UNIVERSITY OF LOUISIANA
AT LAFAYETTE

STEP Committee

Technology Fee Application

Transforming Engineering Education: Enhancing Learning through Immersive Virtual Reality Technology
Title

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Name of Submitter
(Faculty or Staff Only)

College of Engineering
Organization

Title: Transforming Engineering Education: Enhancing Learning through Immersive Virtual Reality Technology
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ABSTRACT (250 words or less):

The purpose of this proposal is to transform engineering education through the utilization of immersive virtual reality technology. This proposal requests funds for 10 VR setups, including 10 Meta Quest 2 headsets, required desktops and monitors, and 10 lifetime licenses of a three-phase crude oil separator simulation for $63,726.58. This equipment with software can accommodate 10, 20, or 30 students at a time. Integrating this simulation across various classes throughout the college will enable students to bridge the gap between theoretical knowledge and practical applications, foster engagement, support a deeper understanding of complex concepts, and develop critical thinking and technical skills. Incorporating virtual reality (VR) aligns with the requirements of ABET accreditation and supports the university's ADVANCE goals by promoting innovation in teaching and learning. Across 23 classes, this will benefit over 1000 students per year throughout several departments in the college of engineering. In addition, VR technology enhances recruitment activities by creating memorable and impactful first impressions, potentially reaching over 2000 prospective incoming students per year. And finally, VR promotes industry collaboration by having current, cutting-edge technology that allows opportunities for continuing education or professional workshop developments. This investment holds immense potential to revolutionize teaching and learning practices within the engineering college, empowering students to excel in their respective fields.

Purpose of grant

The purpose of this proposal is to enhance engineering education at UL Lafayette through the use of virtual reality (VR) immersive technologies. Manufacturing stands as one of the most expansive topics in engineering, encompassing all disciplines while emphasizing design and processes advancements in many different industries. However, engineering education primarily focuses on industrial applications involved in chemical and compound manufacturing which presents challenges in bringing real equipment and systems into the classroom environment for student engagement.

Virtual reality can generate highly authentic and immersive chemical processes and equipment simulations, enabling students to explore these intricate systems safely and interactively. It provides a controlled environment facilitating hands-on experience when diverse equipment and operations are inaccessible to students. VR has been used extensively in other educational fields, such as health, general education, and sciences.[1] Still, it has not gained traction in engineering education[2], albeit many chemical and petrochemical industries utilize immersive VR technologies for operator training, such as BP, ExxonMobil, Honeywell, Shell, and BASF. Studies suggest that virtual reality training outperforms traditional training in fostering technical and practical skills development.[3]

Furthermore, in conventional curriculums, students design processes or specific equipment for their capstone design project, even though they may have never had the opportunity to visit or engage with a fully operational processing plant or any equipment. These designs are rooted in steady-state conditions, representing ideal scenarios that do not accurately reflect the complexities of real-world industrial operations. Core subjects such as material and energy balances, thermodynamics, heat transfer, transport phenomena, and safety are taught linearly, focusing on individual concepts and progressively building upon them. To ensure students are adequately prepared, strict measures are taken to establish prerequisites and co-requisites for these subjects to ensure their success. Figure 1 illustrates core chemical engineering subjects' typical pre- and co-requisite requirements. However, this linear approach often overlooks the interconnectedness of these subjects (Figure 2) and fails to provide the necessary context for understanding their real-world applications. Consequently, students and instructors alike often neglect dynamic factors that significantly influence the performance and reliability of chemical processes, such as process fluctuations, equipment failures, and changing operating conditions, which encompass all subjects simultaneously. As a result, there is a need to bridge this gap and provide a more comprehensive and holistic understanding of these subjects.

This is where virtual reality can make a significant difference. The VR technology implemented with the right software allows for immersive and interactive simulations that accurately represent the complexities of chemical processes. By engaging students in realistic scenarios, VR can provide a holistic understanding of how different concepts and core subjects are interconnected and how they influence processes. The use of VR can enable students to actively engage with these dynamic factors and allow them to make decisions and draw conclusions based on their understanding of the subject matter in a real-world context. They can troubleshoot issues, observe causes and effects, optimize process parameters, and evaluate the implication of their actions within a risk-free environment. This active participation enhances the critical thinking skills necessary for their success and prepares them for real-world challenges as engineers.

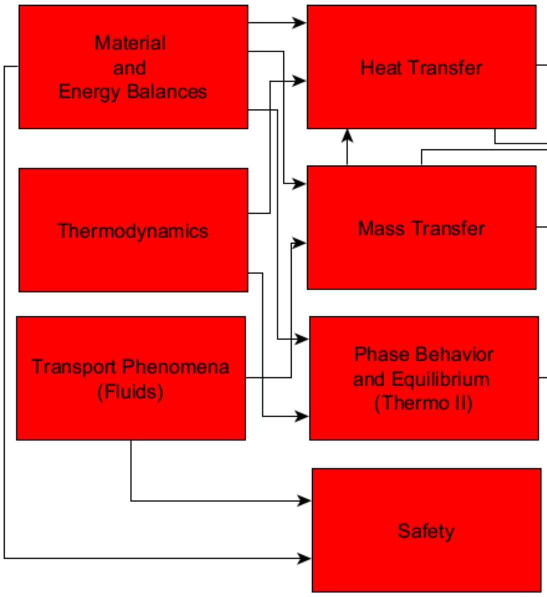


Figure 1: Engineering Core Subject Lineage

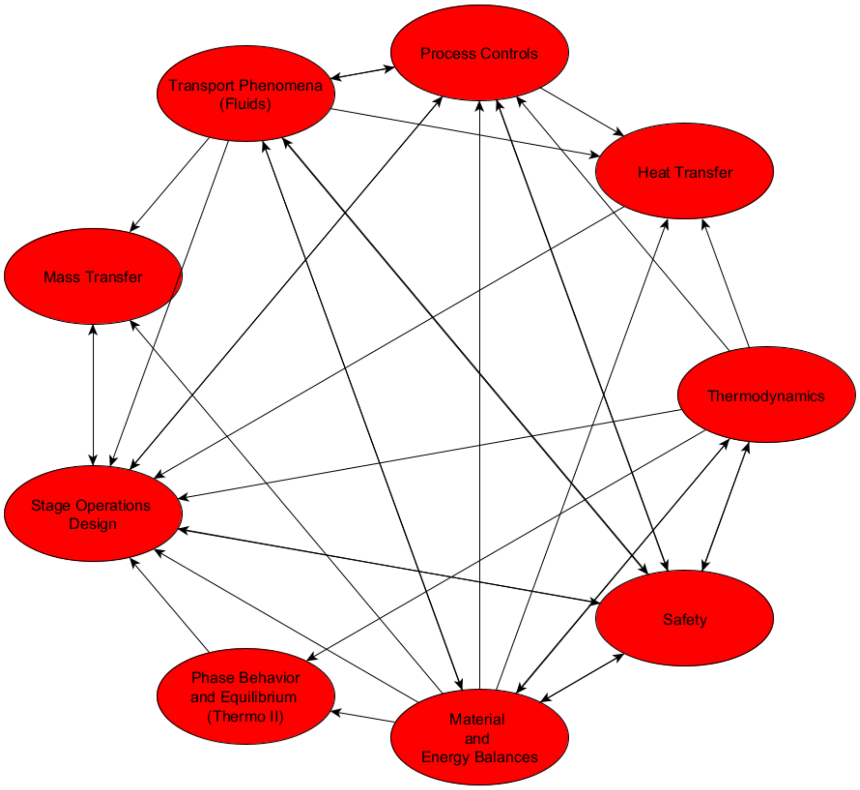


Figure 2: Engineering Core Subject Network

Furthermore, undergraduate students have limited exposure to actual industrial environments due to various factors, including safety and security considerations, confidentiality and intellectual property, and adherence to regulatory compliance. As a result, students face challenges in comprehending the intricacies and complexities inherent to physical equipment. When teaching, the primary focus is typically on understanding the phenomena occurring within the equipment, with design parameters such as sizing discussed, but operational parameters receive limited attention. Individual pieces of equipment are often complexed with various sensors, valves, pressure relief systems, and safety features required for safe and effective operation, which are not emphasized when teaching theory. As stated above, most phenomena are taught at steady or non-changing conditions. Therefore, understanding cause-and-effect relationships can be challenging because these relationships involve multiple pieces of equipment, intricate interactions, and multiple phenomena. It is not always easy to pinpoint a single cause or identify all the contributing factors leading to a specific effect, as changes in one aspect can propagate throughout the system, resulting in multiple simultaneous effects.

Additionally, the presence of time delays between causes and their resulting effects adds another layer of complexity. To overcome these challenges, hands-on experiences become invaluable as they provide opportunities to observe and comprehend the cause-and-effect relationships in action. Such practical experiences help bridge the gap between theoretical knowledge and real-world applications, allowing students to appreciate the intricacies and nuances involved in understanding and *addressing* process dynamics.

Engineering education relies on practical application but lacks sufficient hands-on experience in most cases. Students are mandated to participate in a unit operations laboratory, engaging in pre-designed experiments designed to be inherently safe. These experiments are carefully structured to minimize risk at a learning expense. While the controlled nature of these laboratory exercises ensures a safe learning environment, which is the priority, it also results in a constrained range of possibilities and limited exposure to real-world process variations. Thus, students encounter challenges in gaining hands-on experience with the complexities and uncertainties associated with chemical processes. Having hands-on experience in real-world settings is vital in enhancing students' ability to bridge theory with practical application, fostering engineering competence, and nurturing innovative problem-solving skills to tackle novel challenges. Unfortunately, some students may graduate without acquiring sufficient professional hands-on experience, which is crucial for their future career readiness and understanding the dynamic aspects of the field. Even for the students that gain cooperative experiences, numerous risk factors impose limitations on interns' ability to acquire and apply operational skills effectively, which can be addressed by integrating simulated environments, such as the proposed technology.[4] This broader exposure can enhance students' understanding of the diverse challenges and variations they may encounter in their future careers while building further on their critical thinking skills which are essential in engineering fields.

The requested funds are for the software and equipment required to fully support ten individual immersive plant simulator licenses that include:

1. 3D interactive virtual plant
2. Multicomponent dynamic process simulator for a three-phase separator within the plant
3. A control room operator graphical interface with DCS (distributed control system) for the three-phase separator
4. Built-in exercises that support individual and collaborative efforts between students

The three-phase separator model is an industrial-size (65-foot) horizontal crude oil separator that separates natural gas, oil, and produced water. Within a horizontal three-phase separator, the mixed feed enters the vessel via an inlet and encounters an inlet diverter to promote the initial separation of the liquid and vapor. Once the vapor (natural gas) is separated from the oil and water, it passes through several valves to maintain pressure in the vessel before exiting the system for subsequent downstream processing. Next, in the liquid collection region of the vessel, the oil and water-oil emulsion undergo separation. A weir regulates the oil level, while an interface liquid level controller ensures the maintenance of the water level. The oil overflows beyond the weir and is controlled by a level controller that operates an oil dump valve to maintain its desired level. Traditionally, an interface level controller detects the position of the oil-water interface, and this controller can trigger another valve, releasing an appropriate amount of water from the vessel to uphold the interface height. A typical depiction of a three-phase separator used for teaching is shown in Figure 3. Unfortunately, as with others, this depiction does not give a good representation of the equipment in the field (Figure 4). For this equipment and other chemical processing equipment, pumps, valves, sensors and controllers, and pressure relief devices are required for safe and effective operation. Piping connects these all together, which involves space allocation. The typical teaching curriculum also looks over other safety features such as flares or fire mitigation systems.

