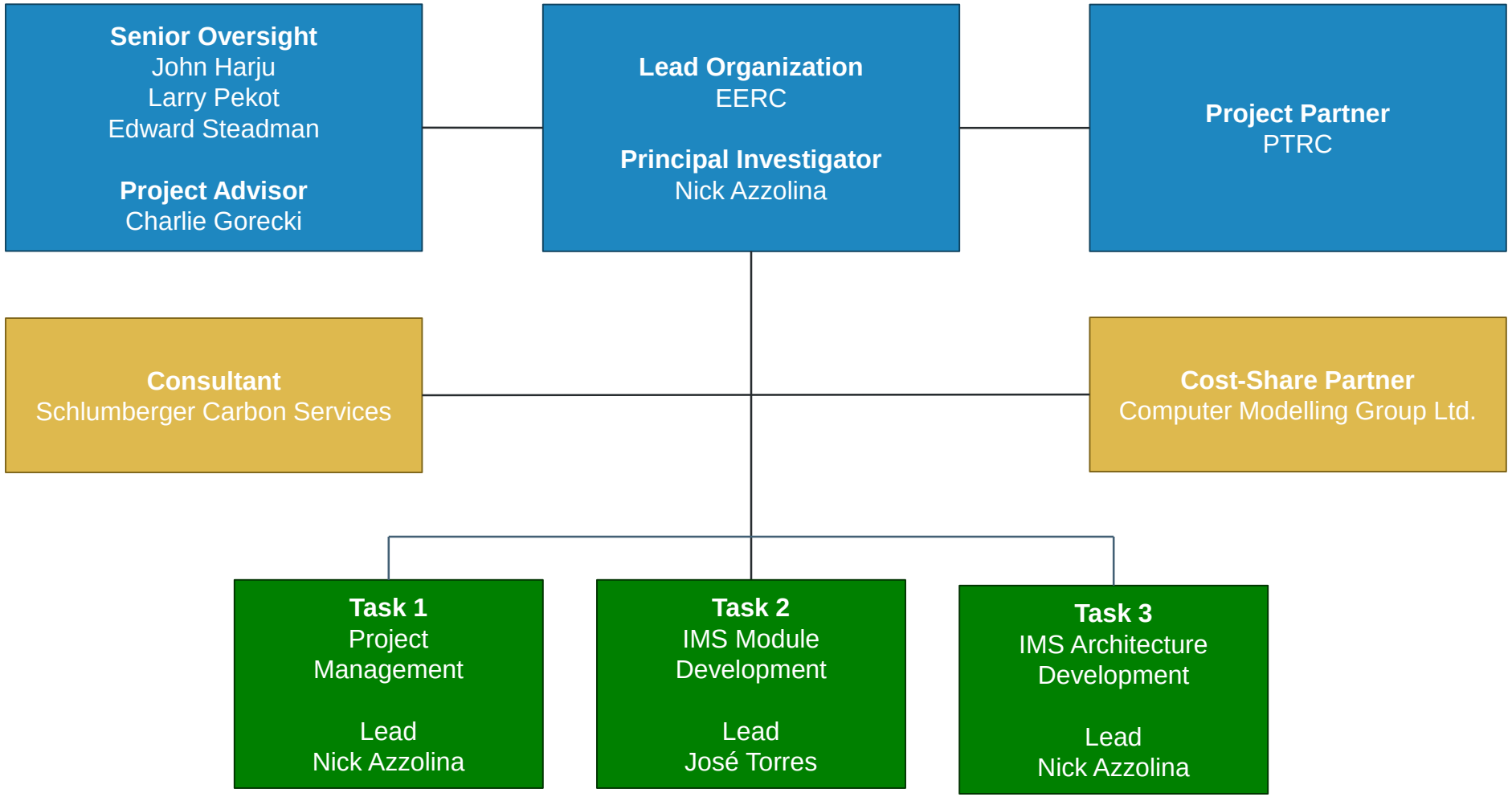
PROJECT OVERVIEW – DELIVERABLES

Task/ Subtask	Milestone/Deliverable Title	Completion Date	Verification Method	Comments
1.1 – Project Management	D1 – Updated Project Mgmt. Plan	12/22/15	PMP file submitted	Completed
1.2 – Project Reporting	D2 – Data Submission to EDS	09/30/16	Data uploaded to EDX	Completed
2.3 – Seismic Data Integration	D3 – Interim Report: Shot Record Plume Tracking	12/28/17	Interim report submitted	Completed
3.2 – Data Integration	D4 – Topical Report: Data Integration for Risk Profiling	12/28/17	Interim report submitted	Completed
1.2 – Project Reporting	D5 – Final Technical Report	09/30/18	Submitted to DOE	In progress

