FINAL TECHNICAL REPORT

NDIC Funding to Support Research of Petroleum Engineering Program at University of North Dakota

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Table of Contents

Project Summary

The goal of the present project was to strengthen the scientific visibility and overall performance of the Petroleum Engineering Department at UND (PE). In order to accomplish this major endeavor, its success was measured by focusing on giving students the opportunity to have full-time, research-focused graduate student position at a research university, advancing graduate student graduation, enhancing graduate student conference participation and presentations showcasing the UND Petroleum Engineering Department, and enhancing laboratory capabilities facilitating cutting edge research, most of all the Full-Scale Reservoir Simulated Drilling and Completions Lab (DRACOLA) which is a unique feature to UND. Originally, this project provided a total of 15 graduate student positions to interested and high-quality graduate students, mostly at the PhD level to foster research output from this program. Nevertheless, in 2022 there were up to 61 graduate students being paid from this program as during the height of the pandemic it was close to impossible to hire and interview well-qualified faculty at any university, including UND. Advancing student graduation therefore had a two-fold goal: it would ensure that graduate students would complete their projects quickly, and at the same time increase the research output and therewith the quality of the program. The increase in student graduation with a MEng. or PhD degree and coupling graduation to presenting at conferences also ensured that student conference participation (as much as possible during a pandemic) and presentation of research results as posters or talks remained high. However, it should be noted that because of the pandemic, many students had no choice but to present online, and several conferences had to be cancelled because of the small number of potential participants, especially during 2020 and 2021.

The job placement rate of graduate students coming out of the UND Petroleum Engineering program was good as far as the data tracking shows. Students that graduated with a MEng. degree generally chose to remain in the program to pursue a PhD. However, students obtaining a PhD were mostly transitioning to the Energy & Environmental Research Center (EERC) at UND, but also to oil and gas or consulting companies, and in one case to UND to become the graduate director of the Petroleum Engineering program.

The laboratory resources at UND are very good, and much of it is state of the art thanks to investments made from this project. The Drilling Simulator Lab is especially well attended and could be expanded to offer professional training. This facility provides resources for teaching and research, and currently several students are taking advantage of what UND offers in order to complete their theses. Even more critical is the general PE lab, especially the “Auotolab” device that is used in several theses that are funded from the current project. However, all of this work is part of PhD theses, and these theses will be completed during the second phase of the project in 2025.

Very unique nationwide, and also worldwide, is the presence of DRACOLA in the PE department at UND. This project was instrumental in building this system and making it into a training and research facility not only for UND PE students but also for industry professionals nation- and worldwide.

Introduction

This project was focused on advancing the Petroleum Engineering (PE) Department at UND on multiple levels: as a research institution by promoting and funding graduate students, PE publications in peer-reviewed journals and at conferences, as a teaching department with hiring a new professor, and by establishing a world-class and hands-on drilling lab (DRACOLA). While the general mission has succeeded and this project as well as its successor indeed promoted UND's Petroleum Engineering program, its onset coincided with the worldwide pandemic and left several goals unobtainable. The start date of March 2020 matches exactly that of the pandemic (for the PI 5th of March 2020) which made hiring of a professor not feasible. No on-campus interviews could be held, people could not move easily, everything came to a standstill. As a consequence, the funding originally intended to hire a new faculty was spent on financing more graduate students and therefore to advancing research output and visibility of UND's Petroleum Engineering department, the original goal of this project.

Additionally, the chair of the Petroleum Engineering Department left UND unexpectedly in July of 2022 taking several of the students originally funded by this project and one faculty with him. At the same time, one of the other faculty went on sabbatical leaving the Petroleum Engineering department with just 2 active faculty. Therefore, the last eight months of the project were mostly focused on reorganizing the department and assigning graduate students left behind new advisors. This period included the naming of an interim chair and graduate program director. Nevertheless, the below listed tasks were completed and this report will give an overview on how the department advanced from March 2020 on by carefully assigning the project money to the tasks spelled out in the proposal.

Tasks completed that show Petroleum Engineering Department Excellence

Advancing graduate student graduation

This project and the funding directly contributed to 32 graduate students graduating with either a MEng., a PhD, or both during the course of this project. Several graduate students, however, started after the project had already begun and therefore did not graduate before the project ended in February, 2023. A good number of the Petroleum Engineering graduate students, though, graduated during the successor of this project which is also supported by the NDIC and therefore either have already graduated, or will graduate soon and before the successor of the present proposal is running out.

