Drilling Simulator Advancement

Final Report

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Executive Summary

Academic advancement and industry exposure via WPX Drilling Simulator allows students to gain hands-on experience with common drilling practices, specific drilling problems, and well control events. This project’s scope rests upon the successful implementation of both the DrillSIM 5000 simulator and the 20 DrillSIM 5 workstations into previously established courses in the Petroleum Engineering program, such as Introduction to Petroleum Engineering, Basic Drilling Engineering, and Drilling Fluids Lab. In addition, ensuing construction of a business model for an industry based well control course demonstrates the profitability potential the simulator holds for the University of Wyoming. Successful completion of this project has been achieved, and team members are now able to demonstrate fundamental technical skills pertaining to both hardware and software components of the drilling systems, applications of current drilling practices, evaluation of drilling data, and identification and resolution of multiple well control scenarios. As such, future students enrolled in the listed courses will also gain technical knowledge associated with the simulator.

Project members initially chose various fields from different regions in the United States to study and simulate. Although field research represented just a minor fraction of the project, the associated drilling practices and problems derived from the field research were imperative to accurately provide a realistic and applicable drilling simulation. Input parameters on the DrillSIM 5 workstations were evaluated in order to properly gauge the further research required to create an accurate drilling simulation. Following simulations on the DrillSIM 5, formation data was transferred to the DrillSIM 5000.

The DrillSIM 5000 system was developed to meet the requirements of operators, drilling contractors, and service company personnel. This fact draws the conclusion that it is very important to keep the industry involved throughout the enactment of this project and the future of. Moving forward, the WPX Drilling Simulator presents a unique opportunity for the University of Wyoming to stay connected with the oil and gas industry by providing well control courses and teaching students. The results of the work conducted by this team will help kick-start the movement toward technical learning and industry exposure.

The teaching materials developed for Introduction to Petroleum Engineering, Basic Drilling Engineering, and Drilling Fluids Lab will serve as a hands-on learning experience for undergraduate students. The addition of lab components in these courses will allow students to experience the physical meaning behind the topics presented in the course material. Teaching materials received from Diamond Offshore and Colorado School of Mines have served as guidelines for the creation of comprehensive lesson plans.

Another important element considered in the duration of this project was the satisfaction and approval of the stakeholders involved. The stakeholders potentially involved in the project were represented by a wide array of individuals; from University professionals to prospective students and industry personnel alike. Moving forward, all parties involved will benefit from the work conducted on the WPX Drilling Simulator.
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Nomenclature

- PETE: Petroleum Engineering
- PETE 2050: Introduction to Petroleum Engineering
- PETE 3255: Basic Drilling Engineering
- PETE 3265: Drilling Fluids Lab
- UWAA: University of Wyoming Alumni Association

Special Thanks

Special thanks goes to supporting faculty within the Department of Petroleum Engineering, WPX Energy, Colorado School of Mines, and Diamond Offshore for their willingness to collaborate with students. In addition, Group 2 would like to thank Professor Ken Baum for serving as both a mentor and a positive influence throughout this project.
1 Introduction

The main goal of this project was to help broaden the scope of education and implement technical knowledge into the Petroleum Engineering program at the University of Wyoming. Ultimately, the addition of drilling simulator lab components in previously established courses will help students understand the importance of hands-on experience and technical knowledge. Advancement of the drilling simulator will make use of a state of the art piece of equipment that has a wide range of teaching capabilities.

To begin the project, team members conducted research on various fields to become familiar with the background, geology, and common drilling practices and problems associated with each field. The five areas of research included the Bakken, Salt Creek, Eagle Ford, Gulf of Mexico (Upper Miocene), and Jonah fields. Common problematic drilling conditions within each of these fields will further be discussed in the Deliverables section.

After the initial formation research, it was important for team members to understand the input parameters of the WPX Drilling Simulator to create comprehensive and useful course material. Descriptions of the course material created for previously established courses, student involvement, and a future business model involving the simulator will be discussed in this report. In addition, information collected based on a survey conducted in several PETE classes will be discussed to showcase the importance of this project.

In order to ensure timely project completion, team members were required stay up to date with the project schedule (Gantt Chart) and follow the path outline via the workflow diagram. The Gantt Chart and workflow diagram are included in this report to define project milestones, present a generalized timeline, and portray an overview of the order of various completed tasks.

A risk assessment was conducted to understand the risks within the project planning and any potential risk that could be encountered throughout the implementation of the project results. Project stakeholders were considered in the risk analysis, as they have a large impact on the success of this project moving forward. For example, the team still needs supporting faculty and underclassmen to take over and implement the material developed by the team.