Learning and troubleshooting these actual systems through hands-on experience is beneficial for students, as theory alone may not adequately prepare them to handle real-life situations. Take, for instance, the concept of overfilling a three-phase separator. This carries various safety and process impacts, such as increased risks of leaks, reduced separation efficiency, pressure build-up that can lead to explosions, loss of level control, instrumentation failure, and elevated fire and explosion hazards. Overfilling can be caused by various factors, including malfunctioning level control systems, excess inlet flow rates, pump failures, changes in operating conditions, or even human error. While safeguards are in place, such as alarms or automated controls to prevent such incidents, multiple process changes can result from a single disruption. Teaching and thus comprehending all potential scenarios and outcomes in theory alone can be challenging. This virtual reality software will allow hands-on experience in a safe, controlled environment that enables students to experiment and develop problem-solving skills that learn to anticipate, diagnose, and resolve issues that can arise in operating a three-phase separator.

Within this simulation, exists a fire and gas mitigation system with a flare and flare monitoring. All controllers, valves, pumps, and sight glasses are interactive and representative of pieces of equipment found in the field with the ability of interaction. In addition, there are built-in exercises with scoring for assessments that include, but are not limited to:

1. Start-up
2. Shutdown
3. Level indicator failure
4. Pressure control valve sticking
5. Pressure relief valve lifting light, causing flaring
6. Pump failure
7. Pressure relief valve lifting light, causing flaring and pump failure combined
8. Pump failure and fire

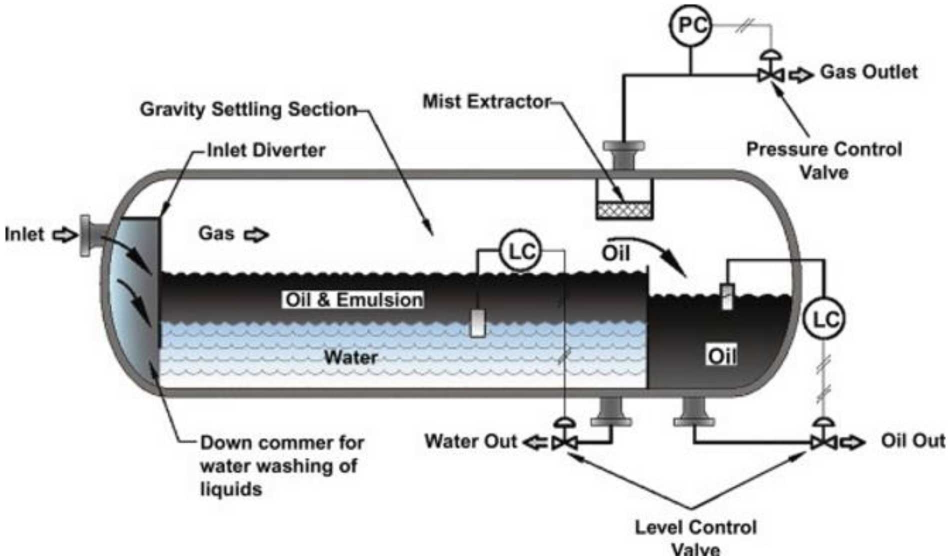


Figure 3: A typical three-phase crude oil separator adapted from Stewart (2021)[5]

Figure 4: Three-phase separator simulation

In the petroleum industry, particularly in production operations managed by chemical, petroleum, and mechanical engineers, using three-phase separators is crucial for facilitating the efficient production and transportation of oil and gas. These separators are pivotal in maintaining operational efficiency, ensuring product quality, and meeting regulatory standards throughout the production and transportation processes[5]. In general, *all* produced fluids are routed to a three-phase separator, with horizontal types representing the majority of installations[6]. The United States alone witnesses significant crude oil production, estimated at 11.9 million barrels per day, with further increases anticipated in the coming years.[7] Additionally, three-phase separators find extensive applications in the chemical process industry. They play a vital role in the pretreatment of feeds by effectively separating water or gas from three-phase mixtures. This separation process serves multiple purposes, including extracting desired products from other components, and safeguarding liquid handling equipment like pumps by preventing vapor entry and potential damage. Moreover, three-phase separators are commonly employed in the overhead systems of fractionators, also known as distillation columns which serve as the prevailing separation technique in the chemical industry.

Another aspect of chemical processing and associated equipment involves the utilization of controls and control systems. Engineers often collaborate closely with operators who rely on distributed control systems (DCS). A DCS is a comprehensive system comprising sensors and controllers distributed throughout a plant of process. These components are interconnected with a central computer, enabling virtual control over specific variables. The DCS facilitates continuous monitoring and precise control of the process while providing alarms for detecting abnormal or changing conditions. Distributed control systems are extensively utilized in various industries, including chemical and petrochemical, to oversee complex operations. However, it is essential to note that not all process variables can be manipulated solely through a DCS and often requires manual manipulation. This emphasizes the significance of collaboration and effective communication between engineers and operators to ensure seamless operation and control of the system.

This simulation has a modern DCS interface (Figure 5) that allows interaction with the virtual plant. It is designed to be a sandbox environment, so the number of scenarios that can be created is unlimited. Real-time running, trending, event logging, and alarm system representative of industrial control systems exist (Figure 6) within the software. Students can collaborate between the DCS and plant as they would, which in reality is impossible to obtain in traditional class activities. The control and management of process variables, including temperatures, pressures, flow rates, and liquid levels, interact in the system comprising multiple components, phases, and non-ideal characteristics; students gain the ability to monitor and control process variables effectively, ensuring optimal performance and facilitate adjustments to maintain system stability, efficiency, and safety. This powerful tool offers capabilities for handling both routine and challenging operational scenarios, simple and complex scenarios, while providing robust assessment functionalities.

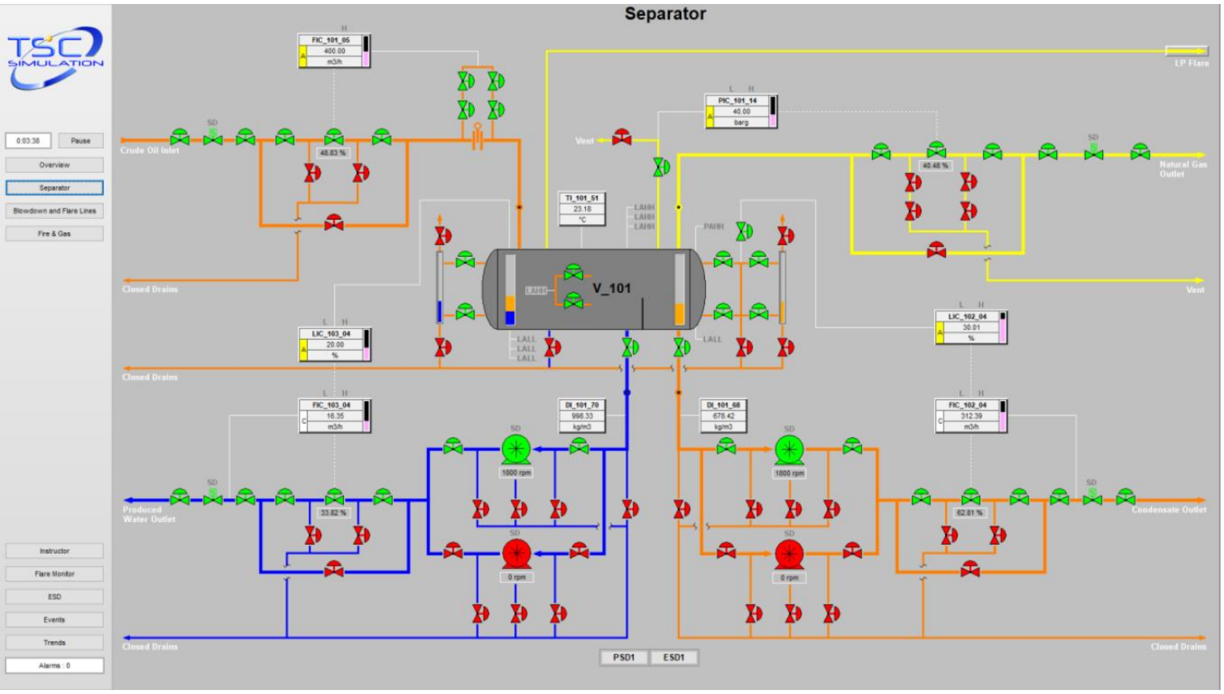
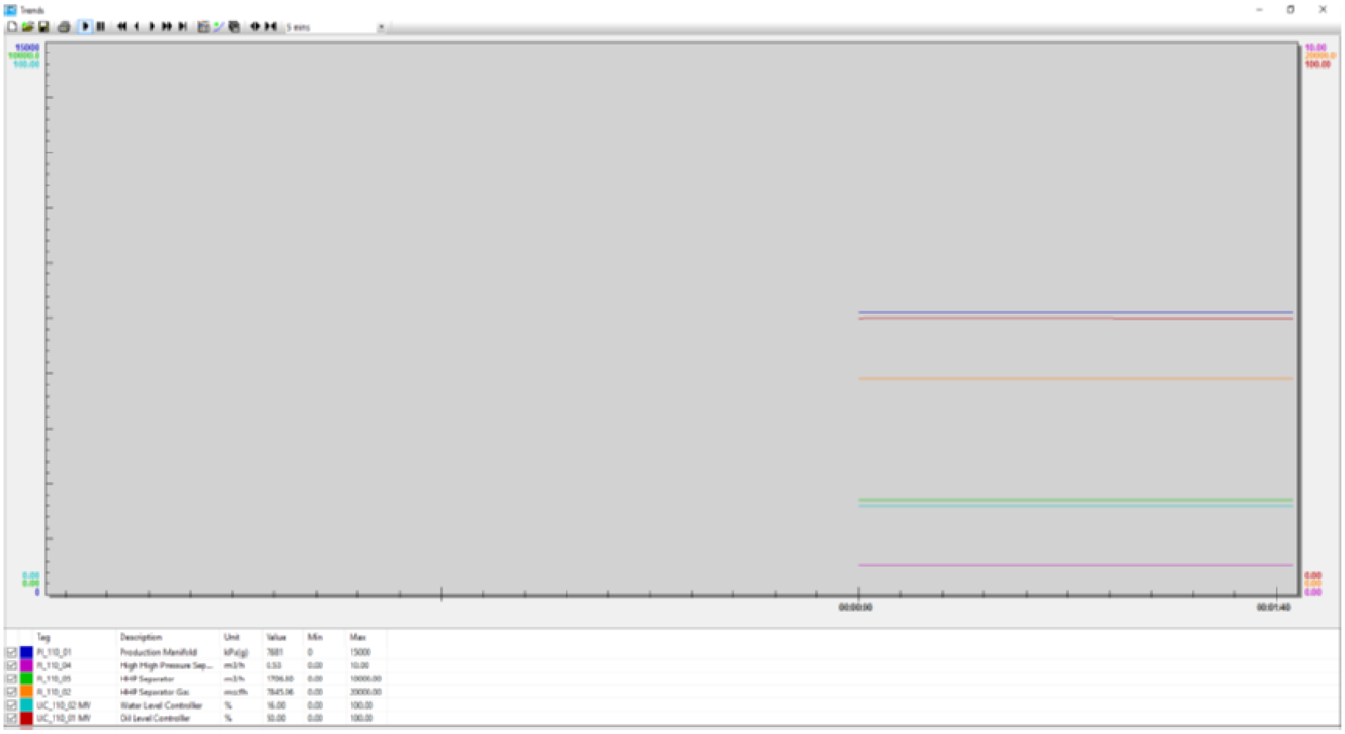