Due to the unusual circumstances of a pandemic, the project supported many more than the originally planned 15 graduate students, and when it became clear that it was impossible to interview suitable Petroleum Engineering candidates for a professor position the funds were used to attract more graduate students. Between its start in 2020 and its end in 2023, the project supported no less than 45 graduate students at any given time, and up to 61 graduate students in 2022. These numbers are 3 to 4 times the amount that was originally planned.

Most graduate students' schedule did not fully align with the project. They either started their projects earlier than the project was active or continued their research well after it ended. From

the 32 graduate students who graduated either with a PhD, or with a MEng. during the project, only 19 were funded primarily from this project. Others have received partial financial support, either to cover initial expenses while starting a project, or to ensure their graduation. The data shows that from a total of 32 students who graduated with the help of this project, 7 of the students continued with a PhD after completing their MEng. degree in PE at UND.

Seven graduate students were funded by this project until the original PI, Vamegh Rasouli, left UND and took them with him to Wyoming, an action that is not unusual for professors when they change employers. Over the course of four calendar years, 19 graduate students were originally partly funded by this project but did not finish their degree programs (3/2020; 5/2021; 9/2022; 2/2023). This is also not unusual as a PhD is not for everyone. According to Google, the dropout rate nationwide varies between 9 and 71% for PhD students based on a plethora of reasons. The number reported here is therefore much closer to the lower end of this value than to the 71%. That said, the pandemic also heavily influenced this number, and we can count ourselves lucky that not more students panicked during the pandemic and left their PhD projects for good. This is a testimony to the quality of the project as well as the program, and the broad aims it was able to communicate to the graduate students. The approach of this project made students stick to their project during a time in their lives when any student in any discipline is struggling, and it is not uncommon to find students in such a situation who opted not to complete a doctorate or Master's degree. It should also be noted that the project aimed at hiring students into PhD positions, and it largely succeeded. The reason for hiring students preferentially into PhD positions is that the research output is significantly higher from PhD than from Master's students, and the high number of PhD students therefore increased the scientific output of the UND PE program. However, many of the Master's students opted to complete a PhD after they had finished their Master's studies, a testimony to the quality of the program that managed to maintain good-quality graduate students and convince them to pursue a PhD degree rather than finishing one's education after completing a Master's degree.

Conference participation and presentations to showcase UND Petroleum Engineering Research

One measure to assess the success of a program is by assessing the participation of graduate students in active research projects, mainly through the participation in conferences. While a conference participation in general is commendable, the presentation of research results is even more so. The success of the project investment will therefore also be measured by the amount of graduate student presentations on conferences of various kinds.

During this project, more than 113 graduate students presented their results at national and international conferences and/or published their research in reputable scientific journals (see Appendix 1). That is a huge amount of presentations considering the project was active in the middle of the pandemic where very few people were able to travel, and most conferences did not take place. In addition, students attended 80 conferences or workshops during the project to enhance their knowledge and skills and network with other researchers, industry, and government agencies (see Appendix 2). Figure 1 provides the publication output of the PE department during the last three years.

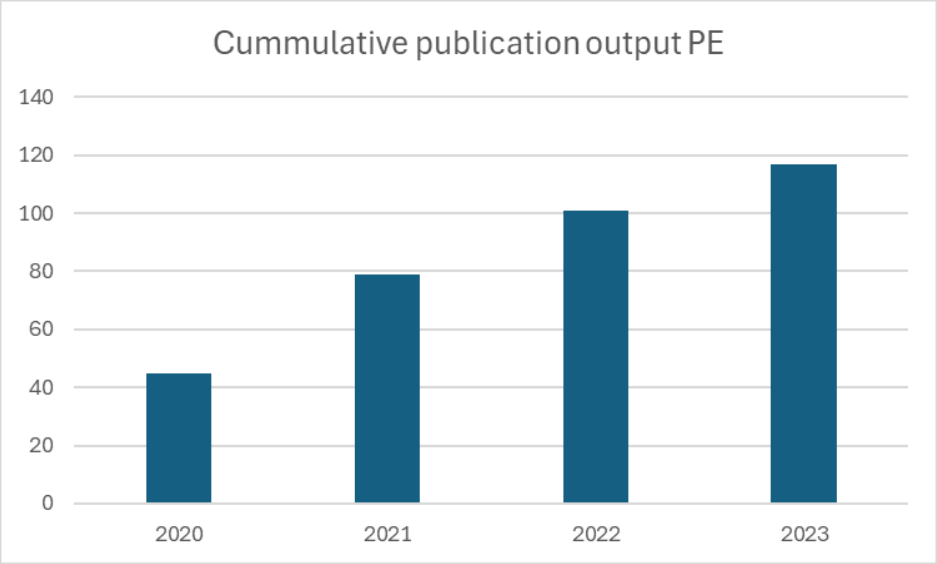

Figure 1. PE Department publication output during the last three years

So many of the students chose online presentations in order to still get their research out and present the advances in science coming from UND to the world in real-time, just not in person as this was often not possible. The success of the UND Petroleum Engineering program is also visible in the abundant publications and conference papers published throughout the course of this project, and beyond.