This report also discusses the results of the project and what the team members have done to keep the project moving forward. After gaining full access to the DrillSIM 5000, team members were able to make substantial progress in learning the system and creating course material. Collaboration with organizations outside of the University was also a large part of this project, as team members were able to further understand the importance of comprehensive teaching materials. Moving forward, the results of this project will positively impact the Petroleum Engineering program at the University of Wyoming.
2 Primary Deliverables

2.1 Field Research

Team members initially chose five fields of research to gain knowledge of local geology, common drilling practices, and problematic drilling conditions. The Bakken, Salt Creek, Eagle Ford, Gulf of Mexico (Upper Miocene), and Jonah fields were chosen as areas of research. Five individual fields were chosen to provide a wide range of problems and information to serve as a foundation for course material. Problematic drilling conditions in these fields are listed below in Table 1.

<table>
<thead>
<tr>
<th>Field</th>
<th>Problematic Drilling Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bakken</td>
<td>wellbore stability, gas influx</td>
</tr>
<tr>
<td>Salt Creek</td>
<td>lost circulation, stuck pipe</td>
</tr>
<tr>
<td>Eagle Ford</td>
<td>pore pressure destabilization, natural fractures</td>
</tr>
<tr>
<td>Gulf of Mexico (Upper Miocene)</td>
<td>rig failure, stuck pipe</td>
</tr>
<tr>
<td>Jonah</td>
<td>bit wear, reservoir influx (kicks)</td>
</tr>
</tbody>
</table>

These problematic conditions served as the basis for a Basic Drilling Engineering accessory lab, which will be further discussed in the next section. While students will be learning about problematic drilling conditions in PETE 3255, they will have the opportunity to see the changes in many different parameters while drilling ahead. Students will gain the visual and hands-on experience by using the main panel on the DrillSIM 5000, seen in Figure 1.

Figure 1: DrillSIM 5000 Panel
2.2 Course Material

Incorporation of the WPX Drilling Simulator to enhance education within the Petroleum Engineering Department was accomplished through the development of multiple academic style teaching experiences. The team has developed a total of seven accessory labs to be incorporated into the current curriculum. These labs will play an integral role in furthering education in PETE 2050, 3255, and 3265. Each lab builds upon fundamental concepts developed in each class and will aid students in understanding the physical meaning behind the theory. Materials developed for these courses will involve the use of the DrillSIM 5 workstations and the DrillSIM 5000, seen in Figure 2.

Figure 2: DrillSIM 5 Workstations (Top) & DrillSIM 5000 (Bottom)
The Introduction to Petroleum Engineering accessory lab will focus on the key elements of a drill site and drilling operations. To begin, students will conduct a pre-lab assignment that will teach the basic components of a drilling rig. In the pre-lab, students will identify all components of the well control system, the fluid system, and the major mechanical components of the rig. During the first part of the lab, students will be taken on a fly around of the drilling site on the DrillSIM 5000. This will serve to show the placement of each system and explain the mechanical elements of a rig. Next, students will see how the process of drilling is carried out and be able to observe the flow path of drilling fluid as it travels through a top drive, down the drill string, out of the bit, and finally up the annulus while normal circulation is carried out. After the primary demonstration, students will perform simple tripping and drilling operations on the DrillSIM 5. For this portion of the lab, an instruction sheet will be provided so that students can conduct drilling operations with minimal support from an instructor. After concluding the physical lab, a post-lab assignment will ask students to define each component identified in the pre-lab and that component’s function in the drilling system. This lab will serve as the foundation from which students will further develop their education utilizing the WPX Drilling Simulator.

Basic Drilling Engineering will provide students with the bulk of their experience on the WPX Drilling Simulator. The first lab for PETE 3255 will serve to familiarize students with the operation of both the DrillSIM 5 and the DrillSIM 5000. In the pre-lab assignment, students will be given a comprehensive rig diagram and will need to identify all rig components as well as define the function of each component. The physical lab will require students, in groups of three, to properly line up the flow path for normal circulation on the DrillSIM 5000. Each member of the group will then drill ahead and make a connection. Simultaneously, the students that are not working on the DrillSIM 5000 will be drilling ahead on the DrillSIM 5 stations independently. The post-lab assignment will ask students to determine a mud weight for given conditions, pipe and annular capacity given well bore and tubular dimensions, flow rate for given liner and stroke rate, maximum hook load for given number of lines, tensile strength of drill line, and safety factor. This lab will establish the fundamental operations students will need to know before moving forward in with the remainder of the PETE 3255 labs.