Figure 5: Instructor view of the three-phase separator's DCS



		Tag	Description	Unit	Value	Min	Max
☑	🟦	PI_110_01	Production Manifold	kPa(g)	7681	0	15000
☑	🟪	FI_110_04	High High Pressure Sep...	m3/h	0.53	0.00	10.00
☑	🟩	FI_110_05	HHP Separator	m3/h	1706.60	0.00	10000.00
☑	🟧	FI_110_02	HHP Separator Gas	mscf/h	7845.06	0.00	20000.00
☑	🟦	LIC_110_02 MV	Water Level Controller	%	16.00	0.00	100.00
☑	🟥	LIC_110_01 MV	Oil Level Controller	%	50.00	0.00	100.00

Figure 6: Trend monitoring in the TSC simulator

Overall, this virtual reality technology and future technology has the potential to revolutionize how engineering is taught and researched while offering several advantages to students and instructors. The proposal aims to leverage VR technology to enhance the learning experience, improve student engagement, and promote a deeper understanding of engineering concepts and principles with the goal of equipping all students with valuable skills and experiences that align with industry demands, foster innovation, and prepare them for successful careers in engineering. Furthermore, it can be used in recruiting efforts, support ADVANCE pathways, and assist in industry collaboration. The utilization of this virtual reality technology holds transformative potential in the realm of engineering education, presenting numerous benefits to both students and instructors alike. If funded, the departments will be at the forefront of engineering education, equipped to prepare students for the industry's ever-evolving landscape and expand to other emerging simulations.

Impact on the student body

Implementing this technology would profoundly impact the college of engineering, enriching their educational experience in several ways. Firstly, the integration of VR technology would foster an immersive and engaging learning environment, enhance student motivation, participation, and knowledge retention directly related to pedagogical strategies to promote active learning, critical thinking, and problem-solving skills to develop a deeper understanding of complex chemical engineering concepts and their practical applications within courses.

Moreover, incorporating VR into the curriculum would align with the requirements of the Accreditation Board for Engineering and Technology (ABET) accreditation, ensuring that the program meets the established standards for educational quality and professional readiness. Using innovative teaching methods and technological advancements would demonstrate the program’s commitment to continuous improvement. Additionally, the proposal aligns with the university’s ADVANCE program and would promote research within the curriculum. Furthermore, incorporating VR would enhance recruitment efforts by showcasing the program’s commitment to cutting-edge technologies and the ability to develop career workshops around this software.

In general, the proposal’s impact on the student body extends beyond the classroom, offering transformative learning experiences, aligning with accreditation standards, promoting research, and strengthening recruitment efforts, all of which contribute to a high-quality and forward-thinking engineering program.

Pedagogical Strategies and Practices

There has been a persistent difficulty in fostering the acquisition of sufficient cognitive, technical, and socio-emotional skills among students, partly due to the restricted availability of hands-on training and limited access to suitable content and learning environments. Engineering education often encounters significant obstacles in offering students the essential pedagogical experiences required to cultivate practical skills.[3] This virtual reality (VR) will foster many learning strategies to overcome these challenges and cater to different students, such as experiential, inquiry-based, problem-based, and cooperative learning approaches. This range of pedagogical strategies will enhance student engagement, knowledge acquisition, and long-term knowledge retention. Students will be able to explore and discover knowledge independently in a safe and controlled environment that would be otherwise impossible in real-life scenarios.

Through this simulation, students can actively engage with a crude oil separator with controls, collaborate in group settings like in the real world, investigate cause and effect, experiment with complex scenarios, and tackle real-world problems for a comprehensive learning experience and knowledge retention. These approaches enhance students' understanding, critical thinking, and problem-solving skills. In addition, authentic assessment methods can be employed to evaluate student progress, ensuring that the learning outcomes are aligned with practical application and promoting a deeper understanding of the subject matter. A summary of pedagogical strategies with specific impacts is in Table 1.

Table 1: Impact of Learning Strategies

Teaching Pedagogy	**Impact to Students**
Experiential Learning	• Presents students with authentic problems that reflect real-world scenarios • Provide students with a "hands-on" learning environment • Allows students to engage with material and their knowledge in practical situations
Inquiry-Based Learning	• Requires students to create questions on their own • Obtaining supporting evidence to answer questions • Explaining evidence collected • Connecting the explanation to the knowledge obtained from the investigative process
Problem-Based Learning	• Promotes deep understanding of concepts • Develops students' critical thinking skills as they analyze problems, evaluate evidence, and make decisions • Enhances students' problem-solving skills by providing opportunities to identify, analyze, and develop solutions during troubleshooting exercises • Fosters long-term retention of knowledge as students engage in problem-solving and connect theory to real-world scenarios
Cooperative Learning	• Establishes shared goals for a group • Promotes positive interdependence and the idea each student's efforts and achievements are interconnected • Nurtures positive interpersonal relationships and effective communication

Course Alignment

By aligning courses with industry demands, such as dynamic operation and operation of distributed control systems, students would be equipped with relevant skills and competencies that enhance their employability and future success. They will also gain the critical thinking skills essential for students to become competent engineers. The following courses with aligned activities are described below in Table 2, which enrolled 1071 students throughout these courses in 2022 The shift away from a linear approach, as depicted in Figure 1, leads to a more interconnected curriculum where topics are interdependent and cannot be effectively utilized in isolation for real-life applications. By utilization of the software and VR, students will gain a heightened awareness of this interdependence. They will actively observe and engage in the connection between these topics, as illustrated in Figure 7. The three-phase separator encompasses the whole network of these topics allowing the software to serve as a bridge, enabling a cohesive learning experience that demonstrates the interplay between different subject areas and promotes a holistic understanding of topics. It is noteworthy to mention that although Figure 7 shows chemical engineering courses, these topics are also taught in the respective engineering courses.

Table 2: Course Alignment

	COURSE	**No. of Students/year**
Chemical Engineering	CHEE 101 – Introduction to Chemical Engineering	39
	CHEE 201 – Chemical Engineering Calculations	55
	CHEE 310 – Chemical Engineering Thermodynamics	76
	CHEE 307- Safety, Ethics, and the Environment	32
	CHEE 401- Stage Operation Design	24
	CHEE 405 – Heat Transfer	46
	CHEE 413 – Process Controls	46
Petroleum Engineering	PETE 321 – Phase Behavior of Hydrocarbon Systems	10
	PETE 431G – Petroleum Production Engineering	18
	PETE 432 – Petroleum Production Laboratory	18
Mechanical Engineering	MCHE 101 – Introduction to Mechanical Engineering	126
	MCHE 358 – Energy Systems Lab	97
	MCHE 362 – Thermal Engineering	73
	MCHE 471 – Fluid Mechanics	23
Electrical Engineering	EECE 447 – Electrical Machines and Power	33
	EECE 450G – Power Systems	9
Engineering Technology	ENGT 250 – Construction Materials and Methods I	60

	ENGT 268 – General Safety and Accident Prevention	56
	ENGT 399 – Advanced Safety	0
Other	ENGR 304 – Fluid Mechanics	115
	ENGR 305 – Transport Phenomena	66
	ACSK 120 – Topics in Academic Skills	12
	UNIV 100 – First Year Seminar	19

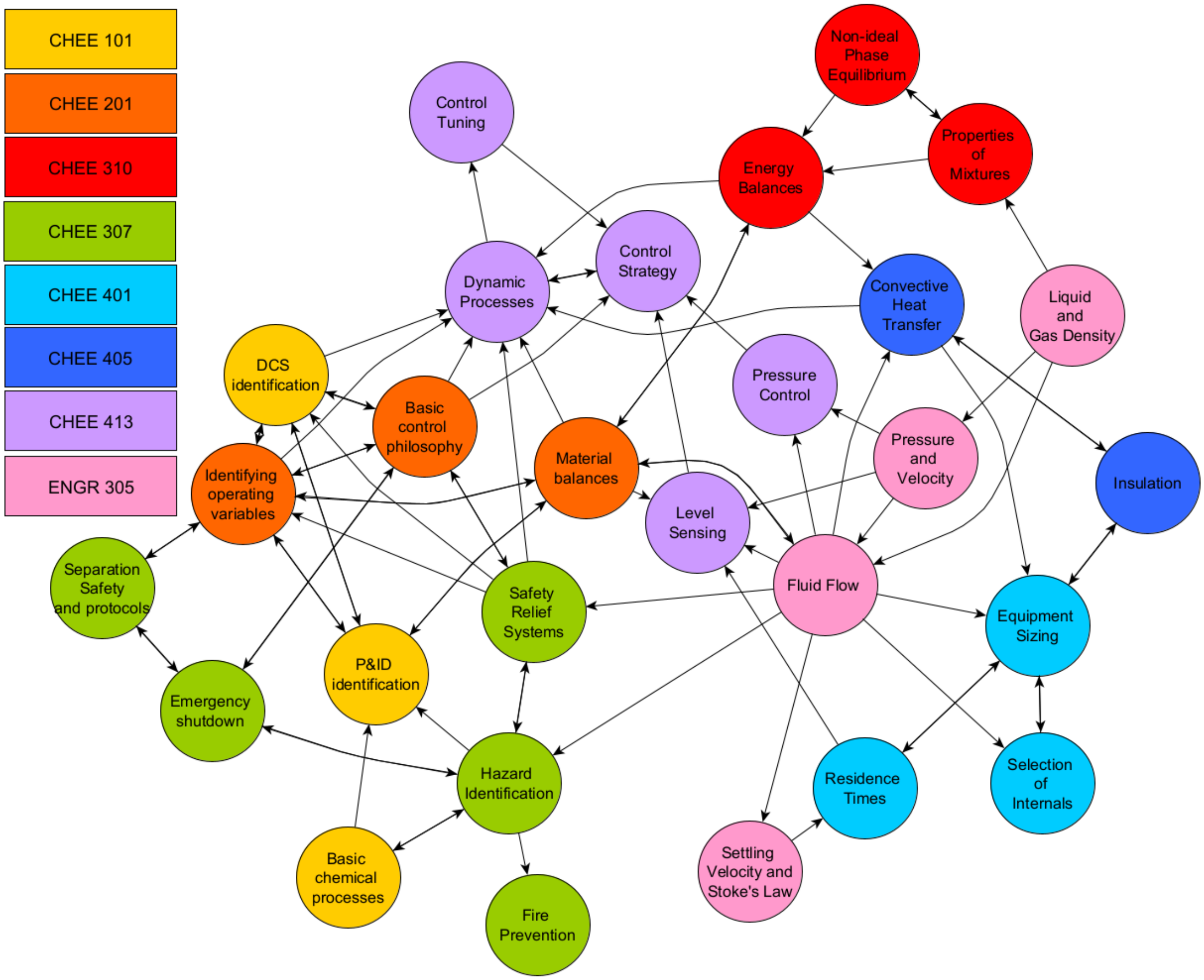


Figure 7: Interdependence of course topics with respect to the three-phase separator specific to chemical engineering

ABET accreditation

By integrating virtual reality into the curriculum, the program would align itself with the stipulations of ABET accreditation, thereby guaranteeing adherence to the prescribed benchmarks for educational excellence and professional preparedness. This accreditation impacts students by assuring the quality of their education, expanding financial aid opportunities, supporting professional licensure, improving employment prospects, and fostering ongoing improvements. Incorporating cutting-edge instructional approaches and technological advancements would serve as tangible evidence of the program's dedication to continuous improvement and staying ahead of developments in engineering education. The software and hardware employed would actively support the attainment of program educational objectives and student outcomes while providing means to assess specific outcomes. Through the utilization of this software with various applications, the following student outcomes can be effectively achieved:

1. ABET STUDENT OUTCOME 1: an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. ABET STUDENT OUTCOME 4: an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
3. ABET STUDENT OUTCOME 5: an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
4. ABET STUDENT OUTCOME 6: an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.

