Integrated Wellbore Integrity Analysis Program for CO_2 Storage Applications

DE-FE0026585

Mark Moody

Battelle, Columbus, Ohio, USA

U.S. Department of Energy

National Energy Technology Laboratory

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

August 16-18, 2016

Presentation Outline

1) Benefit to Program
2) Project Overview
3) Technical Status
4) Accomplishments to Date
5) Synergy Opportunities
6) Summary

- Appendix Material

Benefit to the Program

- This project addresses Funding Opportunity 1240 Area of Interest 2: Wellbore Leakage Identification and Characterization.
- The project is designed to establish an effective approach to determining the location/depth, nature, and severity of well integrity issues for wells exposed to CO_2 environments in the subsurface.
- Project results will provide new and improved predictive methods to survey, identify, characterize, and manage wellbore integrity defects for CO_2 storage applications.

Project Overview:
Goals and Objectives

- The objective of this project is to develop and validate a program for identifying and characterizing wellbore leakage potential for CO_2 storage applications based on analytics of well records validated with sustained casing pressure field monitoring.
- The project will develop and advance technologies that will significantly improve the effectiveness and reduce the cost of implementing carbon storage.

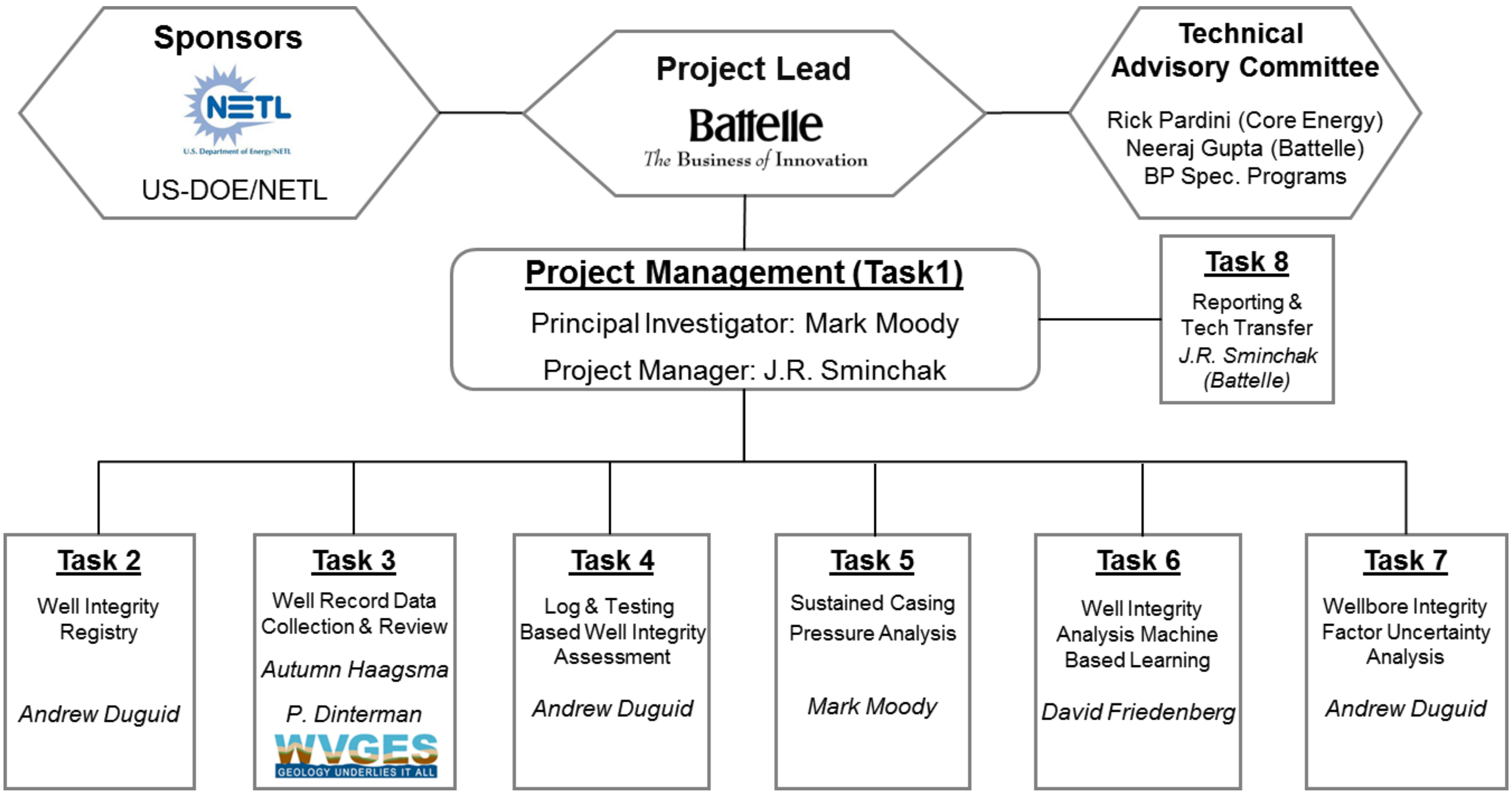
Battelle
The Business *of* Innovation

Project Overview:
Goals and Objectives

- Integration of casing pressure test results with automated machine based learning analytics can identify wells with poor integrity
- Development of an integrated program to identify, survey, measure, analyze, and remediate CO_2 migration in wellbores.
- In addition, the type of well defect (micro-annulus, cracks, cement voids, and incomplete cement coverage) may be better characterized to select to the most appropriate remediation technology.