Job Placement of UND graduate students from the NDIC project

Traditionally, mostly graduates with an undergraduate degree in Petroleum Engineering at UND found a well-paying job as a Petroleum Engineer, nearly all of them in the oil and gas industry where deep knowledge in drilling was needed. However, this program was exclusively designed to graduate students with a graduate degree, both MEng. and PhD, the latter of which is generally exclusively targeted at students who want to continue in academia. There is currently a shift in the petroleum industry that has started to favor Master's and PhD degrees over undergraduate degrees, and this project took full advantage of that trend. It is therefore not surprising that the numbers of the students that UND was able to track records that students who were funded and who graduated with this project have wonderful employment chances not only in academia but also in industry. Not only major oil companies were hiring PhDs in PE (e.g., Chevron), but also small and mid-size oil companies communicated their interest, especially in students with a MEng. degree.

Research capabilities and lab resources

There are four laboratory spaces at UND in the PE Department three of which are included in the proposal: the Drilling Simulator Lab, a general lab space that also houses the "Autolab" pressure device, and DRACOLA - a Full-Scale Reservoir Simulated Drilling and Completions Lab. The lab resources are very well maintained throughout, a lab manager has been put in place to make sure everything in the labs is functional: the machines in the lab are state of the art, some are standard, and others and very desirable to have (e.g. Autolab) and are rented out to other

research organizations. They also serve as the base equipment for several PhD thesis that were started during this project and are completed during the second phase of this project. The DRACOLA facility is currently housing an original full-sized drill rig that is envisioned to be used as both research and a training facility for industry and academia in the future. Building this worldwide unique facility was only possible with the help of this project; all details of the major work steps undertaken from March 2020 to the end of February 2023 are elaborated in detail below in Appendix 3.

Conclusions

The following achievements have been made during this project:

- Although originally planned to fund 15 graduate students, between 45 and 61 students were funded from this project at any given time between March 2020 and February 2023.
- 32 graduate students completed their studies with a Master's or a PhD in PE funded by this project.
- This project boosted the publications and research coming from the PE department. Over 110 contributions as a result of this specific project are listed in Appendix 1.
- Conference participation was high during this project. Eighty conference presentations are the direct result of this project (Appendix 2).
- This project was key to enhancing the output and strength of the UND PE Department and providing significant benefits to students during a difficult time with the pandemic.

Appendix 1: Journals and conference papers since 2020

1. A. Abarghani, M. Ostadhassan, P. C. Hackley, A. E. Pomerantz, S. Nejati, (March,2020), 'A chemo-mechanical snapshot of in-situ conversion of kerogen to petroleum' Geochimica et Cosmochimica Acta, 273:37-50.

2. A. Abarghani, T. Gentzis, B. Liu, S. Hohlbauch, D. Griffin, B. Bubach, M. Shokouhimehr, M. Ostadhassan, (April, 2020), 'Bacterial vs. thermal degradation of algal matter: Analysis from a physicochemical perspective', International Journal of Coal Geology: 103465.

3. A. Abarghani, T. Gentzis, M. Shokouhimehr, B. Liu, M. Ostadhassan, (February, 2020), 'Chemical heterogeneity of organic matter at nanoscale by AFM-based IR spectroscopy', Fuel 261:116454.

4. A. Abes, D. Irofti, G. Ifrene, S. Djemai, V. Rasouli, (June, 2021), 'The Impact of Geometric Attributes of Fractures On Fluid Flow Characteristics of Reservoir: A Case Study in Alrar Field, Algeria', 55th US Rock Mechanics / Geomechanics Symposium.A. Boualam, V. Rasouli, C. Dalkhaa, S. Djezzar, (July, 2020), 'Advanced Petrophysical Analysis and Water Saturation Prediction in Three Forks Reservoir, Williston Basin' SPLWA–750.

5. Aoun, A.E., Rasouli, V. & Khetib, Y. ***Assessment of Advanced Technologies to Capture Gas Flaring in North Dakota***. ***Arab J Sci Eng*** (2023). https://doi.org/10.1007/s13369-023-07611-4

6. Ala Eddine Aoun, Hui Pu, Youcef Khetib, Mohamed Cherif Ben Ameur, ***Natural gas flaring status in the Bakken shale play and potential remedial solutions***, **Fuel**, Volume 342, 2023, 127807, ISSN 0016-2361, https://doi.org/10.1016/j.fuel.2023.127807

7. A. Boualam, V. Rasouli, C. Dalkhaa, S. Djezzar, (July, 2020), 'Stress-Dependence of the Permeability and Porosity of Thin Bed Reservoir, Three Forks, Williston Basin', 54thUS Rock Mechanics/Geomechanics Symposium held Golden. Colorado, USA.