And the program's educational objective for graduates expected within a few years of graduation to have:

1. Established themselves as practicing professionals or engaged in advanced application of chemical engineering design
2. Demonstrated their ability to work successfully as a member of a professional organization and function effectively as responsible professionals

While ABET outcome 1 can be easily achieved through traditional coursework, outcomes 2, 5, and 6 present more significant challenges in such settings due to various factors. However, implementing this software introduces transformative opportunities for students to recognize ethical and professional situations and make informed judgments in a controlled environment. By directly observing the impact of their decisions within economics (how much product is produced in the simulation), environmental (flare monitoring), and safety contexts (hazards such as a fire), students gain valuable insights. The collaborative nature of the software's realistic operations satisfies the requirements of ABET outcome 5, as students engage in group and individual tasks within the group. Furthermore, the software's sandbox environment offers various situations and outcomes for analysis, allowing students to interpret data trends and draw meaningful conclusions. By effectively achieving these student outcomes, the program's educational objectives are better positioned to be fulfilled, providing students with the critical thinking skills needed to have a strong foundation for success.

Advance program

Incorporating TSC’s simulation software into the curriculum will impact the students by providing a robust foundation for students to excel in research endeavors, foster a passion for scientific inquiry, and prepare them for future research opportunities. In complete accordance with ADVANCE’s goal 1, which aims to increase student participation in meaningful research experiences, the proposed courses outlined in Table 2 perfectly align with ADVANCE’s definition of student research experience (SRE). As per ADVANCE’s definition, an SRE involves a sustained effort by a student to apply their subject knowledge, skills, and abilities to a highly regarded project within the discipline. This includes engaging in systematic inquiry to uncover facts, principles, or perspectives, as well as the application of professional skills.

By actively participating in these courses, students gain hands-on experience by conducting “what if” analyses, observing trends, analyzing data, and drawing meaningful conclusions. Since the software is designed to be a sandbox environment with unlimited scenarios that can be created, the students are encouraged to explore different approaches, test hypotheses, and make evidence-based decisions. In addition, students have the flexibility to manipulate boundary conditions, alter variables, and observe the corresponding outcomes, allowing them to deepen their understanding of cause-and-effect relationships within the context of research.

Recruitment and Outreach

Incorporating the three-phase separator into our recruitment efforts presents an exceptional opportunity to captivate and engage prospective students, leaving a lasting impression. By harnessing the immersive and interactive capabilities of the VR simulator, we can offer aspiring students a truly unique and compelling experience that showcases the vibrant learning environment and our unwavering commitment to cutting-edge technologies. This integration enhances the overall appeal of our program and demonstrates our dedication to innovative teaching methodologies and the continual advancement of technological advancements. By positioning ourselves as a forward-thinking program that embraces emerging technologies widely employed in industry, we can attract a diverse pool of talented students who are inspired and ignite a curiosity about the field. As a result, we can attract top-tier talent and cultivate a vibrant and diverse student body, shaping the future of our program. When incorporated into recruiting efforts, it has the potential to impact more than students. Activities and student numbers from 2022 are shown in Table 3.

Table 3: Student numbers in outreach activities for the college of engineering

Outreach Activity	**No. of students in 2022**
Engineering and technology day	1000+
College tours	40+
High school visits	650
Preview days	268
Junior day (2023 expected)	315

Additionally, this technology can be utilized in the college's career workshop development program which is open to all engineering majors and designed to prepare students for their professional careers. This will directly impact 80 students per year.

Future growth and industry collaboration

In addition to the proposed model for the three-phase separator, the hardware in this proposal can be extended to encompass a broader range of chemical processes and simulations, taking advantage of technological advancements. Furthermore, readily available hardware can enhance the potential for obtaining donations from prospective sponsors, who may be more inclined to support hands-on learning experiences. Building on this momentum, efforts will be made to establish connections with industries, with the possibility of arranging virtual tours similar to Exxon Mobil's participation and sponsorship of the Digital Garage at the Society of Women Engineers Conference in 2022. These collaborative endeavors will provide students with valuable insights and real-world exposure, fostering of a deeper understanding of industry practices and inspire their career aspirations.

Assessment of learning outcomes specific to VR technology

To understand if learning outcomes are being achieved, as well as if the VR is impacting the student body, as mentioned above, assessment methods will be developed and maintained. Currently, senior exit interviews are required and measure specific aspects of the program, including students' perspectives of their knowledge in particular subjects such as mass and energy balances, transport phenomena, heat transfer operations, thermodynamics, stage operation, process controls, and also how the integration of these concepts related to skills such as safety, professionalism, communication, problem-solving, ethics, teamwork, the impact of engineering solutions, the importance of life-long learning, and knowledge of contemporary issues. After a few semesters of gathering data, the data will be compared pre-VR and post-VR by significance testing. This survey can also easily be adjusted to include questions incorporating the VR simulation to gauge student's long-term retention, engagement, course materials integration, and the overall perspective of VR technology. A similar approach to the VR evaluation survey conducted by Halabi in 2020 (Figure 8) can be utilized to guide the development of the assessment survey and ensure comprehensive data collection.[8]

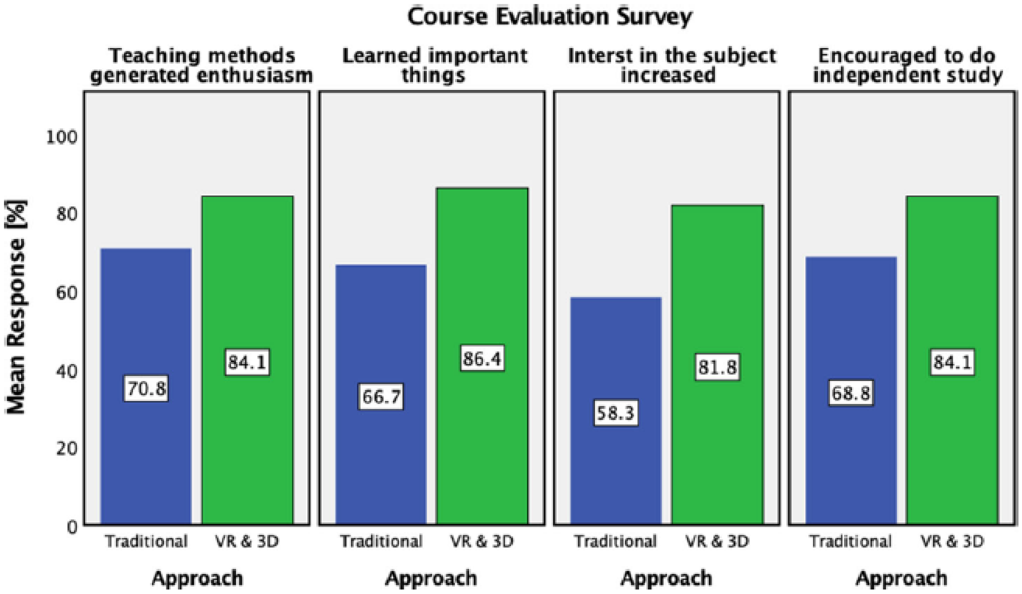


Figure 8: Halabi (2020) Course Evaluation Survey

The method discussed above is subjective, so averages of assessments (exams and assignments) pre- and post-VR will be compared that cover topics mentioned in the course alignment (Table 2). VR experience metric tools have not been created, so innovation in developing metrics that matter most must be discussed with faculty and advisory board members simultaneously. However, this platform can collect data on student interactions and performance during learning activities, such as time spent on tasks and decision-making processes with outcomes. By collecting this data, the department can gain valuable insights into students' progress in subject matter and practical skills development, critical thinking abilities, problem-solving proficiency, and overall student engagement. The departments can gain valuable insights into student progress and identify improvement areas by analyzing these metrics. Overall, by analyzing gathered data over multiple semesters, assessment methods will provide valuable insights into the effectiveness of the VR approach, its impact on student learning outcomes, facilitate continuous improvement (required by ABET), and refinement of engineering education. Results can be published at an American Society for Engineering Education (ASEE) journal or conference.

Projected lifetime of enhancement

The anticipated lifespan of the technology is projected to be five years or longer, ensuring a sustainable and valuable investment. Although the software license is deemed a lifetime purchase, it should be acknowledged that ongoing advancements and updates in technology are likely to occur. As a result, determining the precise projected lifespan of the enhancements is challenging due to the dynamic nature of VR technology. However, the enhancements are expected to remain relevant and effective for a considerable period, estimated in the upward of 10 years.

Responsible parties

i. *Implementation*

Ashley Mikolajczyk, P.E., an instructor in chemical engineering, is responsible for implementation. In this role, she will oversee the procurement process by placing purchase orders for the necessary software and hardware components and effectively manage all logistical aspects to ensure a smooth integration of the VR system within the curriculum. She will also collaborate with other faculty members within the college.

ii. *Installation*

Timothy Boudreaux, the laboratory technician in the chemical engineering department, will oversee the installation of the software and hardware on PCs. The Oculus headsets and controllers will be connected to the PCs to access the interactive plant. TSC will support the installation process of the software in collaboration with Timothy Boudreaux. Since lifetime licenses will be purchased, technical support will be provided by TSC when headsets are compatible with operating on a server, estimated around three to five years.

iii. *Maintenance*

Ashley Mikolajczyk and Timothy Boudreaux are responsible for maintaining all the equipment and software funded through the STEP grant. Additionally, the software comes with a one-year ongoing support package provided by TSC to address any malfunctions or technical issues with the TSC software.

iv. *Operation*

Several faculty members within the college of engineering will assume responsibility for the operation of the software. This collaborative effort ensures that the software is effectively utilized across different courses and instructional activities, as mentioned above. In addition, faculty will oversee the integration into their respective courses, guiding students through the virtual simulations and facilitating interactive learning experiences.

v. *Training*

The software package includes two training sessions conducted by a TSC staff member, specifically focusing on the more complex aspects of the TSC software. Ashley Mikolajczyk will undertake the training sessions to gain expertise in these advanced areas and assume the responsibility of training other faculty members. As the designated faculty member for software implementation, Ashley will receive comprehensive training to ensure a deep understanding of the software's functionalities and capabilities. She will leverage this knowledge to effectively train and support other faculty members in utilizing the software to its full potential.