Project Overview

3-Year Project; October 2015 - September 2018

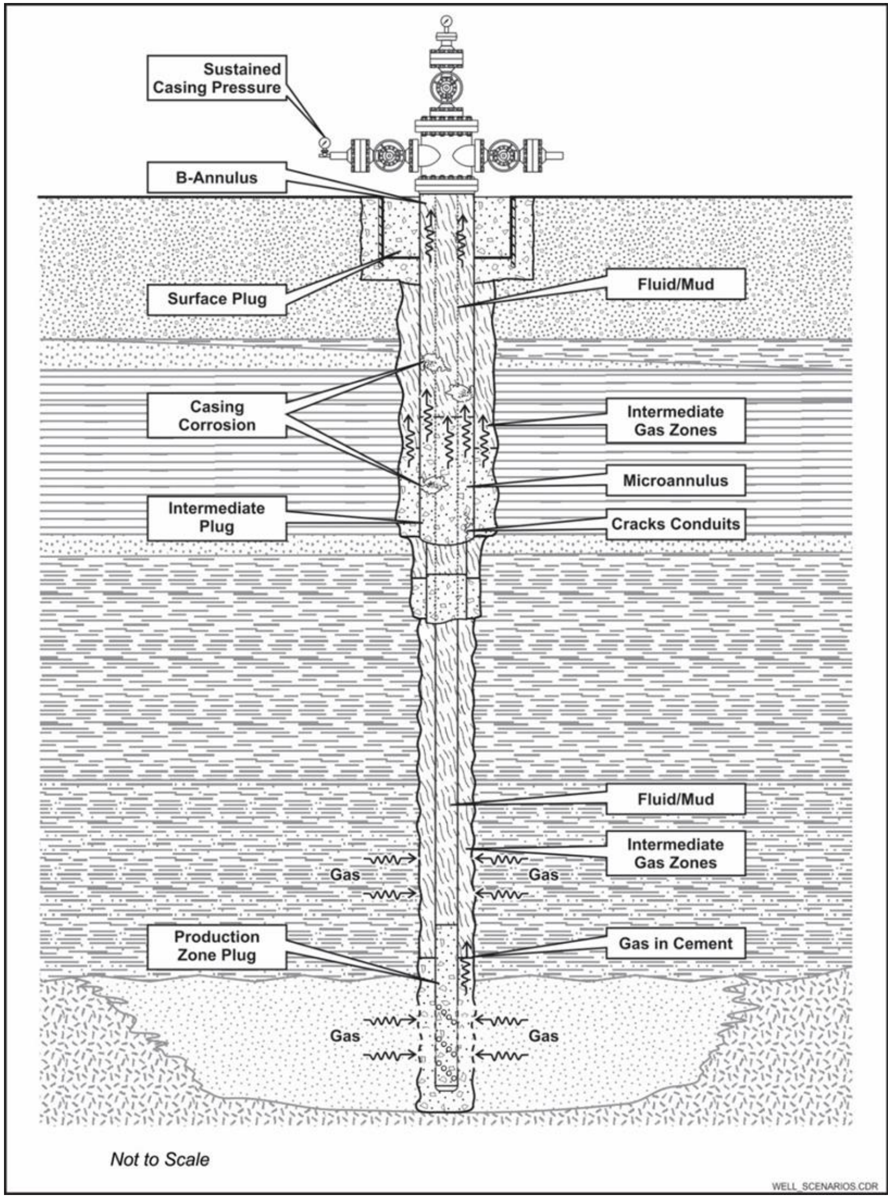


Technical Status - Well Integrity Registry Task 2

- Literature and experience based research
- Identify wellbore integrity issues, and where and how they occur
- Five subtasks explored

Well Construction	Well Casing	Well Cement	Geologic Processes	CO_2 Environments
• Methods • Materials	• Corrosion/wear • Leaks	• Contamination • Defects	• Geomechanical • Geochemical	• Influence of CO_2 of cement, casing, etc.