9. A. Chemmakh (September, 2021), 'Machine Learning Predictive Models to Estimate the UCS and Tensile Strength of Rocks in Bakken Field', SPE Annual Technical Conference and Exibition (ATCE 2021), Dubai, UAE.

10. A. Chemmakh, A. Merzoug, H. Ouadi, V. Rasouli, A. Ladmia, (Accepted to be published Oct 2021), 'Machine Learning predictive models to estimate the minimum miscibility pressure of CO2-Oil system', Abu Dhabi International Petroleum Exhibition & Conference (ADIPEC), Abu Dhabi, UAE.

11. A. Fadairo, G. Adeyemi, T. Ogunkunle, K. Ling, V. Rasouli, E. Effiong, J. Ayoo, (February 2021), 'Study the suitability of neem seed oil for formulation of eco-friendly oil-based drilling fluid', Petroleum Research (In press)

12. A. Fadairo, K. Ling, V. Rasouli, A. Adelakun, O. Tomomewo, (October 2020), 'An improved hydraulics model for aerated fluid underbalanced drilling in vertical wells', Upstream Oil and Gas Technology 5:100009.

13. A. Zandy, X. Wan, L. Jacobson, J. Hamling, N. Bosshart, V. Rasouli, (September, 2020), 'Understanding the Impact of Formation Properties on Stress Shadow in Multistage Hydraulic Fracturing Through Modeling and Simulation', AIChE Annual Meeting, Virtual.

14. A. Assady and H. Jabbari (December, 2020), 'Assessment of Permeability Hysteresis during Stress Loading/Unloading in Unconventional Reservoirs', Rock Mechanics and Rock Engineering.

15. A.G. Almetwally, H. Jabbari, (April, 2020), 'Experimental investigation of 3D printed rock samples replicas', Journal of Natural Gas Science and Engineering 76: 103192

16. A.G. Almetwally, H. Jabbari, (April, 2020), 'Finite-difference simulation of coreflooding based on a reconstructed CT scan; modeling transient oscillating and pulse decay permeability experiment', Journal of Petroleum Science and Engineering: 107260.

17. Bakelli, Omar, Chellal, Hichem Aimen Ketib, Aoun, Ala Eddine, Khetib, Youcef, Mellal, Ilyas, and Ling Kegang. "Integrated Reservoir Simulation and Discrete Fracture Network Modeling for Produced Water Source Identification in Tight Reservoirs, Case Study from the Bakken Formation, Williston Basin." Paper presented at the 57th U.S. Rock Mechanics/Geomechanics Symposium, Atlanta, Georgia, USA, June 2023. doi: https://doi.org/10.56952/ARMA-2023-0864

18. Chellal, Hichem A. K., Malki, Mohammed Lamine, and Sven Egenhoff. "Assessing the Feasibility of Above Injection Zone Pressure Monitoring of CO_2 Geologic Storage in the Williston Basin, North Dakota, USA." Paper presented at the International Geomechanics Symposium, Al Khobar, Saudi Arabia, October 2023. doi: https://doi.org/10.56952/IGS-2023-0359

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22. B. Jia, B, L. Jin, B. Mibeck, J. Sorensen, (March, 2020), 'An Integrated Approach of Measuring Permeability of naturally Fractured Shale', Journal of Petroleum Science and Engineering, 186.

23. C. Feng, Z. Yang, Z. Feng, Y. Zhong, K. Ling, (July, 2020), 'A novel method to estimate resistivity index of tight sandstone reservoirs using nuclear magnetic resonance logs', Journal of Natural Gas Science & Engineering.

24. C. Feng, Z. Yang, Z. Feng, Y. Zhong, K. Ling, (2020), 'A novel method to estimate resistivity index of tight sandstone reservoirs using nuclear magnetic resonance logs', Journal of Natural Gas Science & Engineering.