Along with software training, ongoing training and support mechanisms will be provided to faculty to easily integrate the technology into the existing curriculum while maximizing its educational benefits.

Budget Justification

VR headsets are necessary to implement the software, with Meta Quest 2 being the recommended choice for optimal compatibility with TSC's three-phase separator software. Twelve Meta Quest 2 headsets are budgeted, allowing ten headsets to be active while keeping two spares for backup and maintenance purposes at $328.89 per headset and controller, equating to $3,946.68. A budget allocation of $38,400 is designated for ten-lifetime licenses of the TSC Simulation three-phase separator simulator. This software comes with user guides for both students and instructors, standard operating procedures (SOPs), and maintenance procedures. To run the simulation on the headset, 10 Dell OptiPlex Plus 7000 series desktops are required with an NVIDIA RTX 3070 graphics card. The desktops cost $1398.00 per computer and the graphics card cost $499.99. An additional 256GB is recommended and cost $50.00 per unit. Twenty-two-inch monitors are quoted at $190.00 per unit. A total amount of $63,726.58 is requested. All quotes are attached in the supporting documentation section.

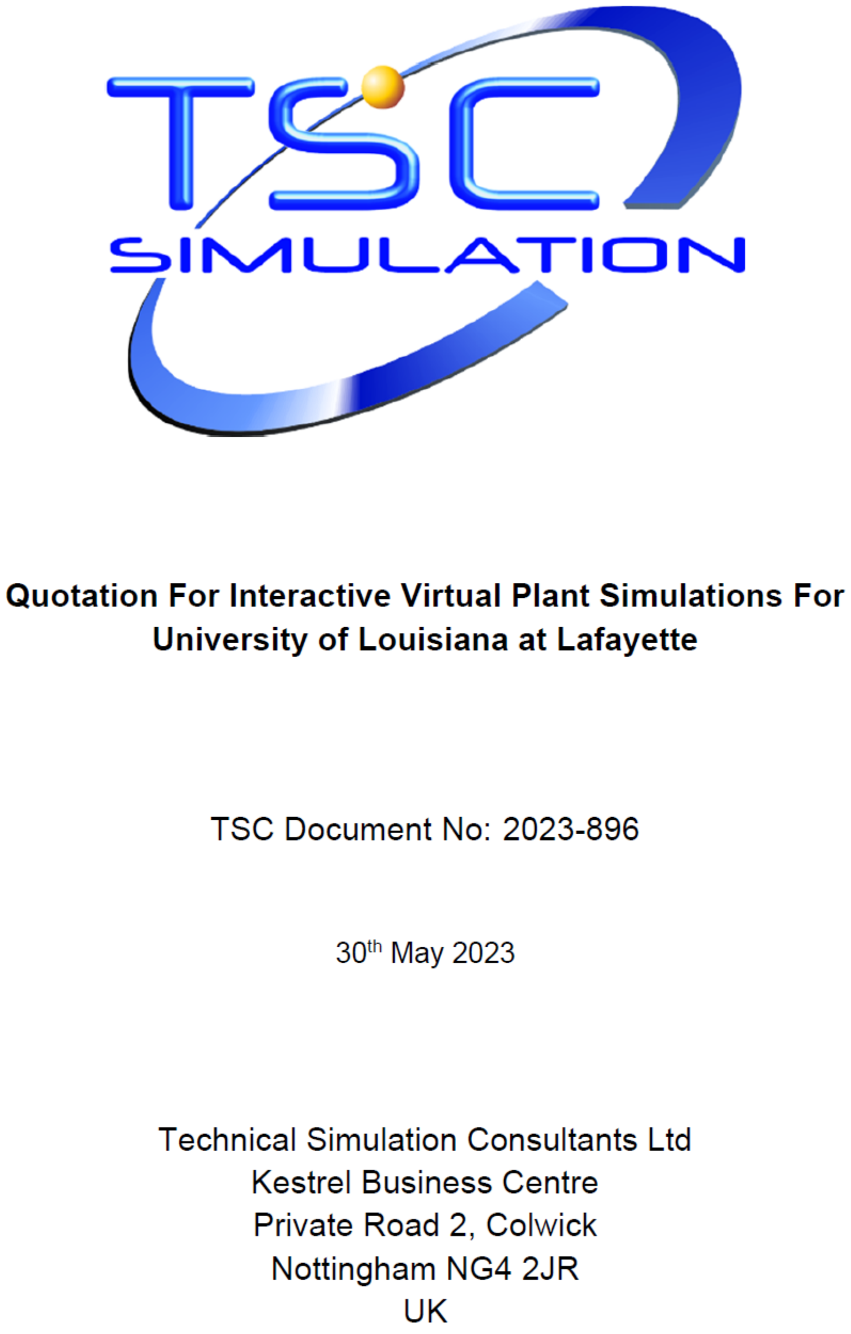
Budget

Quantity	Item	Cost/Unit	Cost
	Equipment		
10	Meta Quest 2 Headsets (128 GB)	$328.89	$3946.68
10	Dell Optiplex Plus 7000 series Desktops	$1398.00	$13,980.00
10	NVIDIA GeForce RTX 3070 Graphics Card	$499.99	$4,999.90
10	250 GB Internal SSD	$50.00	$500.00
10	Dell 22” Monitor	$190.00	$1900.00
	Software		
10	Lifetime License of TSC Simulation Software (Three-Phase Separator)	$3,840.00	$38,400.00
		Total:	$63,726.58

References

1. Kavanagh S, Luxton-Reilly A, Wuensche B, Plimmer B. A systematic review of Virtual Reality in education. *Themes Sci Technol Educ*. 2017;10(2):85-119.
2. Kumar VV, Carberry D, Beenfeldt C, Andersson MP, Mansouri SS, Gallucci F. Virtual reality in chemical and biochemical engineering education and training. *Educ Chem Eng*. 2021;36:143-153. doi:10.1016/j.ece.2021.05.002
3. Angel-Urdinola DF, Castillo-Castro C, Hoyos A. Meta-analysis that assesses the effects of virtual reality training on students' learning and skills development. *World Bank Gr*. 2021;(9587):1-50. http://www.worldbank.org/prwp.
4. Ouyang SG, Wang G, Yao JY, Zhu GHW, Liu ZY, Feng C. A Unity3D-based interactive three-dimensional virtual practice platform for chemical engineering. *Comput Appl Eng Educ*. 2018;26(1):91-100. doi:10.1002/cae.21863
5. Stewart M. 13 - Above ground storage tanks. In: Stewart MBT-SPO, ed. Gulf Professional Publishing; 2021:677-776. doi:https://doi.org/10.1016/B978-0-12-803722-5.00013-6
6. Ahmed T, Makwashi N, Hameed M. A Review of Gravity Three-Phase Separators A Review of Gravity Three - Phase Separators. *J Emerg Trends Eng Appl Sci*. 2017;8(3):143-153.
7. Environmental Impact Assessment. U.S. crude oil production will increase to new records in 2023 and 2024. Published 2023. https://www.eia.gov/todayinenergy/detail.php?id=55299#:~:text=In 2022%2C U.S. crude oil,our forecast growth in production.
8. Halabi O. Immersive virtual reality to enforce teaching in engineering education. *Multimed Tools Appl*. 2020;79(3-4):2987-3004. doi:10.1007/s11042-019-08214-8

Supporting Documentation



Quotation For Interactive Virtual Plant Simulations For University of Louisiana at Lafayette

TSC Document No: 2023-896

30th May 2023

Technical Simulation Consultants Ltd
Kestrel Business Centre
Private Road 2, Colwick
Nottingham NG4 2JR
UK

Contents

1. TSC Introduction

TSC Simulation has over a 40-year history in the provision of process simulators for education and industry. Specialising mainly for the Oil and Gas and Energy industries, but including for the food, drink, pharmaceutical and nuclear sectors. Our PC-based software for training and engineering has been supplied to companies and establishments all around the world.

Dynamic process simulators are supplied for specific situations or from a well proven selection in the TSC model library. The simulators are developed by our in-house team of graduate chemical engineers. Between them the existing team have over 250 man-years of experience in the development of such software and systems. The TSC SimCreate software is thermodynamically accurate and is fully owned and supported by the company. The software is specifically geared for high level dynamic engineering support and training, with scenario and assessment capability built into every process item in each model, no matter how simple or complex.

TSC Simulation developed the first concept of the Virtual Control Room (VCR) initially in conjunction with the Excel Training Centre at the (then) Shell Refinery at Stanlow around 1997 - 2000. Subsequent ongoing development to incorporate technical and software advances has continued to maintain the technical lead that TSC has in this system capability. The company continues to progress innovative developments, and now has a world leading position on linking the TSC SimCreate simulators to Interactive 3D plant. The ultimate “digital twin” capability, also now a major innovation area for TSC in the steel manufacturing industry.

A small example of our client list includes:

- BP Caspian Technical Training Centre in Azerbaijan
- BP Sunbury and BP Houston
- University of Nottingham
- University of Hull
- Centrica Gas Storage Limited
- BNFL Sellafield and Gen2 Training
- Shell Refinery Stanlow (now Essar)
- ASET Aberdeen College
- Instep Training classrooms for Petronas in Malaysia
- ExxonMobil in Sakhalin, Qatar, and Chad
- University of Cape Breton in Canada
- Pembrokeshire College in Wales
- PDO in Oman
- TTE International in Middlesbrough
- New Horizon in Ellesmere Port
- Forth Valley College, Grangemouth in Scotland
- University of Sheffield

and many others in 32 countries of the world.

2. Project Specifications

This proposal includes costings for both 10 and 20 licenses of the TSC 3 Phase Separator Interactive Virtual Plant Model and for the TSC Hazard Identification model.

3. Classroom Interactive Virtual Plant

3.1. Overview

This proposal is for the provision of the TSC's Interactive Virtual Plant Simulations run on a local PC.

Options for 10 and 20 sets of 1 software bundle is included and costed on a permanent licence basis.
The Software bundles that are proposed are:

- Three Phase Separator

The bundle consists of several software elements:

- The 3D Interactive Virtual Plant.
- Multi component dynamic process simulator of the actual process plant using TSCs SimCreate process simulation platform.
- Control Room Operator graphical interface.
- TSC's OPC Server that facilitates communication between the 3D and Process Simulator.
- Includes P&IDs and Startup, Shutdown and Maintenance Procedures.

The bundle enables Field and Control Room Operators to work together carrying out start-up and shut down procedures, problem solving or hazard awareness exercises. The software also has a powerful scenario and fault system allowing complex problems to be created on plant.