Well Component	Integrity Issue	Description	Causes	When	Leakage Pathway
Casing	Thermo-mechanical cycling	Contraction and expansion of well casing	Differences between properties of materials	Construction, operation, workover, abandonment	Debonding along cement interface (microannulus)
	Wear	Wear to the casing	Casing interactions with wellbore and tools	After drilling, during workovers	Burst, collapse, holes in casing
	Corrosion	Corrosion of casing	Contact with corrosive fluids saturated with CO_2	Construction, operation, workover, abandonment	Holes in casing, cracking
Cement	Degradation	Dissolution or alteration of cement	Contact with corrosive fluids saturated with CO_2	Construction, operation, workover, abandonment	Pores in cement or along degraded cement at interfaces
	Microannulus and cracking	A small gap between casing and cement and cracks in the cement	Casing and cement debond, or bond was never established or was broken	Construction, operation, workover, abandonment	Along casing-cement interface
	Mud contamination	Poor mud removal before cementing	Poor cement job design, poor hole cleanout	During construction	Along interfaces or through bulk cement
	Eccentering	Casing is not centered in the borehole	Poor centralization	During construction	Along casing, cement, or mud interfaces
	Mud channels	Cement slurry fingers through the mud in the annulus	Poor cement job design	During construction	Along mud channel interface or through flowing mud
	Fluid invasion	Invasion of fluids into cement	Poor cement slurry design and loss of hydrostatic pressure	During construction	Poor zonal isolation
Borehole wall (Geologic Processes)	Formation lithology	Borehole breakout and drilling induced fractures	Induced stress greater than maximum of the formation stress	During drilling	Poor cement bond to borehole wall
	Geomechanical stresses	Changes in stress field	Pressure gradient changes and creep	Construction, operation, workover, abandonment	Cement and casing damage or failure



Battelle
The Business of Innovation

Technical Status - Well Data Collection Task 3

- Goal is to collect readily available well records
- Built a database of well construction, operation, and workovers/leakage
- Databases will be used to develop models to predict wellbore integrity problems

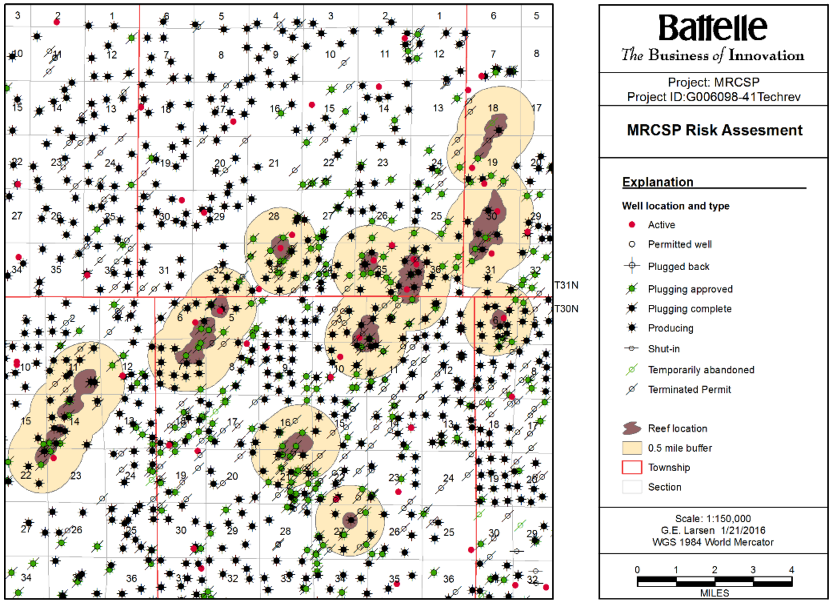
Well Construction	Operational	Workover/leakage
• Cementing • Drilling • Casing	• Pressure • Production • Tests	• History of leaks, defects • Mechanical stresses

