

Techno-Economic Analysis of a Remote-Reset Post-Emergency Shutdown Drone Verification System for Unmanned Offshore Production Platforms

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ABSTRACT

Based on offshore operations for remote unmanned platform philosophy, an emergency shutdown (ESD) can only be manually and locally reset by human intervention. Personnel shall be dispatched from the nearest manned facilities to verify that the impacted offshore facilities are safe before manually resetting the fire and gas system and resuming hydrocarbon production. However, sending personnel via boats to remote unmanned platforms can be challenging and pose an increased risk to humans, especially during adverse weather events such as a monsoon, which may prolong to two weeks until weather conditions subside. Furthermore, the fire and gas system at a remote unmanned offshore platform is prone to failure, giving wrong signals and causing the platforms to shut down spuriously, causing unnecessary delays in oil and gas production. This research aims to demonstrate the feasibility of using drones instead of sending personnel to ESD-affected remote unmanned platforms to address spurious ESDs caused by faulty fire and gas detectors. The design references international industry standards of the International Society of Automation ISA TR84.00.07-2018 and the National Fire Protection Association NFPA 72, which resulted in a 5-meter grid track size for the drones to travel and perform the verification process. Economic analysis also demonstrates this research project is viable. Despite the high discount factor of 25%, the net present value remains positive at USD 1.5 million after 15 years, with a healthy profit-investment ratio value at 2.93 for 15 years of operation and a positive internal rate of return of 46%.

Keywords: Emergency shutdown; remote reset; unmanned offshore platform; drone

INTRODUCTION

In recent years, the drone industry has been undergoing rapid development, and deployment has been increasing worldwide. Based on the accepted philosophy of offshore operations for unmanned drilling platforms, an emergency shutdown (ESD) can only be manually reset by human intervention. Remote reset of the ESD signal for such facilities is currently prohibited. Personnel shall be dispatched from the nearest manned facilities to verify whether the impacted offshore facilities (normally

unmanned) are in a safe state, namely clear from hazardous hydrocarbon gas or liquid, smouldering, and naked flames, prior to manually resetting the fire and gas system (FGS) and resuming hydrocarbon production.

However, sending personnel via boats to the remote unmanned platforms can be challenging and pose an increased risk to humans, especially during monsoon season, adverse weather, and when the sea state is rough, which is typical in tropical climates. Not all remote unmanned platforms have helicopter decks for landing, and if they are available, the cost to send personnel via helicopter is significant. Based on previous experience,

these situations can prolong for up to two weeks until weather conditions subside.

The FGS at a remote unmanned platform, despite being maintained in the recommended manner, is still prone to failure or faults, sometimes giving wrong signals and causing the platform to shut down spuriously, causing unnecessary oil and gas production deferment and loss of revenue, while potentially harming the reputation with the local host government or authorities.

To address the issue of sending personnel to the remote unmanned platforms during adverse weather events, a systematic, tangible, and practical approach is needed for safe verification on the ESD-affected platforms, without human presence. Herein, the use of drone technology is systematically considered.

PROBLEM STATEMENT

The normal operation of the shutdown system involves continuous status monitoring of the central platform from a remote unmanned satellite platform via line-of-sight microwave signals or subsea cables. This is illustrated in Figure 1.

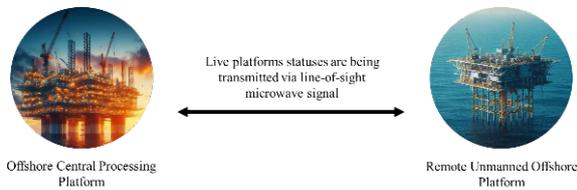


FIGURE 1. Illustration of the live platform communication protocol

Typically, there are two types of shutdowns for offshore facilities, process shutdown (PSD) and ESD. PSD can easily be reset depending on the alarm(s), once the process is normalised and reset. This verification process can be remotely monitored, and a remote signal can be sent from the central platform to the remote unmanned satellite platform, and the process can be restarted without personnel being sent for verification.