It is important to make the field and control room operators work together like they would in the real world.

3.2. Three Phase Separator Bundle

The TSC Three Phase Separator model is comprised of a 20m long three phase separation unit. It has a crude oil feed with volumetric flow control. The feed is then flashed into 3 phases, Natural Gas, Oil and Produced Water.

After the natural gas is separated from the oil and water, it goes through pressure control valve and emergency shutdown valve before leaving the system for further processing.

The oil and water separate in the pre-weir side of the separator along its length. The interface level is controlled by varying the produced water outlet flow under cascade level/flow control. The post-weir oil level is controlled in an equivalent manner.

The 2 liquid outlet lines both have pumps with duty standby and leave the system for further processing.

There is a full ESD system with blowdown and dual mechanical pressure relief. There is a simple fire and gas system with flare CCTV monitoring available from the control room interface.

The instructor pages of the model detail all hand valves, sight glasses and other pieces of equipment only found in the field.

3.2.1. Interactive Virtual Plant

Below is a series of pictures that show the 3D digital twin, note that all Indicators, control valves and ESD valves have active feedback from the simulation and that all valves are interactive and send position information to the simulation.

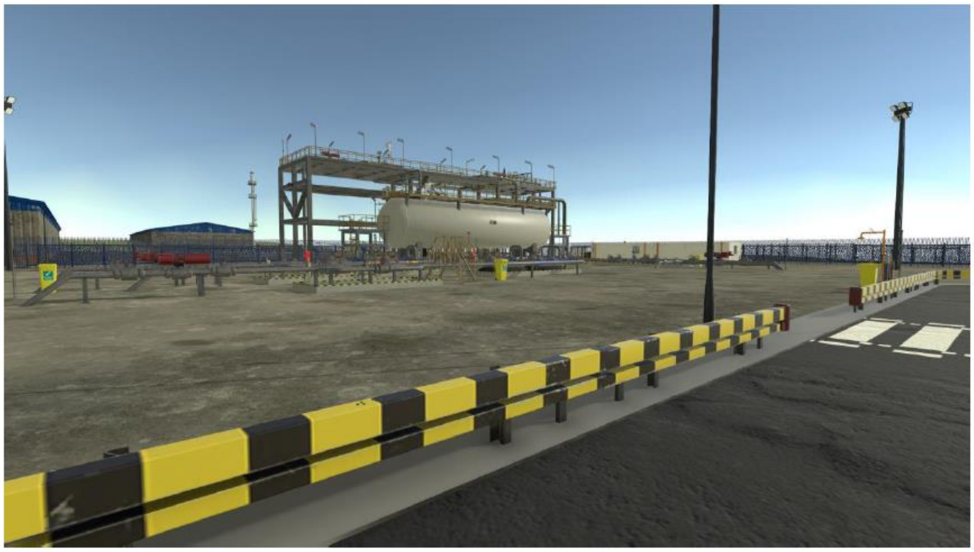


Figure 1 - Starting Position in the 3D Environment

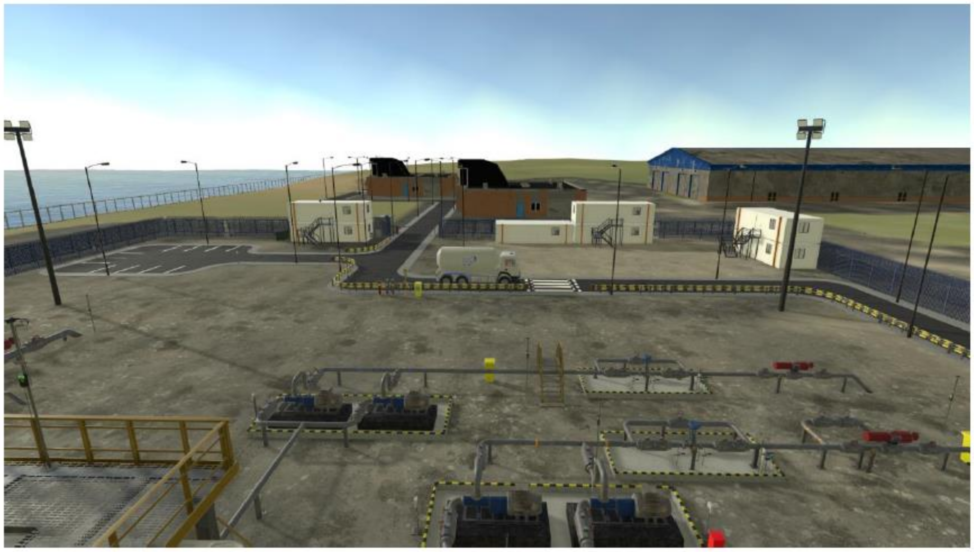


Figure 2 – View of Pumps from top platform

Figure 3 – Back of separator showing sight glasses

Figure 4 – Crude oil feed showing control valve and inlet flow controller

Figure 5 – Image showing valve selection/interaction

Figure 6 – Duty and Standby water pump

Figure 7 – Top of platform PCV with isolation, bypass and drain valves

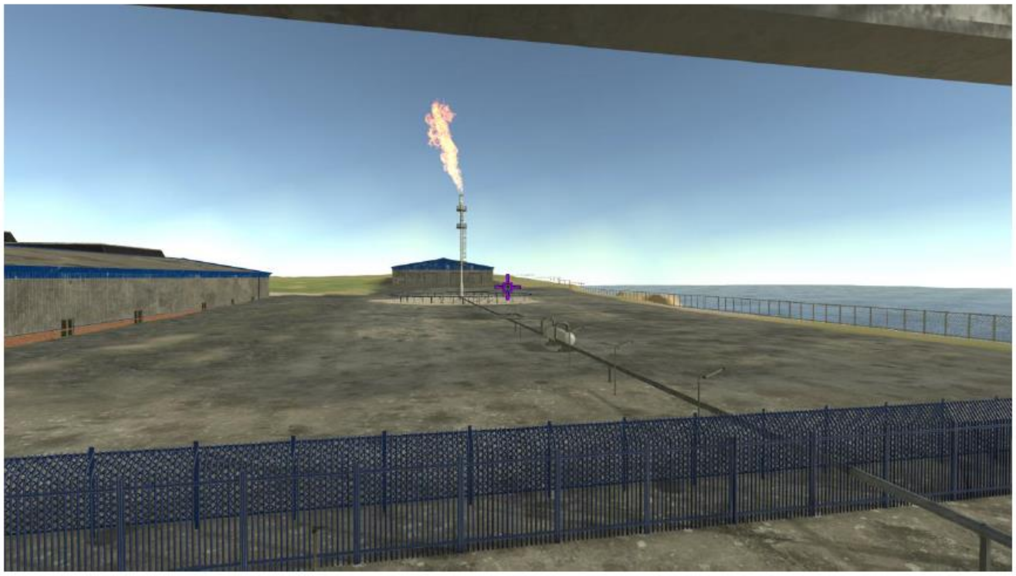


Figure 8 - Flare stack active when system Emergency Shutdown has been pressed

3.2.2. Dynamic Simulation with Control Room Interface

TSC’s dynamic process simulation platform is a multi-component process simulation engine with full molar mass and energy balance typically used for site specific operator training simulators using non-ideal equation of states.

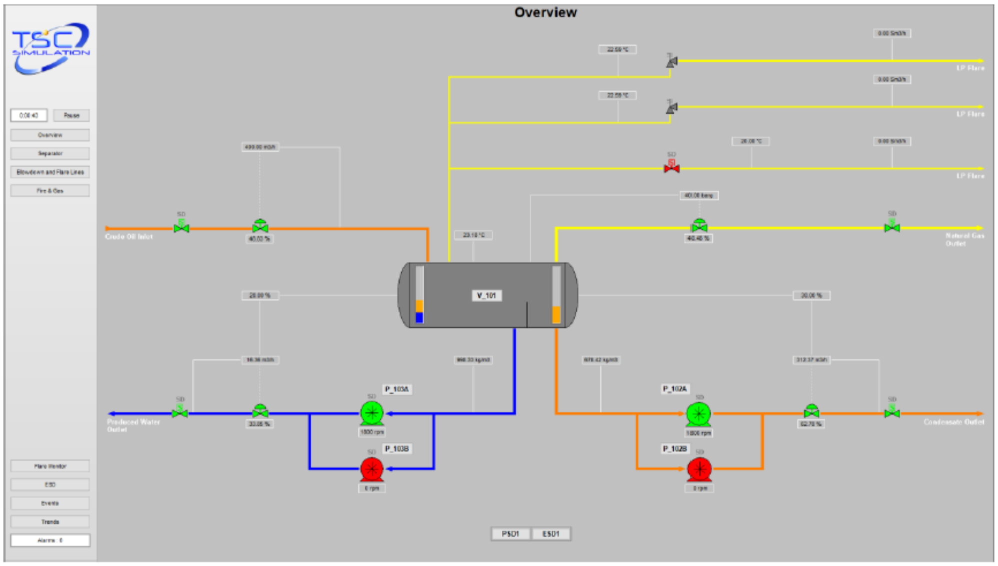
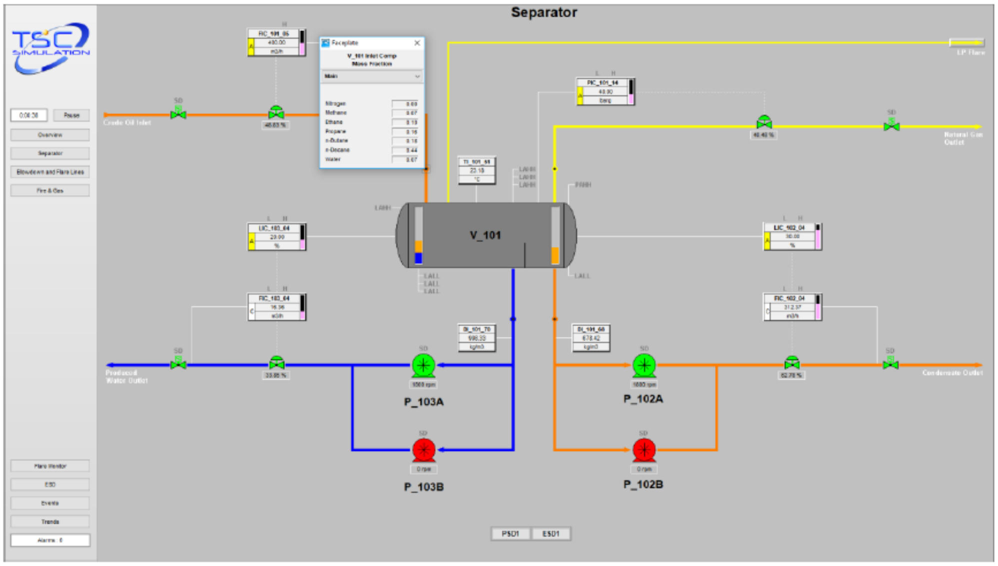


Figure 9 – Control Room Operator Process Overview



V_101 Inlet Comp
Mass Fraction

Main

Nitrogen	0.00
Methane	0.07
Ethane	0.13
Propane	0.16
n-Butane	0.16
n-Decane	0.44
Water	0.07