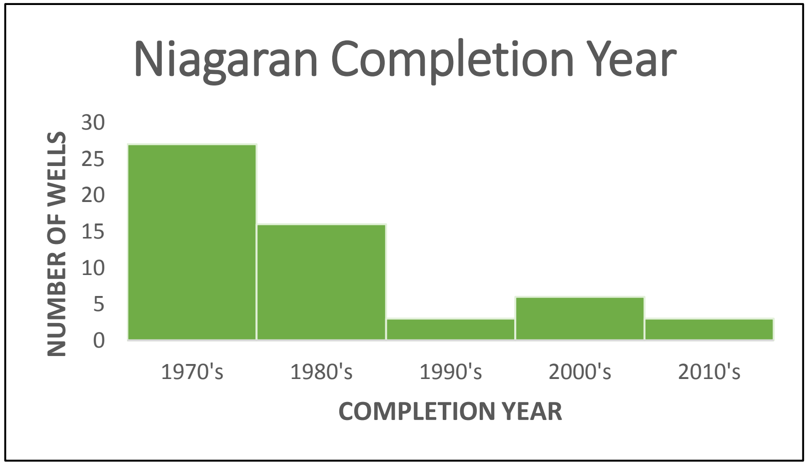
Battelle
The Business of Innovation

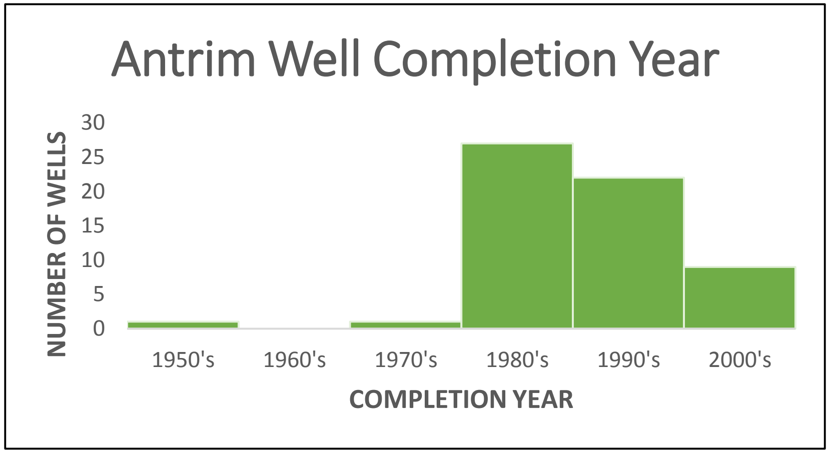
Technical Status - Well Data Collection Task 3

Michigan Basin Site

- Over 1600 wells within the study area
- Antrim shale natural CO_2 producer
- Niagaran reef CO_2 enhanced oil recovery project







Technical Status – Well Data Collection Task 3

Weyburn CO_2 Storage Project

- Located in the northern rim of the Williston Basin, 16 km south east of Weyburn
- Approximately 650 production and injection wells in operation
- Vast, publicly accessible collection of historic records back to 1954
  - Approximately 600 cores and geophysical logs
- CO2 injection commenced in 2000

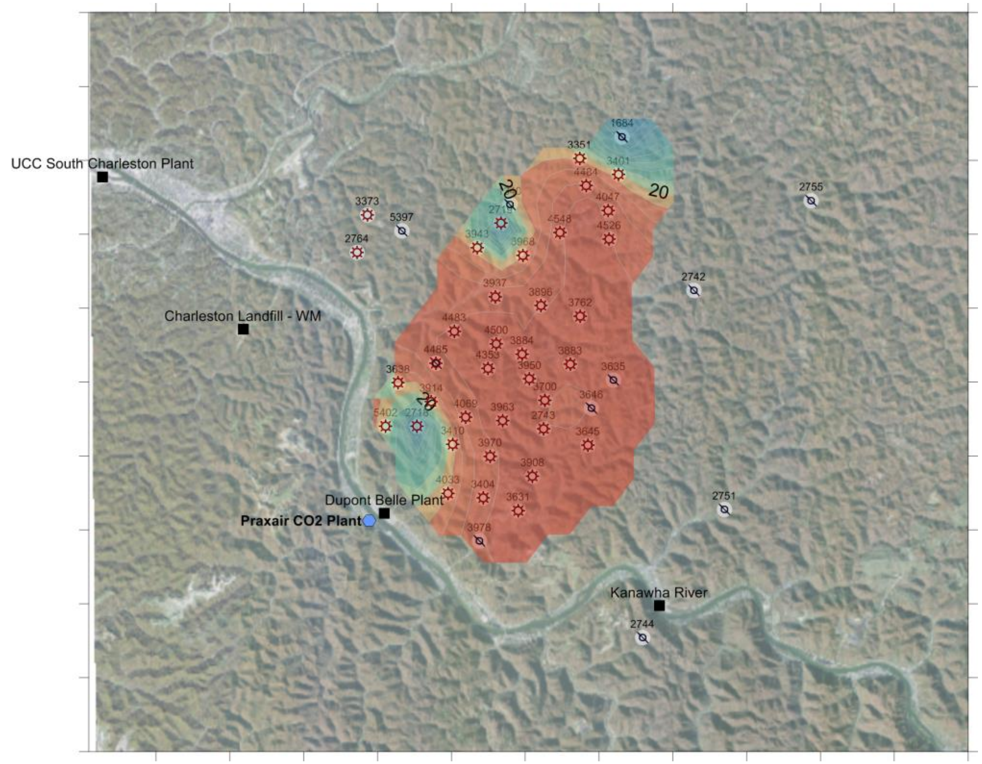
Geographic location of the Weyburn field taken from Wilson et al. (2004). The field is set in the Williston sedimentary basin, which stretches across much of the north of the USA and central
Canada

Battelle
The Business of Innovation

Technical Status - Well Data Collection Task 3

Indian Creek Field, Kanawha County, WV

- Natural CO_2 producing field
- Approximately 40 producing wells
- Producing formation is the Silurian-aged Tuscarora sandstone
- Gas analysis indicated 61% to 65% CO_2 content in the gas
- Industrial gas supplier purchases gas and upgrades CO_2 for sale to food and beverage industry