25. C. Li, H. Pu, X. Zhong, Y. Li, J.X. Zhao, (May, 2020), 'Interfacial interactions between Bakken crude oil and injected gases at reservoir temperature: A molecular dynamics simulation study', Fuel 276: 118058

26. F. Badrouchi, V. Rasouli, (October, 2020), 'Simulation of Settling Velocity and Motion of Particles in Drilling Operation', Journal of Pet. Sci. and Eng.: 196: 107971. DOI: 10.1016/j.petrol.2020.107971

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28. G. Han, G. Ma, Y. Gao, H. Zhang, K. Ling. 2021. A new transient model to simulate and optimize liquid unloading with coiled tubing conveyed gas lift, Journal of Petroleum Science and Engineering, 108394

29. G. Liu, L. Zeng, H. Li, M. Ostadhassan, M. Rabiei (May, 2020), 'Natural fractures in metamorphic basement reservoirs in the Liaohe Basin, China', Marine and Petroleum Geology 119

30. H. Fu, Lu. Yang, H. Liang, S. Wang, K. Ling, (October 2020), 'Diagnosis of the single leakage in the fluid pipeline through experimental study and CFD simulation', Jour. Of Pet. Sci. and Engg. 193:107437.

31. H. Fu, S. Wang, K. Ling, 'Detection of two-point leakages in a pipeline based on lab investigation and numerical simulation', Journal of Petroleum Science and Engineering (in review).

32. H. Lee, A. Abarghani, B. Liu, M. Shokouhimehr, M. Ostadhassan, (June, 2020), 'Molecular weight variations of kerogen during maturation with MALDI-TOF-MS', Fuel 269: 117452

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34. J. Zhao, L. Jin, NW. Bosshart, C. Wu,Y. Yu, K. Ling, Experimental and Simulation Study of CO2 EOR and Associated Storage in a Naturally Fractured Reservoir. 2021 AIChE Annual Meeting (Under Review)

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96. Pandey, V. J. Feb 3-5, 2022. Attend and presented in SPE's HFTC 2022: Pandey, V. J. and Rasouli, V. Estimating Fracture Containment in Layered Formations Using 3D Fracture Growth Assumptions. SPE-209151-MS.

97. Pandey, V. J. May 4-6, 2021. Virtually attended HFTC 2021 and presented the paper: Pandey, V. J. and Rasouli, V. Vertical Growth Of Hydraulic Fractures In Layered Formations SPE-204155-MS.

98. Pandey, V. J. May 4-6, 2021. Virtually attended HFTC 2021, Paper: Pandey V. J., Ganpule, S. and Dewar, S. Optimization of Coal Seam connectivity in Multi-Seam Pinpoint fracturing operations in Walloons Coal measures in Surat Basin. SPE- 204190-MS.

99. Pandey, V. J. Sept 21-23, 2021. Virtually attended ATCE 2021 (Dubai) and presented the paper: Pandey, V.J. Pressure Interpretation in Acid Fracturing Treatments. SPE-205990-MS. Also, Session Chair.

100. Pandey, V. J., October 27 – 29, 2020. Attended the SPE Annual Technical Conference and Exhibition (Virtual) and chaired session #38 on “Fracture Geometry and Fracture Driven Interactions”.

101. Pandey, V.J.: Society of Petroleum Engineers (SPE) 2020 Outstanding Technical Reviewer Award. List published in the November issue of SPE Production & Operations and the December issue of JPT.

102. Porlles, J. 2020 Geothermal Rising Conference Annual Meeting & Expo. Oral presentation.

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106. Khetib, Youcef, Rasouli, Vamegh, Rabiei, Minou, Chellal, Hichem Aymene Katib, Abes, Abdelmalek, Bakelli, Omar, and Ala Eddine Aoun. "Simulation of Drilling Challenges in Pressurized Saltwater Disposal: A Case Study in the Williston Basin." Paper presented at the 56th U.S. Rock Mechanics/Geomechanics Symposium, Santa Fe, New Mexico, USA, June 2022. doi: https://doi.org/10.56952/ARMA-2022-0531

107. Malki, M. L., Rasouli, V., Saberi, M. R., Mellal, I., Ozotta, O., Sennaoui, B., and H. Chellal. "Effect of Mineralogy, Pore Geometry, and Fluid Type on the Elastic Properties of the Bakken Formation." Paper presented at the 56th U.S. Rock Mechanics/Geomechanics Symposium, Santa Fe, New Mexico, USA, June 2022. doi: https://doi.org/10.56952/ARMA-2022-0147

108. Malki, M. L., Rasouli, V., Saberi, M. R., Sennaoui, B., Ozotta, O., and H. Chellal. "Effect of CO2 on Mineralogy, Fluid, and Elastic Properties in Middle Bakken Formation Using Rock Physics Modeling." Paper presented at the 56th U.S. Rock Mechanics/Geomechanics Symposium, Santa

Fe, New Mexico, USA, June 2022. doi: https://doi.org/10.56952/ARMA-2022-0148 Effect of Mineralogy, Pore Geometry, and Fluid Type on the Elastic Properties of the Bakken Formation

109. Jin Zhao, Lu Jin, Nicholas A. Azzolina, Xincheng Wan, Xue Yu, James A. Sorensen, Bethany A. Kurz, Nicholas W. Bosshart, Steven A. Smith, Chenyu Wu, James L. Vrtis, Charles D. Goreckiet al. "Investigating Enhanced Oil Recovery in Unconventional Reservoirs Based on Field Case Review, Laboratory, and Simulation Studies." Energy & Fuels 36.24 (2022): 14771-14788.