Figure 10 – More detailed process page showing feed composition faceplate

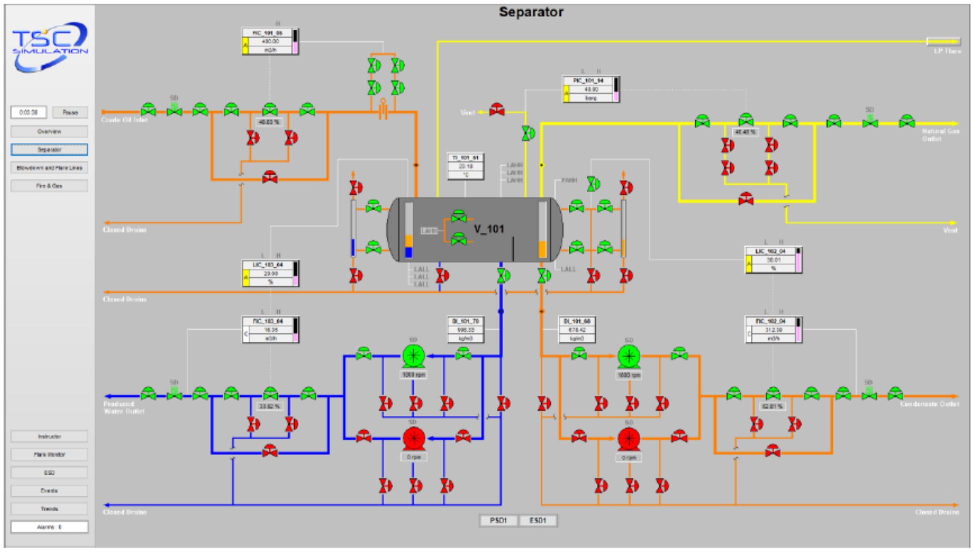
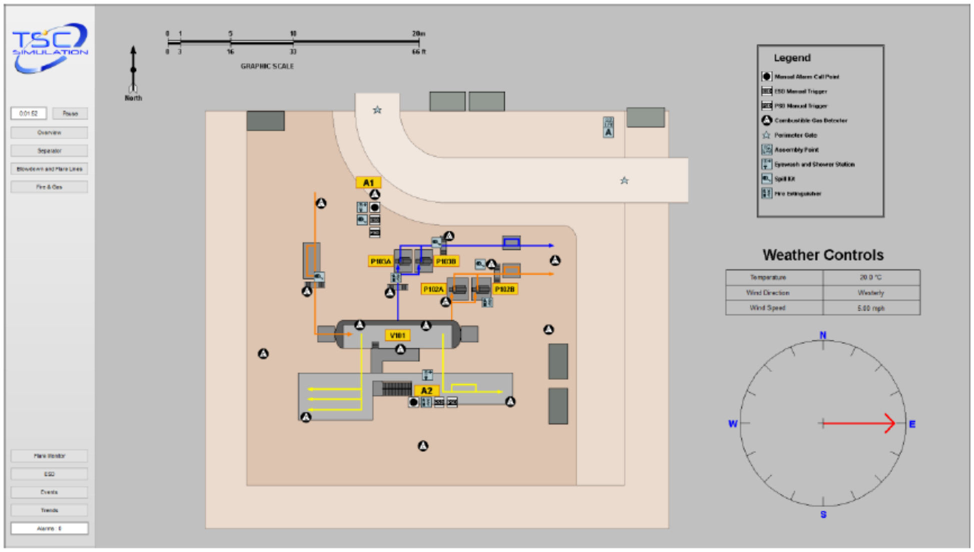


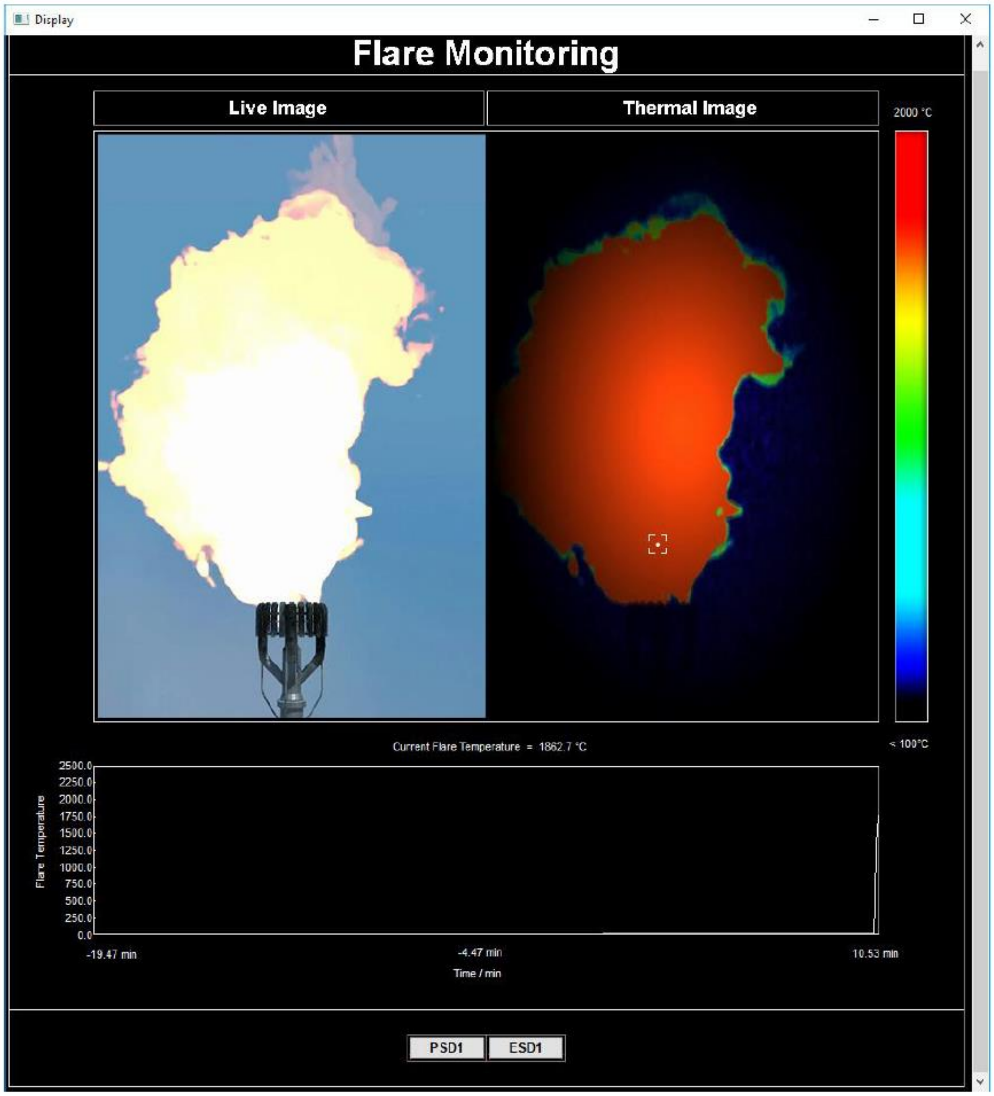
Figure 11 – Logging in as an instructor reveals all the manual hand valves that can't usually be seen in a control room



Weather Controls

Temperature	20.0 °C
Wind Direction	Westerly
Wind Speed	5.00 mph

Figure 12 – Simplified Fire and Gas Information with weather feedback



Current Flare Temperature = 1862.7 °C

Figure 13 - Flare System

4. TSC Generic Interface

The TSC generic interface incorporates the following features:

- Modern DCS style interface with multiple graphic screens
- DCS style controllers and faceplates
- Model pause and resume run function
- Real time running (with speed up and slow down function)
- Trend package including channel selection and scaling, and printouts
- Event logging to electronic file
- Saves and resumes of the model in any condition.
- Menu driven model selection with start-up in design conditions or at any trainer predefined condition.
- Alarm system with Acknowledge and priority listing
- ESD Cause and Effect Matrix with inhibit and override capability
- Ability to alter all boundary conditions
- Malfunction – The simulation allows for a wide variety of faults to be input to the running simulation.
- Replay ability to view previous sessions.

The simulation software will be installed locally on each PC. Using the existing TCP/IP network between PCs, the system will allow local running, or the Instructor to start the models on the PCs remotely, and to monitor each PC remotely even when it is started locally.

Control System

The TSC system has an easy to use, modern DCS type interface to allow simulation interaction. This includes pop-ups for controllers, indicators, pumps, fans, motors and valves.

The simulation includes an easy to use navigation system to moving around the model and clear graphics to provide process information.

The screen shot below shows a typical background image for a 3 phase separator with a controller and indicator faceplate pop-up open.

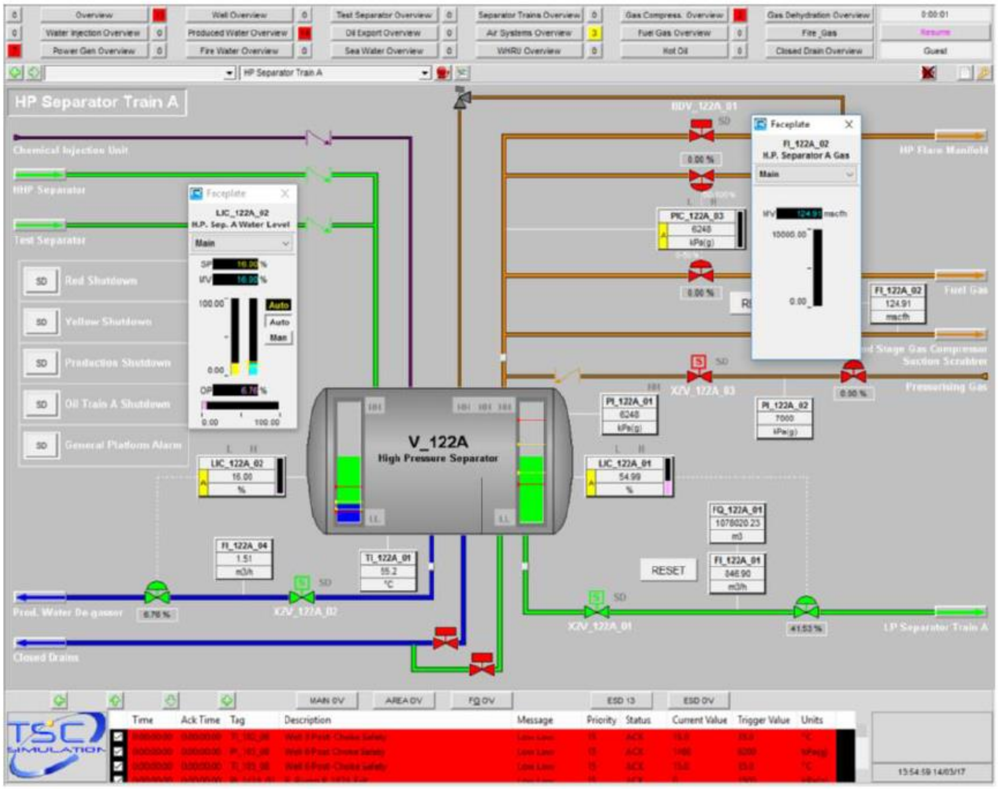
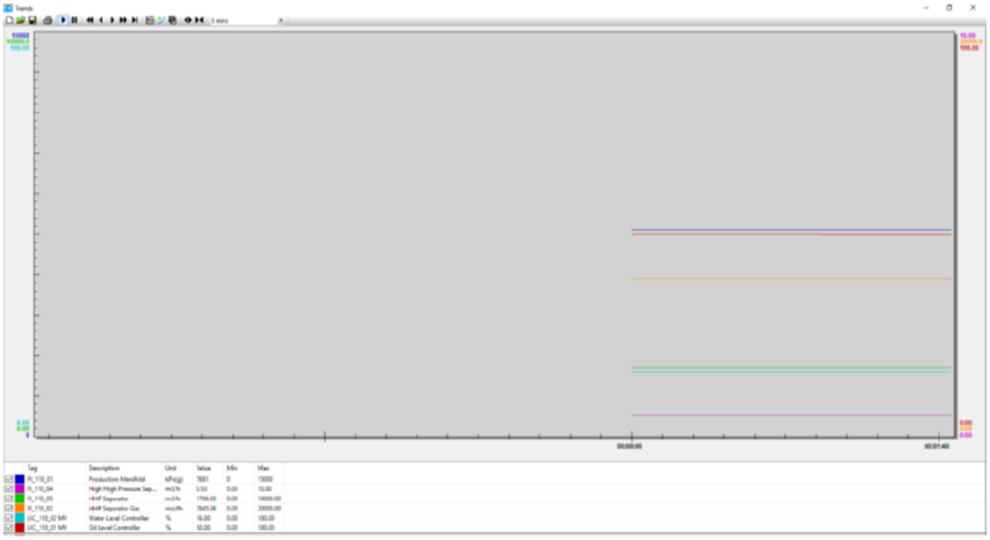