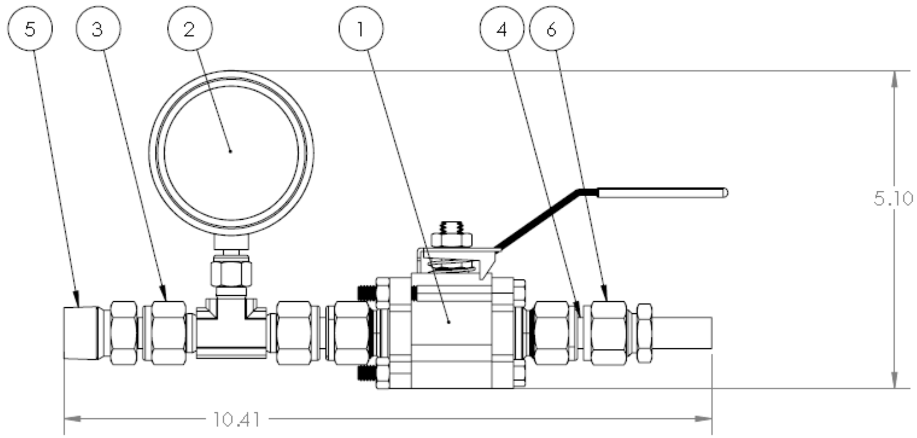


Technical Status – SCP Analysis Task 5

- Michigan Niagaran Reef EOR field
- Weyburn field
  - CO_2 EOR/Storage Project
  - 30 Wells with SCP
  - SCP data gathering kits
    - Pressure recorders
    - Choke nipples
    - Instructions for measuring head space
- Indian Creek, WV field
  - Communicating with operator to acquire SCP data

Battelle
The Business of Innovation

Technical Status – SCP Analysis Task 5



NOTES:
1. HYDROSTATIC TEST TO 750PSI, HOLD TIME 30 MIN

2. ITEM #6 CAN BE REPLACED TO CHANGE ORIFICE DIMENSION:
1/8" ORIFICE P/N: SS-810-R-8PD-E-125
1/4" ORIFICE P/N: SS-810-R-8PD-E-250

BOM TABLE

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	SS-63TS8	316 SS 60 SERIES 2-WAY BALL VALVE 1/2"	1
2	PGI-63C-PG1000-LAQX	316 SS C SERIES PRESSURE GAUGE 0-1000 PSIG 1/4" TA	1
3	SS-810-3-8-4	316 SS REDUCING TEE 1/2" X 1/2" X 1/4"	1
4	SS-811-PC	316 SS PORT CONNECTOR 1/2"	2
5	SS-8-TA-1-8	316 SS ADAPT 1/2" TA X 1/2" MNPT	1
6	SS-810-R-8PD-E-063	316 SS REDUCER 1/2" X 1/2" TA WITH 0.063" ORIFICE PLATE	1

SIGNATURE REQUIRED: REV. A

CONCEPT DRAWING
Swagelok
SCIOTO VALVE & FITTING COMPANY

- DRAWING NOT TO SCALE.
- DIMENSIONS ARE IN INCHES
- DRAWING IS SUBJECT TO CHANGE WITHOUT NOTICE

THIS PRINT IS THE EXCLUSIVE PROPERTY OF SWAGELOK COMPANY. IT MUST BE RETURNED ON REQUEST ALONG WITH ANY DOCUMENTS CONTAINING INFORMATION OBTAINED FROM THE PRINT. NEITHER THIS PRINT NOR ANY PART OF IT NOR ANY INFORMATION CONCERNING IT MAY BE COPIED, DISCLOSED TO OTHERS OR USED FOR ANY PURPOSE EXCEPT IN FURTHERANCE OF YOUR BUSINESS WITH SWAGELOK. THE PARTS REFERRED TO ON THIS PRINT MAY BE THE SUBJECT OF PATENTS AND/OR PENDING APPLICATIONS AND MAY NOT BE MANUFACTURED WITHOUT PERMISSION FROM SWAGELOK COMPANY.

DRAWN BY: SF 7-14-2016
APPROVED BY: .
TITLE: VALVE MANIFOLD ASSEMBLY
PART NO.: S3652-ASSEM-47

Note: Drawing is of a tube assembly. Same can be replicated in pipe.

<u>Data Collected At Each Well Site:</u>

1. GPS coord. & timestamped photo of well connection
2. Initial pressure
3. Orifice size
4. Time and delta P of depressurization
5. Record of pressure build-up

<u>Piping Manifold Cost</u>: $220
(includes parts and assembly)

Monitoring Depressurization

Technical Status – SCP Analysis Task 5

Inputs

Gas	Methane	
Gamma	1.32	
R, gas constant	518.3	J/(kg K)
Capital Gamma	0.77	
To	150	degF
	339	K
Dia_orifice	1/4	in
Area_orifice	0.05	in2
	3.16692E-05	m2