110. Ling K, Wu C, Zhao J, Afari S. Investigation of Middle Bakken Samples' Petrophysical and Geomechanical Properties Alternation During Super-Critical Co2 Submerge.

111. Jin, L., Bosshart, N., Ling, K., Zhao, J., Wu, C., Yu, Y., 2021. "Experimental and Simulation Study of CO2 EOR and Associated Storage in a Naturally Fractured Reservoir". AlChe Annual Meeting Abstract #743c, 2021 Annual Meeting.

112. Wan X, Jin L, Jiang T, Sorensen JA, Wu C, Merzoug A. Developing a High-Efficiency Method for Field-Scale Simulation of a Tight and Naturally Fractured Reservoir in the Williston Basin. InSPE/AAPG/SEG Unconventional Resources Technology Conference 2023 Jun 13 (p. D031S058R003). URTEC.

113. Aihar, A., N Bouabdallah, G Ifrene, D Irofti, 2023: Comparing Fishbone Drilling and Hydraulic Fracturing in Ultra-Low Permeability Geothermal Reservoirs. Paper presented at the 57th U.S. Rock Mechanics/Geomechanics Symposium, Atlanta, Georgia, USA.

Appendix 2: Conferences/Workshops attended since March 2020:

1. Abes, A. April 2021: NSI Technologies StimPlan™ Version 8 User Online Course.

3. Adebimpe, A.I. April 2021: NSI Technologies StimPlan™ Version 8 User Online Course.

4. Afari, S. April 2021: NSI Technologies StimPlan™ Version 8 User Online Course.

5. Afari, S., May 2021: Williston Basin Petroleum Conference Annual. Participated.

6. Ait Larbi, K. April 2021: NSI Technologies StimPlan™ Version 8 User Online Course.

7. Ait Larbi, K. May 2021: Williston Basin Petroleum Conference. Participated

8. Allam, L. July 2021: Geothermal Energy: Solutions for a Zero-Emissions Sustainable Energy Future, online.

9. Allam, L. July 2021: NExT Fundamentals of Data Analytics by Schlumberger, on campus.

10. Allam, L., 9-13 August 2021. Williston Basin Core Workshop. Grand Forks, ND.

11. Aoun, A. May 2021: Williston Basin Petroleum Conference, online.

12. Assady, A., Swati, S., Bellal, A. June 2021: ARMA 55th US Rock Mechanics/Geomechanics Symposium. Oral Presentation

13. Bakelli, O. April 2021: NSI Technologies StimPlan™ Version 8 User Online Course.

14. Bakelli, O. July 2021: NExT Fundamentals of Data Analytics class in campus, Schlumberger.

15. Bakelli, O. May 2021: Williston Basin Petroleum Conference, online.

16. Balaji, K. November 2020: ESRI Spatial Data Science: The New Frontier in Analytics. Participated.

17. Benabid, M., Ellafi, A., December 2020: SPE University of Belgrade Online Webinar Series. Oral Presentation.

18. Benouadah, N., May 2021: Williston Basin Petroleum Conference Annual. Participated.

19. Chellal Hichem., 8-10 December 2021. ResFrac Fundamental Training Course. Houston, TX. USA.

20. Chemmakh, A. May 2021: Williston Basin Petroleum Conference.

21. Chemmakh, A. SPE Annual Technical Conference and Exhibition, Dubai UAE, oral presentation.

22. Ellafi, A., November 2020: SPE University of Oklahoma Online Webinar Series. Oral Presentation.

23. Ellafi, A., October 2020: SPE Annual Technical Conference and Exhibition. Oral Presentation.

24. Ellafi, A., September 2020: Canada Unconventional Resources SPE Conference. Oral Presentations.

25. Ifrene, G. April 2021: NSI Technologies StimPlan™ Version 8 User Online Course.

26. Ifrene, G. June 2021: ARMA 55th US Rock Mechanics/Geomechanics Symposium. Poster Presentation

27. Ifrene, G. May 2021: Williston Basin Petroleum Conference, online.

28. Ifrene. G. July 2021: NExT Fundamentals of Data Analytics class in campus, Schlumberger.

29. Irofti, D. April 2021: NSI Technologies StimPlan™ Version 8 User Online Course.

30. Irofti, D. June 2021: ARMA 55th US Rock Mechanics/Geomechanics Symposium. Poster Presentation

31. Irofti, D. May 2021: Williston Basin Petroleum Conference, Participated.