PSD is designed to protect the processing system from process disturbances such as high pressure, low pressure, elevated temperature, low temperature, high flow, low flow, and at some facilities, over vibration. The signal is transmitted as illustrated in Figure 2.



FIGURE 2. Process shutdown (PSD) signal sent to the central processing platform from a remote unmanned offshore platform

The PSD does not require personnel to be dispatched to the remote satellite platform to restart production, as long as the operating parameters are normalised within the accepted envelope and the previous alarm and shutdown signal can be reset, and subsequently, the platform can be restarted remotely, as illustrated in Figure 3.



FIGURE 3. The alarm is reset and a remote restart permissive signal is sent from the central processing platform to the remote unmanned offshore platform

For ESD events at offshore facilities (Figure 4), the industry does not allow a remote reset. This is because the ESD feature is designed for a higher level of shutdown, when it detects unintended hydrocarbon release or fire and gas-related incidents such as loss of the primary containment and fire. Because the magnitude and criticality of this shutdown system are linked to the facility’s FGS, remote reset is not allowed. Conventionally, personnel must be dispatched to the remote unmanned satellite platform by boat or helicopter (Figure 5) from the central platform or onshore facilities to verify and confirm that the platform is physically safe and free from any unintended hydrocarbon release or fire, prior to safely restarting the platform, as depicted in Figure 6.



FIGURE 4. Emergency shutdown (ESD) signal sent to the central processing platform from the remote unmanned offshore platform



FIGURE 5. Personnel are deployed to the ESD-affected remote unmanned offshore platform by boat or helicopter



FIGURE 6. Personnel verify whether the platform is safe to restart

Further data reconsolidation, filtration and analysis will provide historical record and trends for the sampled remote unmanned offshore platform suffered from spurious ESD and prolonged shutdown due to logistical challenges. A typical scenario for Malaysia offshore operation is expected to happen during monsoon season when the platform suffered spurious ESD, and personnel unable to deploy to the platform due to adverse weather. This adverse weather prevents safe access to the platform by boat and swing rope method. This adverse weather may prolong, and the affected platform remains shutdown until weather subsides for personnel to be deployed. This period of production and revenue loss is the main intention of this research to address. The magnitude of revenue loss will be used for the economic analysis and justify the implementation of drone technology.

CHALLENGES, SAFETY, AND ECONOMIC RISKS

Aged remote platforms tend to trigger spurious alarms, and if the remote platform is located significantly far away from the central platform, it is challenging to deploy personnel, especially during monsoon season. Significant distances also inhibit a quick response, resulting in excessive oil or gas production deferment.

Moreover, if a spurious ESD happens during monsoon season, it is not safe to deploy personnel via boat owing to adverse sea conditions (high swell, strong wind, and strong current). This can prolong the ESD until the weather subsides. Additionally, it is necessary to consider the excessive costs associated with deploying boats and helicopters.

RESEARCH SCOPE AND OBJECTIVES

This research quantitatively demonstrates the feasibility of using drones equipped with sensors, instead of sending personnel to remote platforms during ESD situations, thus enabling a remote ESD reset and a safe remote restart.

This research involves explicit boundaries in terms of the specific situations that can be addressed, as identified in Figures 7 and 8. We consider the time from a post-ESD event at remote unmanned offshore oil and gas production facilities until the safe remote reset and restart of the impacted asset.

This scope covers the industry requirements of site verification and intervention, which are conventionally conducted by humans, prior to resetting the ESD signal locally at the site. This research is intended to replace the human presence and intervention at the site with robotic drones, equipped with all the necessary safety sensors, detectors, and monitors, including gas detectors, thermal cameras, FLIR cameras, LIDAR sensors, and UV infrared sensors.