t_vent 0.5 min
30 sec

Required P.Drop 25%

Pi (psig)	30	50	95	150	200	250	300	350	400	450	500	550	600
V (m3)													
0.001	0	0	0	0	0	0	0	0	0	0	0	0	0
0.005	0	0	0	0	0	0	0	0	0	0	0	0	0
0.01	0	0	0	0	0	0	0	0	0	0	0	0	0
0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
0.1	0	0	0	0	0	0	2	5	7	10	13	15	18
0.2	0	0	8	19	29	39	49	59	69	79	89	100	110
0.3	0	7	22	40	57	74	90	107	124	140	157	174	190
0.4	5	13	33	57	78	100	122	143	165	186	208	230	251
0.5	8	18	41	69	94	120	145	171	196	222	247	272	298
0.6	11	22	47	79	107	135	164	192	220	249	277	305	334
0.7	13	25	53	86	117	148	178	209	240	270	301	332	362
0.8	14	27	57	93	125	158	190	223	255	288	320	353	385
0.9	16	29	60	98	132	166	200	234	268	302	336	370	405
1	17	31	63	102	137	173	208	244	279	314	350	385	421
1.5	21	37	72	116	156	195	235	275	314	354	394	433	473
2	23	40	77	124	166	208	250	292	334	376	418	460	502
5	27	46	88	139	185	232	279	325	372	418	465	512	558
10	28	48	91	144	193	241	289	337	386	434	482	530	579
16	29	49	93	146	195	244	293	342	391	440	489	538	587
50	30	50	94	149	198	248	298	347	397	447	496	546	596

Note: Pressure output in psig

KEY

LESS THAN OPTIMAL

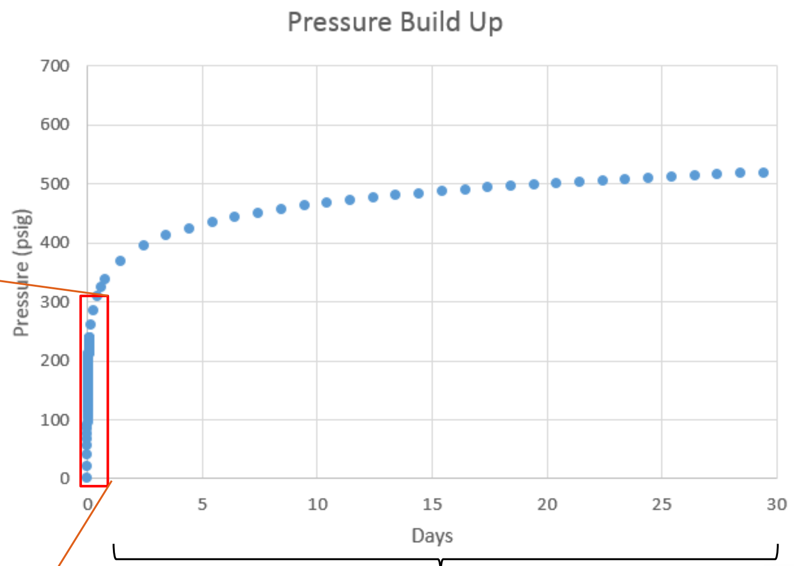
OPTIMAL

NOT VALID

Vessel Pressure After 30 seconds of Venting

Orifice Sizing Calculator for Design Optimization

Technical Status – SCP Analysis Task 5



Pressure Build-Up Monitoring

Frequent Pressure Logging for First 10 Minutes

Occasional Pressure Logging Thereafter

Madgetech image from: http://www.madgetech.com/data-loggers/product-applications/compressor-and-pump-monitoring/prtemp1000.html

Accomplishments to Date
Task 2: Well Integrity Registry

- Construction Methods
- Casing Integrity Issues
  - Wear, Corrosion
- Cement Issues
  - Primary, Remedial and Plugging
- Geological Processes
- CO_2 Environments

Battelle
The Business *of* Innovation

Synergy Opportunities

Synergy to DOE-NETL Carbon Storage Program

- Project has significant synergies with other ongoing work on carbon storage technologies (carbon capture & storage), shale gas developments, other CO_2 storage research.
- Provides a better understanding of wellbore integrity, a key issue for CO_2 storage in the region's deep rock formations.
- Reduces uncertainty related to existing/future power plant locations by.