The second lab incorporated into the Basic Drilling Engineering course will provide fundamental understanding of well control circumstances. The pre-lab assignment will consist of a number of calculations that will prepare the students for completing a kill sheet and provide students with indications that a well control situation is developing. During the physical lab, students will drill ahead, identify that the formation is no longer in control, and perform a hard shut-in. This operation will be performed on both the DrillSIM 5, individually, and on the DrillSIM 5000 as a three member team. In the post-lab assignment, students will perform calculations to estimate the kick size, composition, necessary kill weight mud, loss of hydrostatic pressure due to gas cut mud, and maximum surface pressure due to a kick in water based mud. This lab will prepare students for the second well control operation.
The second well control lab will put students into a realistic scenario where they will have to identify and remediate a well control situation. As a pre-lab assignment, students will write a short essay defining kick identification, well kill techniques, complications that can arise during a well kill operation, and how to check that a well is under control. In the physical lab, students will drill ahead, take a kick, shut-in the well, complete a kill sheet for the method of their choice and kill the well. While this is performed on the DrillSIM 5, groups of 3 will be tested on identifying a kick and performing a soft shut-in on the DrillSIM 5000. Upon completion of the two well control labs, students will have an understanding of well control concurrent with the fundamental level certification previously recognized by the International Association of Drilling Contractors.

The next series in the Basic Drilling Engineering lab portion will assist students in learning and understanding bit hydraulics. To help students learn about bit hydraulics and the impact it has on drilling optimization, they will complete a pre-lab assignment to calculate the hydraulic property changes for various sizes of nozzles and pump speeds. This lab will serve to demonstrate the effects that changes in nozzle size and pump rate have on drilling operations. On the DrillSIM 5000, students will take part in a short demonstration where they will observe changes in drilling properties as nozzle size and pump speed are varied. Next, students will perform a similar operation on the DrillSIM 5 where they will monitor and record property changes. Using this information a post-lab write-up will be performed where students will relate the changes they observed to changes in the hydraulic properties in order to predict whether nozzle size increased or decreased from one model to the next.

The final Basic Drilling Engineering lab will educate students about diagnosing downhole problems during drilling operations. During the pre-lab assignment, students will complete a matrix that indicates relative changes that can be observed from surface that would correlate to a possible downhole problem. In the physical lab, students will be tested by the instructor on the DrillSIM 5000 in pairs. The instructor will utilize the malfunctions menu in the software package to create a downhole problem, as seen in Figure 3.

Figure 3: DrillSIM 5000 Malfunctions
The student will diagnose the malfunction and determine a plan to remediate the problem. As a final element from the lab, students will prepare a group presentation to define the problem they encountered, remediation for the problem, and possible prevention techniques.

In Drilling Fluids Lab, students are introduced to the composition and properties of commonly used drilling fluid additives. To assist students in observing the effects that these additives have on drilling operations, a number of different simulations will be executed. Students will be able to observe the changes in drilling properties due to weight and rheological changes in the drilling fluid. This will be an observation based lab where students will take part in drilling ahead on the DrillSIM 5000 while mud properties are varied. The instructor will utilize the Mud System Initialization screen to change the fluid parameters as students drill ahead, as seen in Figure 4. It will be expected that students incorporate the learning observed in the WPX Drilling Simulator lab into the previously established lab reports.

![Mud System Initialization](image)

Figure 4: Drilling Fluid Parameters (DrillSIM 5 & DrillSIM 5000)
Collectively, these labs will provide students with an alternative learning method as they explore the various concepts in the classroom. The simulator will reinforce concepts taught in the courses and allow students to observe how drilling operations are carried out. Along with learning basic rig layout and well bore construction, students will learn how to handle well control situations, optimize bit hydraulics, diagnose downhole malfunctions, and manage fluid systems. These crucial lessons will be taught in a highly effective manner due to incorporation of the WPX Drilling Simulator.

2.3 Group Project & Student Surveys

In addition to the lab components created for each of these courses, a proposal for implementing a group project in Basic Drilling Engineering has been explored. This will involve students researching a field and designing a well in that field. Although this project will be very time consuming, students will have the opportunity to work on this project throughout the entire semester. Students will be allowed access to drillinginfo.com to conduct their research and successfully complete their project. Figure 5 outlines some of the data which may be found on the site. In addition to drilling data, a large database of subsurface information will be available to students for their research.