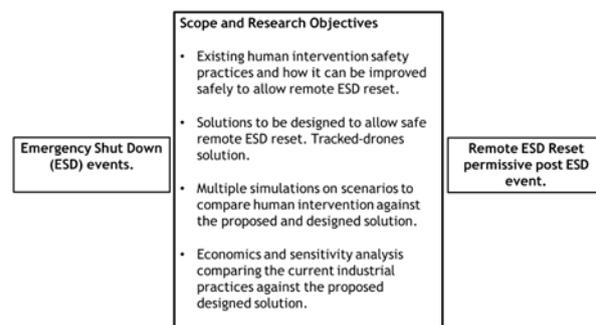


FIGURE 7. Scope and research objectives

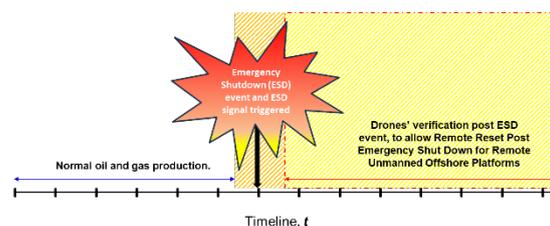


FIGURE 8. Specific temporal boundaries considered in this work

HYPOTHESIS

We expect that the ESD signal can be remotely reset without human presence for verification purposes at offshore unmanned remote production platforms, using drone verification instead.

This research applies the most well-established industrial standards and best practices for reference, particularly in designing and mapping fire and gas detectors. One of the main references is ISA-TR84.00.07-2018, outlined by the International Society of Automation (ISA).

The standards are also used in designing the verification process, as executed by drones. This proposed solution is not intended to replace the original static-mounted fire and gas detectors on the remote offshore unmanned production platform but to complement and provide additional features to the existing FGS. The drone solution is expected to provide justified recommendations and post-due diligence site verification at the ESD-affected platform, allowing humans to make the safe collective decision to initiate a remote ESD reset and proceed with a safe platform restart.

Ultimately, the proposed drone solution provides a wider field of influence (FOI) coverage, superior sweeping for gas leakage coverage, and higher consistency compared with humans, in addition to superior in-demand availability.

TECHNICAL ANALYSIS

The proposed practice of performing remote ESD reset for unmanned offshore facilities is not currently considered a safe practice owing to the lack of verification capability at the site, thus requiring a physical human presence.

Normally, the remote start-up is limited only to the PSD and is not allowed for the ESD. In the case of a real ESD, not a false alarm, serious abnormalities may occur, such as fire and leaks, which require rectification or isolation prior to any safe start-up (Norsok Standard 1998).

The standards clearly state that ESD signals shall not be automatically reset. ESD devices shall be reset locally at the affected remote unmanned offshore production platform. Some examples of the industry standards are quoted below.

“High level ESD (as defined in accordance with Pt 7, Ch 1, 7.1 General 7.1.2, e.g. platform shut-down, production shut-down) should only be provided with a capability to reset each final element locally.”

Source: Classification Society, International Maritime Organization (IMO), 2016

“113 The shutdown command shall not be automatically reset. Significant shutdown devices, (e.g. wellhead valves, riser ESD valves) shall be reset locally following recognition and reset at the main control room.”

Source: Offshore Standard DNV-OS-A101, Det Norske Veritas, 2016

In designing the proposed solution for this drone project, a set of detectors is used to replicate human senses and capabilities, thus determining the presence of fire or gas. The recommended detectors are outlined as follows:

1. Fire detectors to detect flames and extreme heat signatures.
2. Smoke detectors to identify smoke.
3. Infrared gas detectors or FLIR cameras to detect hazardous gases such as carbon monoxide and methane.
4. High-definition cameras to capture real-time images and videos.

DRONE VERIFICATION PROCESS DESIGN

Given that there is no specific industry standard for the remote ESD signal reset at remote unmanned offshore platforms, the most relevant and conservative references are considered to be the fire and gas detector mapping standards, which are well-established and proven.

Adopting industry fire and gas mapping standards to design the drone solution is expected to yield more comprehensive verification coverage, improved consistency, and improved on-demand reliability compared with human capabilities. The following standards are used as references:

1. NFPA 72, National Fire Alarm and Signalling Code, 2022, The National Fire Protection Association.
2. ISA-TR84.00.07-2018, 2018, International Society of Automation.
3. Offshore Technology Report, OTO 93-002, UK Health, and Safety Executive (UK HSE).