Summary- Future Work

Task 3: Well Record Data Collection and Review

In progress

Task 4: Log and Testing Based on Well Integrity Assessment

Task 5: Sustained casing Pressure Analysis

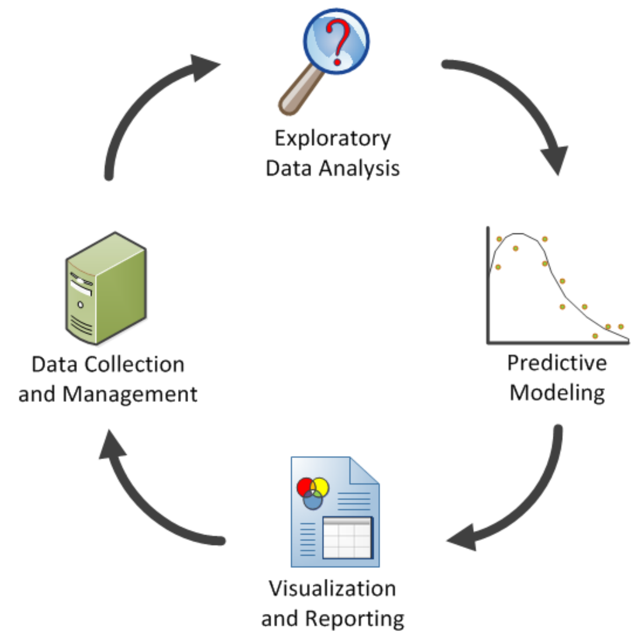
In progress

Task 6: Well Integrity Analysis with Machine Based Learning

Task 7: Wellbore Integrity Factor Uncertainty Analysis

Task 8: Reporting and Technical transfer

Future Work – Task 6



- Big Data
  - Typically characterized as the “3 Vs”
    - Volume (large amounts of data)
    - Variety (many different sources of data)
    - Velocity (real-time streaming data)
- Analytics with Machine Learning
  - Transform raw data into information for decision-making
  - Includes all of the infrastructure required to do that transformation:
    - Data collection & management
    - Exploratory data analysis
    - Predictive modeling
    - Visualization & reporting

Future Work – Task 6

- A few examples:
  - Identify groups of wells for which construction is similar, and better understand the variables that differentiate between those groups
  - Determine whether technique A is better than technique B based on historical data
  - Given operational and geological data, rank several candidate locations based on predicted performance
  - Analyze sensor and image logs to flag formations of interest, going beyond simple threshold and rule-based calculations

Acknowledgements

- The project was funded by the U.S. DOE / National Energy Technology Laboratory under their program on technologies to ensure permanent geologic carbon storage (Contract DE-FE0026585).
  Project Manager – William O’Dowd, NETL Sequestration Division.
- Project team includes Battelle (Lead), Core Energy and the West Virginia Geologic and Economic Survey (WVGES).
- Petroleum Technology Resource Center (PTRC): SCP and well construction data from Weyburn field

U.S. DOE/NETL

CORE ENERGY, LLC

West Virginia Geological and Economical Survey

Battelle
The Business of Innovation

The End. Thank You!