![drillinginfo.com Outline](Image)

Another very important piece of this project was student and faculty involvement. Team members attended Introduction to Petroleum Engineering and Wellbore Operations to gather information based on the students that are currently enrolled in those courses. The survey was based on demographics, types of learners, preferred petroleum disciplines, and their awareness of the WPX Drilling Simulator. The results were based on 1 Freshman, 10 Sophomores, 29 Juniors, and 15 Seniors:
Do UW PETE Students Know We Have a Drilling Simulator?

![Figure 6: WPX Drilling Simulator Awareness](image)

PETE Students Learning Style

![Figure 7: Types of Learners](image)
These results showcase the importance of this project. Unfortunately, 30% of students were unaware of the WPX Drilling Simulator. This percentage will decrease significantly upon successful implementation of this project. Over 35% of students enrolled in Petroleum Engineering are interested in pursuing drilling engineering. The WPX Drilling Simulator will provide students with the opportunity to further explore drilling engineering and understand the physical implications behind the theory.

3 Business Model

The cost of higher education is rapidly increasing while the students see little return on their investment that justifies pursuing an advanced degree. To combat this condition, higher education institutions need to focus on developing programs that make students more versatile and provide a wide skill set to accommodate the broad economic climate. One way this can be accomplished is to develop programs that enhance advanced technical abilities. Generating multiple levels of a practical drilling course would provide students with a valuable skill set making them far more versatile in the industry and greater preparing them for a career within the drilling sector of the energy industry.

While student preparedness is the primary role of higher education, the WPX Drilling Simulator also holds the ability to generate an economic revenue stream when applied to private education via industrial partners. Simulator based programs serve to teach various stages of drilling skill sets as well as provide instruction and certification for all levels of well control. These highly economic programs could be implemented at the University of Wyoming and enhance the national profile of the University. Development of such a program would take time and investment to acquire staff that is appropriately trained and certified to instruct well control.
4 Workflow

Figure 9: Project Workflow Diagram
5  Project Schedule (Gantt Chart)

The Gantt chart served as a useful tool to help the team stay organized and focused on the tasks at hand. As milestones are reached, they are documented at the right side of the chart and labeled with a star. Various tasks are outlined on the left side of the chart, with the associated length and completion dates to the right.

As seen in the project schedule, many milestones have been completed and important deadlines have been met. Major milestones from the spring semester included the DrillSIM Open House, Beta Testing Sessions, and the Senior Design Symposium. Throughout this project, all team members have contributed to reaching the ultimate goal of completing the project in a timely manner.

Although this project has been successfully completed, there were many changes to the original schedule that impacted the final results. For example, the scope of the project was modified when the team did not gain full access to the simulator in time to properly develop an independent advanced drilling course. Since the team did not gain full access to the DrillSIM 5000 until mid-March, development of course materials involving the use of the DrillSIM 5000 was significantly delayed. As a result, the learning curve on the DrillSIM 5000 was fast and steep, but the team managed to successfully develop course material.
6 Risk Analysis

Risk has played an important role in this project, since team members were not entirely certain if they would be able to produce quality results based on the associated risks. Ultimately, organization and management skills led to the successful mitigation of the risks associated with this project. The project was initially divided into six phases as well as a miscellaneous phase to assess risk associated with each phase. Although risk letters and numbers are useful, the list of risks became extensive and difficult to assign letters and numbers. As such, the risk matrix seen in Figure 11 was modified to better understand the risks associated with this project.

![Risk Matrix](image)

Figure 11: Risk Matrix

Each color in the matrix is associated with a severity: Blue: Eliminated Risk, Green: Low Risk, Yellow: Medium Risk, Orange: Serious Risk, and Red: High risk. The risks presented on the following page are described by the assigned color. The risks listed on the left side of the table are the most recent risks at the conclusion of the project. Most risks have been mitigated, although a few remain. Figure 12 shows the results of the previously described risk analysis:
Many different risks were encountered throughout this project. The most difficult and time consuming risks were access issues, lack of expertise in designing course materials, and the successful implementation of results. Although access issues have been resolved, the lack of expertise remains among underclassmen expanding on the results. Time was also a very dangerous risk, as it was directly related to the access issues. The team was able to make the most out of the remaining time and develop comprehensive course material that will positively impact previously established courses. Successful implementation of this project still remains as a risk, since this process is in the hands of future students and faculty. Although underclassmen have taken initiative to implement the results, the future of this process is still uncertain.

The most useful risk management application for this project was team work. Collaboration with many different people, groups, and entities required careful coordination as a team. As the project concluded, the risks will became better understood, which allowed room for risk mitigation. Although most risks presented in this project were manageable, the future of the project results are still uncertain.