32. Jimenez Jacome, M. December 2021: AGU Fall Meeting 2021. New Orleans, LA. Poster Presentation.

33. Jimenez Jacome, M. October 2021: GSA Connects 2021. Portland, OR, Oral presentation.

34. Laalam, A. May 2021: Williston Basin Petroleum Conference, Participated.

35. Larbi, A., 9-13 August 2021. Williston Basin Core Workshop. Grand Forks, ND.

36. Mellal, I. July 2021: NExT Fundamentals of Data Analytics by Schlumberger, on campus.

37. Merzoug, A. 3-5 November 2021, IADC Annual General Meeting, Fairmont Dallas, Dallas TX, United States. Participated.

38. Merzoug, A. 8–10 March 2022. IADC/SPE International Drilling Conference and Exhibition, Galveston, Texas, USA. Partcipated.

39. Merzoug, A. May 2021: Williston Basin Petroleum Conference, Participated.

40. Merzoug, A., 8-10 December 2021. ResFrac Fundamental Training Course. Houston, TX. USA.

41. Merzoug, A., 9-13 August 2021. Williston Basin Core Workshop. Grand Forks, ND.

42. Mouedden, N. April 2021: NSI Technologies StimPlan™ Version 8 User Online Course.

43. Mouedden, N. July 2021: NExT Fundamentals of Data Analytics class in campus, Schlumberger.

44. Mouedden, N. May 2021: Williston Basin Petroleum Conference, online.

45. Mouedden, N., 1-4 February 2022. SPE Hydraulic Fracturing Technology Conference and Exhibition. Woodlands, TX, USA. Participated.

46. Mouedden, N., 24-26 January 2022. SPE Virtual Workshop: Wells Deliverability Enhancement – Sustaining the Baseline. Participated.

47. Mouedden, N., 8-10 December 2021. ResFrac Fundamental Training Course. Houston, TX. USA.

48. Mouedden, N., 8–10 March 2022. IADC/SPE International Drilling Conference and Exhibition, Galveston, Texas, USA. Partcipated.

49. Ouadi, H. May 2021: Williston Basin Petroleum Conference, Participated.

50. Ouadi, H., 24-26 January 2022. SPE Virtual Workshop: Wells Deliverability Enhancement – Sustaining the Baseline. Poster Presentation.

51. Ouadi, H., 3-5 November 2021, IADC Annual General Meeting, Fairmont Dallas, Dallas TX, United States. Participated.

52. Ouadi, H., 8–10 March 2022. IADC/SPE International Drilling Conference and Exhibition, Galveston, Texas, USA.

53. Ozotta, O. Hazards in Hindsight: Lessons for the Future. AEG 63rd Annual Meeting. Poster presentation.

54. Ozotta, O. June 2021: ARMA 55th US Rock Mechanics/Geomechanics Symposium. Poster Presentation

55. Ozotta, O. March 2021: GHGT 15th International Virtual Conference on Greenhouse Gas Control Technologies. Poster presentation

56. Ozotta, O. October 2020. Geothermal Rising Annual Meeting and Exhibition. Participated.

57. Ozotta, O. October 2020. Geological Society of America Connects Online. Oral presentation

58. Ozotta, O. September 2020: Navigating the unknown. NABG 39th Annual Technical Conference. Poster presentation.

62. Pandey, V. J. Nov 16-18, 2021. Committee Member. Virtual Asia Pacific URTEC, Brisbane, Australia.

63. Pandey, V. J. Nov. 2021: Elected SPE's Distinguished Lecturer for 2022-23 Term.

64. Pandey, V. J. Oct 3-5, 2022. Session Chair in SPE's ATCE to be held in Houston, 2022.

69. Porlles, J., July 2021: NExT Fundamentals of Data Analytics class in campus, Schlumberger. Participated

70. Porlles, J., May 2021: Williston Basin Petroleum Conference Annual. Participated.

71. Porlles, J., October 2020: 2020 Geothermal Rising Conference Annual Meeting & Expo. Oral presentation.

72. Porlles, Jerjes., November 2021: Workshop on Data Science – Geothermal Modeling SPE-Europe

73. Prasad Pothana, 10-15 December 2021, Short Course, Multiscale Modeling and Simulation: Scalable Simulation of Nonlinear Coupled Processes in Heterogeneous Fractured Porous Media, TU Delft, The Netherlands. Participated.