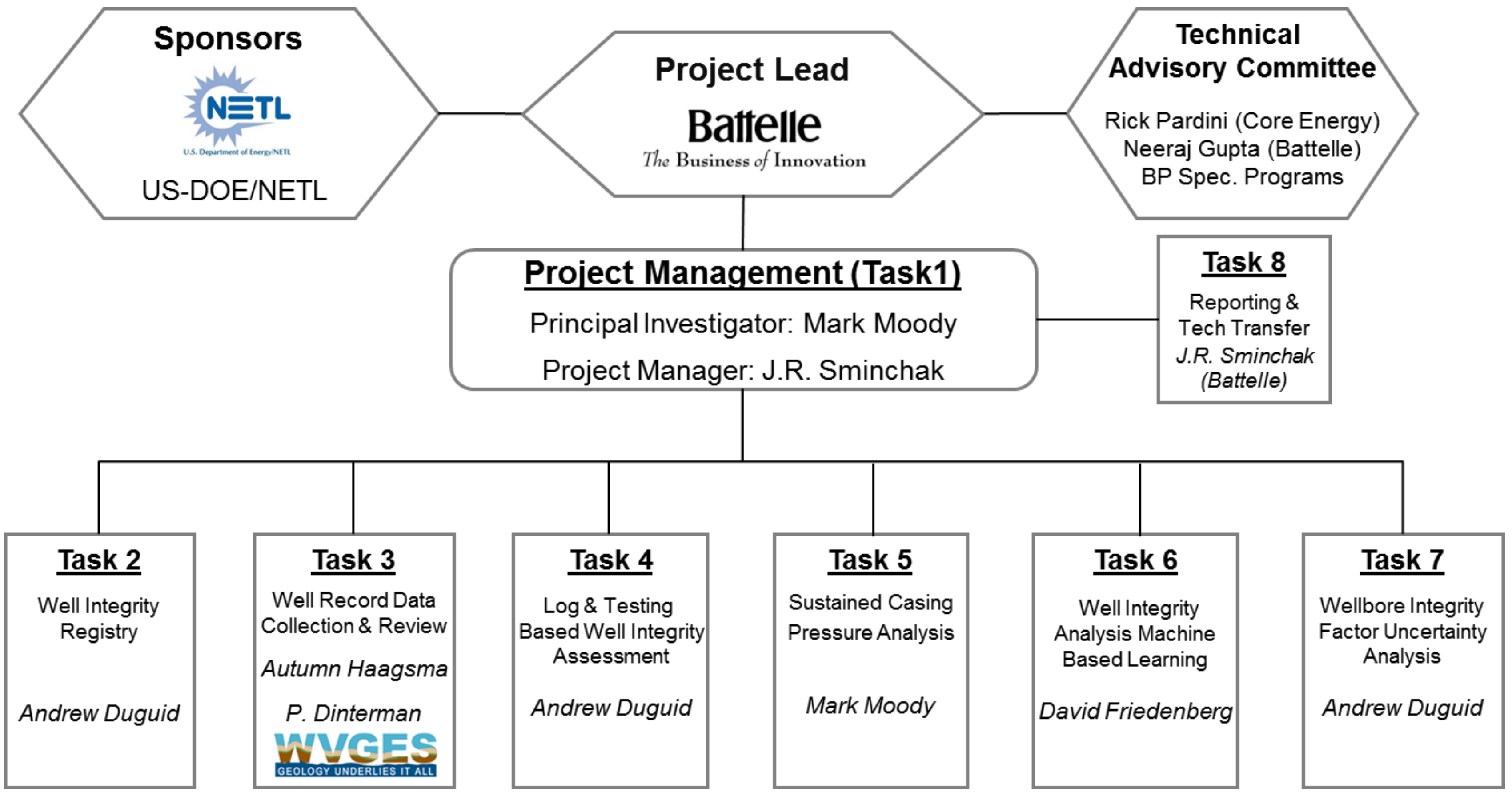
Mark Moody
moodym@battelle.org

Battelle
The Business *of* Innovation

800.201.201 | solutions@battelle.org | www.battelle.org

Additional Project Information

Project Organization Chart



Gantt Chart

- Project is designed with a sequential series of tasks over 3 years.

	BP1				BP2				BP3			
	FY2016				FY2017				FY2018			
Task Name	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task 1: Project Management & Planning												
1.1 Update Project Mgmt. Plan	◆											
1.2 Project Management												
1.3 Progress Reporting												
1.4 Project Controls												
1.5 NEPA Reporting												
Task 2: Well Integrity Registry												
2.1 Well Construction Methods												
2.2 Well Casing Integrity Issues												
2.3 Well Cement Issues												
2.4 Geologic Processes												
2.5 CO2 Environments												
Task 3: Well Record Data Collection & Rev.												
3.1 Cement & Drilling Records												
3.2 Operational Records												
3.3 Well Workover/Leakage Records							◆					
Task 4: Log & Testing Based Well Int. Asmt.												
4.1 Log Analysis												
4.2 Well Record Analysis												
4.3 Well Integrity Evaluation												
Task 5: Sustained Casing PressureAnalysis												
5.1 SCP Field Site Description												
5.2 SCP Field Data Collection										◆		
5.2 SCP Data Analysis												
Task 6: Well Integrity w/Machine Learning												
6.1 Well Int. Regression of Well Int. Indicators												
6.2 Data Analysis Algorithm Dev.w/Mach. Lrng												
6.3 Meta-Modeling on Test Fields												
Task 7: WBI Uncertainty Factor Analysis												
7.1 WBI Identification												
7.3 Uncertainty Reduction												
Task 8: Reporting and Tech Transfer												
9.1 Progress Reports	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
9.2 Technical Reports				◆		◆		◆			◆	◆
9.3 Final Reporting												
9.4 Project Meetings												
9.4 DOE BPM	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆

Deliverables/Milestones

Milestones

Budget Period	Milestone Description	Planned Due Date	Verification Method
1	Update Project Management Plan	30 days after initial award	Project Management Plan
1	Complete Wellbore Integrity Registry	June 2016	Well Integrity Registry Summary Report
2	Collect Well Record Data	June 2017	Well Record Data
2	Complete Log & Testing Based Well Integrity Assessment	September 2017	Log & Testing Based Well Integrity Assessment Summary Report
3	Collect All Sustained Casing Pressure Analysis Data	March 2018	Complied database of Sustained Casing Pressure Analysis Data
3	Complete Well Integrity Analysis Machine Based Learning	June 2018	Well Integrity Analysis Machine Based Learning Summary Report

Bibliography

IEA GHG Weyburn CO2 Monitoring & Storage Project, IEA Greenhouse Gas R&D Programme, Orchard Business Center, Stoke Orchard, Cheltenham, Glos. GL52 7RZ, UK.

J Hamak and S Sigler. **Analysis of Natural Gasses, 1986-1990.** U.S. Bureau of Mines Information Circular, IC 9301.

J Schuetter, S Mishra, M. Zhong, R. LaFollette. **Data Analytics for Production Optimization in Unconventional Reservoirs (URTeC 2167005)** Unconventional Resources Technology Conference, San Antonio, TX, July 2015.

J Schuetter, S Mishra, and D Mooney. **Evaluation of metamodeling techniques on a CO2 injection simulation study.** Proc., 7th International Congress on Environmental Modelling and Software, San Diego, California, USA, DP Ames, N. Quinn (Eds.), June 2014.

J Schuetter, S Mishra, P Ravi Ganesh, and D Mooney. **Building Statistical Proxy Models for CO_2 Geologic Sequestration.** *Energy Procedia* 63 (2014): 3702-3714.

M Zhong, J Schuetter, S Mishra, R LaFollette. **Do Data Mining Methods Matter? A Wolfcamp Shale Case Study (SPE 173334)** SPE Hydraulic Fracturing Technology Conference, The Woodlands, TX, February 2015.