In this study, the drone performs the verification process systematically, by adopting a grid system. To perform the verification using a grid system, the distance between each detector type (fire, gas, and smoke) needs to be determined. The height of the detector location also needs to be determined to ensure the verification process is accurate. Hence, the use of existing industry standards for fire and gas mapping is the main reference point for the drone verification process.

Additional attention is given to the gas detector sizing, considering the hydrocarbon in gas and liquid phases. Typically, the loss of primary containment from a 2-phase process system may cause a gas cloud, which may subsequently be ignited and cause an explosion. This

explosion, depending on the overpressure value generated, may cause damage to the facility.

Notably, each manufacturer provides a product with a certain level of performance, referred to as original equipment manufacturer (OEM) sensors. This performance-based detector specification data can be used as the inputs for fire and gas mapping software such as *Effigy*TM (by *Kenexis*) or *Detect3D* (by *Insight Numerics*). The simulation results can be used to verify whether the drone provides adequate verification coverage and compare it with the verification process performed by humans.

In the absence of the OEM performance-based data, Table 1 provides an initial reference point for the drone project verification path and mapping design.

TABLE 1. Fire, smoke, and gas detectors' grid and height sizing references

Detector type	Recommend height (m)	Recommend distance (m)	Reference standards
Flame Detector	9.1	6.1 max	National Fire Protection Association (NFPA) 72 Chapter 17 Initiating Devices, Sub-Chapter 17.6 Heat-Sensing Fire Detectors <i>Note 1</i>
Smoke Detector	6.4 max	9.1	National Fire Protection Association (NFPA) 72 Chapter 17 Initiating Devices, Sub-Chapter 17.7 Smoke-Sensing Fire Detectors <i>Note 2</i>
Gas Detector	Varies depending on coverage area, engineered design, and OEM performance-based product data. <i>Note 3</i>	5.0	National Fire Protection Association (NFPA) 72 International Society of Automation, ISA-TR84.00.07-2018 Offshore Technology Report, OTO 93-002 by UK Health and Safety Executive (UK HSE)

Note:

1. Based on the projected beam construction ceiling exceeding 100 mm. Typical for remote unmanned offshore platforms.
2. This table applies in the absence of specific performance-based design criteria.
3. Fire and gas mapping software, such as *Effigy*TM (by *Kenexis*) or *Detect3D* (by *Insight Numerics*), has a pre-loaded database of OEM gas detectors (e.g., *Draeger*, *MSA*, *Det-Tronics*, and *Crowcon*.)

GAS DETECTION MAPPING - GEOGRAPHIC OR SPHERICAL GAS CLOUD APPROACH

The geographic approach is simplistic and conservative, resulting in numerous fire and gas detectors, very uniformly located, which may pose challenges for installation at the site (Kenexis 2016).

This approach does not account for wind direction, gas cloud orientation, or shape, and hence, the conservative numbers of gas detectors and uniform distance between adjacent gas detectors. This approach is generally more costly, harder to maintain, not optimised, and at some point, may not meet the requirement of gas cloud detection, as specified in ISA-TR84.00.07-2018.

The geographic approach assumes the gas cloud has an ideal spherical shape, as demonstrated in Figure 9. The critical gas cloud size is based on the overpressure value generated when the gas cloud is ignited, based on the flame front that travels to the edge of the critical gas cloud, which subsequently dictates the distance required between two adjacent gas detectors. The steps of this method are illustrated in Figures 9 to 12.

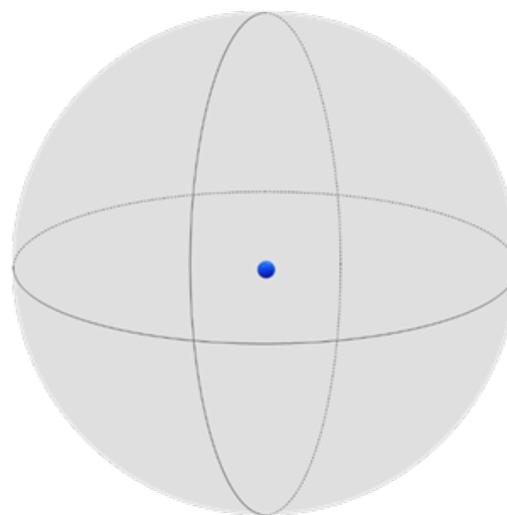


FIGURE 9. Geographic approach using the assumption of a spherical gas cloud with a blue dot representing the centre of the gas cloud