74. Salami R July 2021: NExT Fundamentals of Data Analytics class Online, Schlumberger.

75. Song, X. August 2021: 5th Annual Refrac Wells 2021. Oral Presentation.

76. Song, X. August 2021: North American Liquids-Rich Basins 2021. Participated.

77. Venugopal, K, July 2021: SPE Data Science Convention, Houston, TX, Participated.

78. Venugopal, K, July 2021: URTeC, Houston, TX, Participated and Presented a theater presentation on Accelerating AI adoption for energy companies for Schlumberger

79. Venugopal, K. March 2021: Machine Learning in Oil and Gas Conference, Houston, TX, USA, Panel discussion: Machine Learning case studies and practical insight in the brave new world of Covid-19.

80. Zandy, A. November 2020: AIChE Annual Meeting. Oral Presentation.

Appendix 3: Drilling and Completion Labs (DRACOLA):

As part of this project, funding was granted for the setup and installation of the DRACOLA lab. The lab is located within the old Minnkota Power building in Grand Forks, ND. The Drill Lab / Research Facility is a 17,000 sq. Ft warehouse (Figure 1, left). The lab equipment was donated to the University of North Dakota Petroleum Engineering Department by Terratek in October 2019 by its founder/CEO Sid Green. The DRACOLA lab is poised to be one of the leading labs for experimental field-scale drilling (Figure 1, right). The DRACOLA lab includes a wellbore pressure vessel, a full-scale drill rig and mud pumping capabilities for measuring the performance, wear, deviation and dynamics of full-size drill bits tested at overbalanced or underbalanced drilling conditions at simulated depth.

The DRACOLA lab at UND will play a crucial role in the development of research in drilling and completion for any drilling conditions worldwide. DRACOLA is the only test facility in the world with the capabilities to drill at real world conditions. The lab also will verify analytical modeling, field scale drilling, with costs one-tenth to one-hundredth of field tests, along with the reduced danger of hole fouling. DRACOLA offers low-cost and timely screening of novel drilling and completion techniques. The facility will provide industry services to optimize drilling operations, train hands on practical aspects of drilling operation and machinery to industry people, educate undergraduate students regarding practical side of drilling while they are taught in-class theories, and conduct research in the areas of industry needs by graduate level students.

Figure 1: DRACOLA Facility (left) and equipment in the facility, March 2022 (right).

As of March 2022, significant progress has been made in setting-up DRACOLA (see Figure 2). There was a four-member team working on the lab set-up (Mr. Harry Feilen, Mr. Lannie Fladeland, Mr. Doug Schmidt and Mr. Robert Jensen) along with several dedicated Ph.D. students. Some of the progress made since Aug 2021 are listed as follows. These efforts continue into the successor project.

- Mud tanks and prime pumps are being wired into the SCR House.
- All valves on the mud tank side are being upgraded to pneumatic valves and wired to control panel in the drillers cabin.

- The smaller Gardner Denver triplex mud pump has been rebuilt and is being installed under the drillers cabin.
- A new 125HP motor and VFD has been purchased for the drive motor to the Gardner Denver mud pump to replace the hydraulic system it had, as too many parts were worn out to be useful.
- The 600v generator is being installed on the Caterpillar engine located in the basement to provide power to the large Tri-plex mud pump.
- The P&ID drawings are being finalized.
- The sample holder, cuttings screens, grating, rails and support beams have been placed.
- The top drive 250HP motor has been purchased and being installed on the top drive system along with a VFD for control.
- The top drive transmission is being rebuilt, as during shake down major wear was discovered and new parts were needed.
- The SCR motor control house is connected to the grid and all the support equipment motors are being connected back to the SCR house.
- The drillers cabinet (drillers control room) is being wired and connected to the rig.
- The LabVIEW data system for operation and data collection is being worked on.
- The LabVIEW program is being written.
- Multiple partnerships with leading industry companies/experts continue to be fostered.
- Two fulltime classes, taught at the lab are continuing and have increased enrollment.

(a) (b)

(c) (d)

Figure 2: (a) New valve upgrade; **(b)** Driller control chair and room; **(c)** Gardner Denver mud pump rebuilt; **(d)** 600V generator end being installed by EERC

EERC has joined the team. They inquired as to the possibility of a few of their people coming to work in the lab as they had some extra time available. We are looking forward to working with EERC during the setup of DRACOLA.

Already, many undergraduate and graduate students have worked in the lab towards their project design and elective courses by helping in lab set up, maintenance of different equipment and doing calculations for different sections of the lab. This has been a great practical and hands on experiences for the students and we expect this to grow further when the lab is operational. The expectation is to upgrade the lab to the latest automated status of the current oil and gas industry.

As of the end of this project, work on getting the facility fully operational is continuing.