Figure 14 - TSC Generic Interface

Trending

The TSC interface includes an easy to use trend package for monitoring all process variables. This can be accessed from a trainer PC station to allow monitoring of the trainee performance.

All monitored process variables within the model can be displayed on this scalable trend package.



		Tag	Description	Unit	Value	Min	Max
☑	🟦	PI_110_01	Production Manifold	kPa(g)	7681	0	15000
☑	🟪	FI_110_04	High High Pressure Sep...	m3/h	0.53	0.00	10.00
☑	🟩	FI_110_05	HHP Separator	m3/h	1706.60	0.00	10000.00
☑	🟧	FI_110_02	HHP Separator Gas	mscfh	7845.06	0.00	20000.00
☑	🟦	LIC_110_02 MV	Water Level Controller	%	16.00	0.00	100.00
☑	🟥	LIC_110_01 MV	Oil Level Controller	%	50.00	0.00	100.00

Figure 15 - Trends

6. Suggested VR Head Sets

Meta Quest 2

TSC recommend the Meta Quest 2 headset. Connected to a high spec PC to give a smooth user experience and avoid dizziness.

Figure 20 - Meta Quest 2 Headset

6.1. Interactive Virtual Plant Hardware Specifications

The PCs to run the simulation should be of the minimum specification listed below.

- Intel i7 processor (@ around 3.6GHz).
- Graphics card 3070 or higher.
- 32 GB of RAM.
- 500 GB Hard disk (we don't use all of this but a decent sized one is recommended for future expansion and other programmes).
- Windows 10 x64 Operating System.
- 21” screen of HD 1920x1080 resolution.
- Mouse and Keyboard.
- An integrated sound card and headphones.
- An integrated 1Gb LAN connection.

7. Licensing

TSC supplies simulation software entirely developed and owned by TSC. The simulations run under a Windows operating system, using the TSC Simulation standard program.

There is no requirement for any Licence support other than for the above.

8. Training

Included in this proposal are 2 training sessions for a TSC staff member to carry out “Train the Trainer” sessions on the more complex areas of use of the TSC models.

These sessions would be expected to be around 4 hours to cover all the material.

TSC will also support the installation process of the classroom by University staff.

9. Warranty and Support

Included in this proposal is a software warranty and ongoing support for malfunctions of the TSC software for 1 year.

10. Project Time Line

The TSC 3 Phase Separator would need minor modifications to run on a head set and would be available for installation 2 weeks from order.
The hazard identification model would be available for install 8 weeks from order.

11. Costing

Three Phase Separator Interactive Virtual Plant

10 Life time licenses	$ (US) 38,400.00
20 Life time licenses	$ (US) 51,200.00

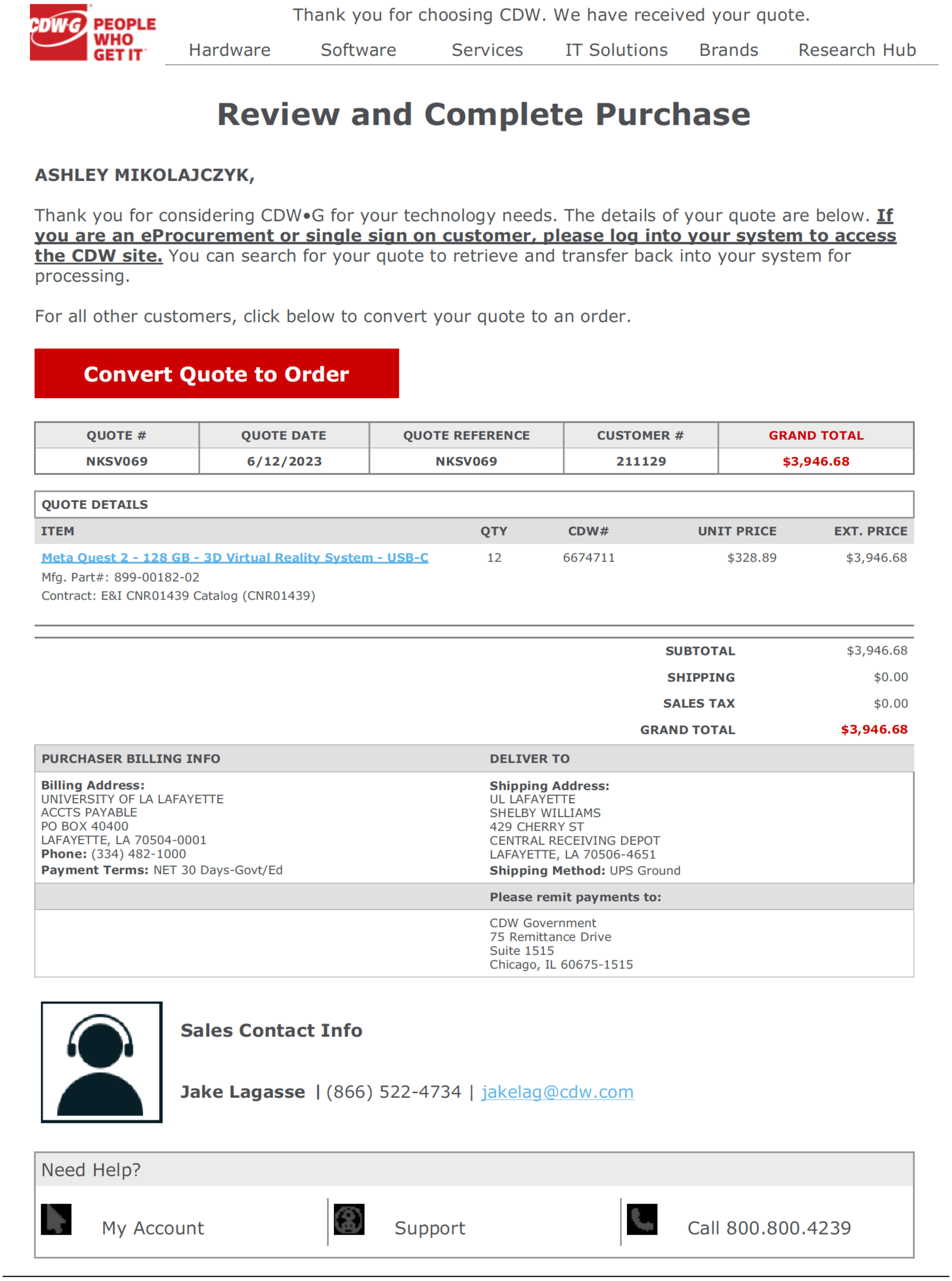
Hazard Identification Model

10 Life time licenses	$ (US) 25,600.00
20 Life time licenses	$ (US) 38,400.00

Please note if non recommended head sets are chosen the simulations would need to be re costed as more development may be required.

12. Terms

- Project will be invoiced 50% on order 50% delivery of simulations.
- Taxes and duties where applicable will be added at the rate ruling for this purchase.
- Payment terms are settlement within 30 calendar days of invoice.



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ASHLEY MIKOLAJCZYK,

Thank you for considering CDW•G for your technology needs. The details of your quote are below. **If you are an eProcurement or single sign on customer, please log into your system to access the CDW site.** You can search for your quote to retrieve and transfer back into your system for processing.

For all other customers, click below to convert your quote to an order.

QUOTE #	QUOTE DATE	QUOTE REFERENCE	CUSTOMER #	GRAND TOTAL
NKSV069	6/12/2023	NKSV069	211129	$3,946.68

QUOTE DETAILS

ITEM	QTY	CDW#	UNIT PRICE	EXT. PRICE
Meta Quest 2 - 128 GB - 3D Virtual Reality System - USB-C Mfg. Part#: 899-00182-02 Contract: E&I CNR01439 Catalog (CNR01439)	12	6674711	$328.89	$3,946.68

SUBTOTAL	$3,946.68
SHIPPING	$0.00
SALES TAX	$0.00
GRAND TOTAL	$3,946.68

PURCHASER BILLING INFO	DELIVER TO
Billing Address: UNIVERSITY OF LA LAFAYETTE ACCTS PAYABLE PO BOX 40400 LAFAYETTE, LA 70504-0001 **Phone:** (334) 482-1000 **Payment Terms:** NET 30 Days-Govt/Ed	**Shipping Address:** UL LAFAYETTE SHELBY WILLIAMS 429 CHERRY ST CENTRAL RECEIVING DEPOT LAFAYETTE, LA 70506-4651 **Shipping Method:** UPS Ground
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Memory: 32GB DDR4

Storage: 1TB SSD, 1TB HDD

Buy Now

Compare

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GPU: GeForce RTX 3070

CPU: Ryzen 7 5800X

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Dell 22" Monitor (/pcdepot/store/dell-22-monitor)

- Maximum Preset Resolution - 1920 x 1080 at 60 Hz
- Cables Included: Power Cable & DisplayPort Cable
- Ports & Slots: Power Connector, HDMI Port, DisplayPort & VGA Connector
- Soundbar not included

Can be added as a stand alone or "2nd monitor"

190.00

ADD TO CART (/CART/ADD/1495)

Product tags:
Desktop (/pcdepot/store/product-tags/desktop)
Monitor (/pcdepot/store/product-tags/monitor)
Accessory (/pcdepot/store/product-tags/accessory)

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