<table>
<thead>
<tr>
<th>Risk</th>
<th>Risk Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access to Drilling Simulator</td>
<td>Stayed motivated</td>
</tr>
<tr>
<td>Failed communication</td>
<td>Kept all parties up to date on project status</td>
</tr>
<tr>
<td>Failure in diplomacy</td>
<td>Discussed the plan and showcasing results</td>
</tr>
<tr>
<td>Software Issues</td>
<td></td>
</tr>
<tr>
<td>Unable to resolve software issues</td>
<td>Worked closely with IT</td>
</tr>
<tr>
<td>Failure of network integration</td>
<td>Understood what the DS network needed to function</td>
</tr>
<tr>
<td>Lack of expertise</td>
<td>Kept contact between IT &amp; Drilling Systems</td>
</tr>
<tr>
<td>Learning Simulator</td>
<td></td>
</tr>
<tr>
<td>Software Malfunctions</td>
<td>Nature of uncertainty, kept team involved to avoid issues</td>
</tr>
<tr>
<td>Well Design on Simulator</td>
<td></td>
</tr>
<tr>
<td>Software inability</td>
<td>The team understands the capabilities of the system</td>
</tr>
<tr>
<td>Software not compatible</td>
<td>Worked with IT to make sure the software is updated on all systems</td>
</tr>
<tr>
<td>Instructional Model Development</td>
<td></td>
</tr>
<tr>
<td>Lack of experience</td>
<td>Sought help from professors and outside organizations</td>
</tr>
<tr>
<td>Unrealistic scope</td>
<td>The scope has changed, but is realistic</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>Made the most out of the remaining time</td>
</tr>
<tr>
<td>Results moving forward</td>
<td>The group needs underclassmen to take over their work</td>
</tr>
<tr>
<td>Unknown Risks</td>
<td>Teamwork</td>
</tr>
</tbody>
</table>

Figure 12: Risk Categorization
7 Summary

This report summarized the results obtained from successfully creating course material utilizing the WPX Drilling Simulator. Although the scope of this project has changed from creating an individual course to implementing the simulator in previously established courses, the overall goal remains the same: to broaden the scope of education and enhance technical skills. The creation of course material coupled with a preliminary business model make for an exciting future for undergraduate students and industry professionals.

The team has created comprehensive course material to be used in Intro to Petroleum Engineering, Basic Drilling Engineering, and Drilling Fluids lab. As a result, undergraduate students enrolled in the Petroleum Engineering program will be able to experience and learn from the WPX Drilling Simulator. In addition to the seven labs created as course material, a proposal for a group project to be conducted in Basic Drilling Engineering has been explored. In this project, students will gain technical skills by designing a well based on research conducted using Drilling Info. From an educational perspective, this will allow students to further understand the role of a drilling engineer. On May 13, 2016, UWAA will be hosting an event involving team members giving demonstrations on the DrillSIM 5000. This event will help students gain experience with the simulator and also give team members a chance to connect with industry professionals from UWAA.

The workflow diagram and Gantt Chart were be used to stay on schedule and complete various tasks accordingly. Extensive field studies allowed the team members to build a foundation of knowledge to create course material. Results from the risk assessment revealed that the team collaborated with many stakeholders to create a finalized product. Satisfaction of the stakeholders involved was crucial, as the final results seemed appealing to a large number of individuals.

8 Conclusion

As previously stated, this report’s scope focused on the successful integration of the DrillSIM 5 and DrillSIM 5000 in the Petroleum Engineering program. By implementing the WPX Drilling Simulator into student and industry enrichment, future drillers and drilling engineers alike will be better prepared as they enter the work force. While individual growth achieved with the addition of lab components in previously established courses is obvious, the University of Wyoming would also benefit financially if a business model is implemented for the industry based courses. With this being said, underclassmen and faculty within the Department of Petroleum Engineering at the University of Wyoming are now in charge of implementing the results of this project.
9 Recommendations

The successful completion of this project is an admirable accomplishment and the future of this project could have significant impact on the Department of Petroleum Engineering at the University of Wyoming. Students and faculty involved in Petroleum Engineering will significantly benefit upon the integration of the WPX Drilling Simulator. The benefits stemming from this project will serve as motivation for underclassmen to continue progress and encourage faculty to be involved. In the future, Group 2 recommends the involvement of underclassmen and faculty to continue integrating the WPX Drilling Simulator. In addition, the expansion of simulator hardware and software will allow students to gain experience with the most current technology.

10 References (Not Shown in Document)