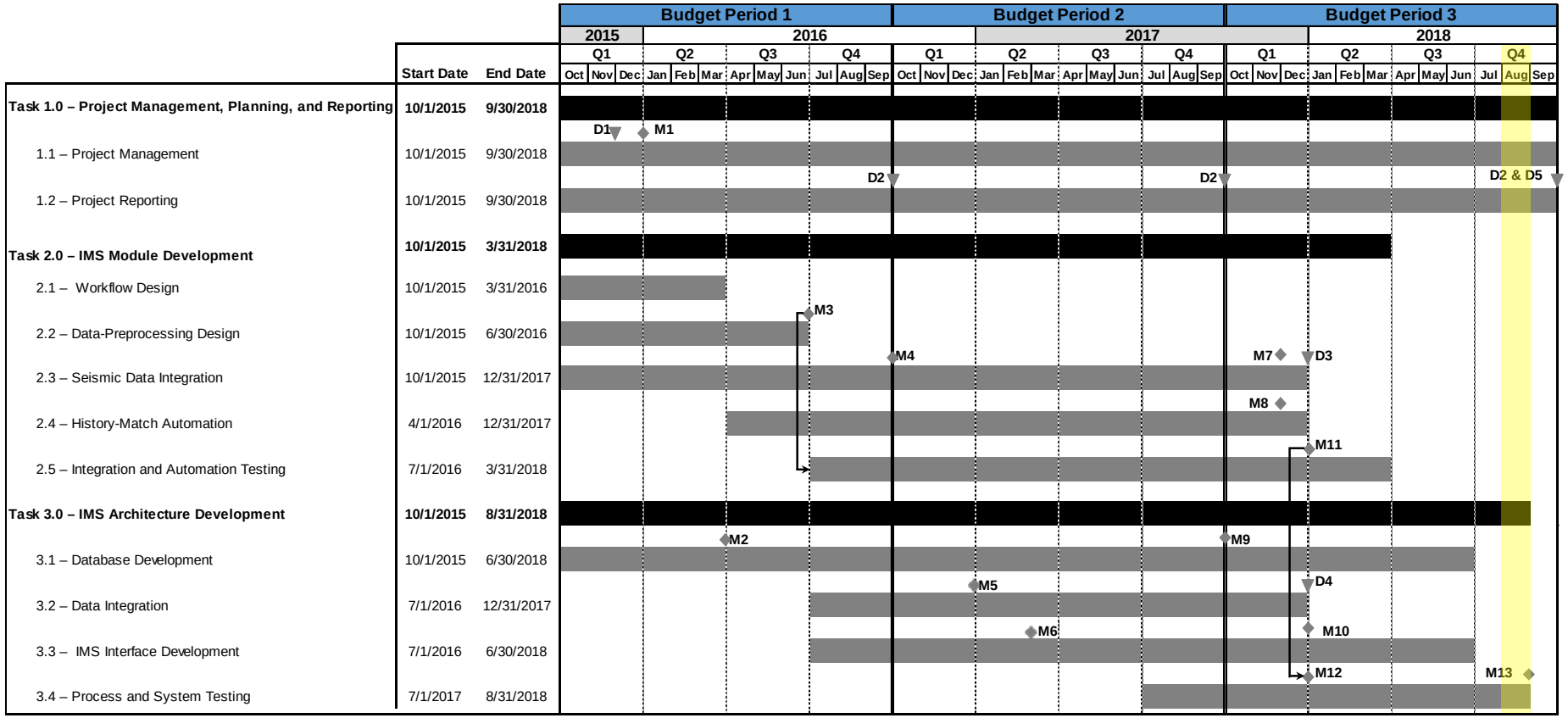
PROJECT OVERVIEW – SUCCESS CRITERIA



ORGANIZATIONAL CHART



GANTT CHART



Summary Task Activity Bar

Milestone (M) Deliverable (D) Critical Path

Key for Deliverables (D)	Key for Milestones (M)	
D1 – Updated Project Management Plan	M1 – Project Kickoff Meeting Held	M8 – Design of History-Match Automation Completed
D2 – Data Submission to EDX	M2 – Initial Database Schema Completed	M9 – Updated Database Schema Completed
D3 – Interim Report – Shot Record Plume Tracking	M3 – Data-Preprocessing Design Completed	M10 – GUI Coding Completed
D4 – Topical Report – Data Integration for Risk Profiling	M4 – 3-D Seismic Algorithm Completed	M11 – Initial Automation Testing Completed
D5 – Final Technical Report	M5 – Draft Data Integration Algorithm Completed	M12 – Full System Testing Initiated
	M6 – Initial GUI Design Completed	M13 – Process and System Testing Completed
	M7 – Shot Record Plume Tracking Tested	

6/22/18 hmv

BIBLIOGRAPHY

- No peer-reviewed publications have been generated from this project to date.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