The gas cloud is assumed to have an ideal spherical shape, with the centre of the gas cloud as the origin. This gas cloud does not represent the critical gas cloud size because the overpressure value is yet to be determined. Furthermore, the gas composition is assumed to be known, and no wind factor is considered.

Next, the ignition source is assumed to be located at the origin of the gas cloud, as depicted in diagram Figure 10.

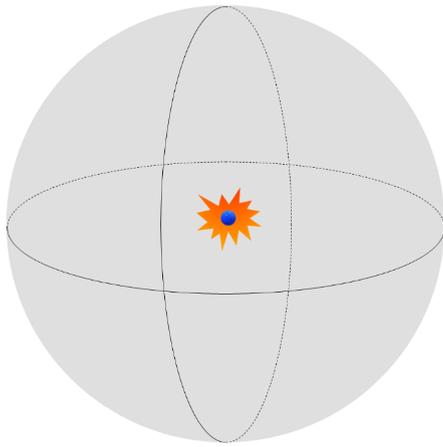


FIGURE 10. Assumption demonstrating that the ignition source is located at the centre of the spherical gas cloud

Ignition initiates the flame front, which travels uniformly and radially in all directions, as illustrated in Figure 11. The flame front travelling from the ignition point towards the outer edge of the gas cloud without obstruction is known to be laminar. At this stage, the maximum flame front velocity and overpressure value have not been reached.

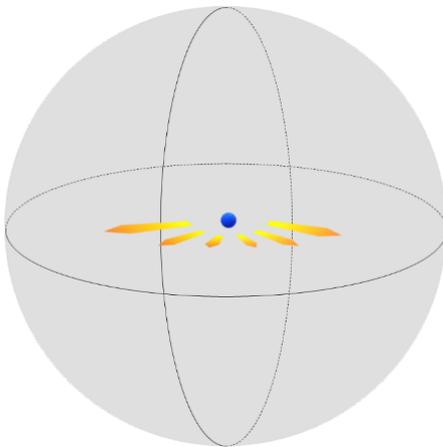


FIGURE 11. Assumption flame front travelling from the source of ignition towards the edge

Next, Figure 12 demonstrates that one of the many flame fronts, dissected horizontally, reaches the edge of the gas cloud, highlighted in red. At this point, the flame front reaches its maximum laminar flame front velocity. Only at this point, the maximum overpressure can be evaluated for comparison with the threshold overpressure limit, thus determining whether it may cause harm or damage. Generally, an overpressure of 0.15 psig is sufficient to shatter glass and cause damage (Oluwafemi Olayebi et al. 2022).

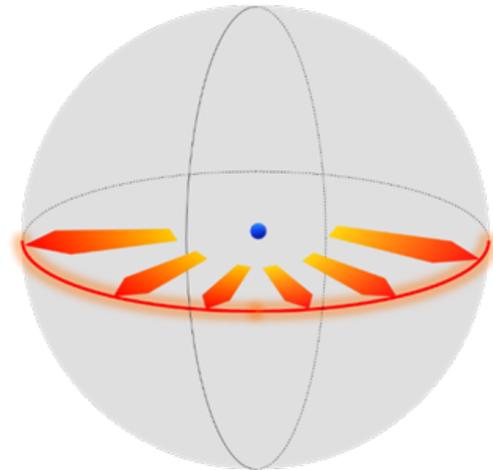


FIGURE 12. Flame front reaches the gas cloud edge and generates the maximum flame front velocity and Overpressure value

In designing gas mapping and detection, the most adopted approach is the spherical gas cloud method, with a 100% lower explosion limit (LEL) assumption. However, a lower LEL concentration can also be used for this sizing. The main objective is to minimise the risk of a gas cloud occurring with 100% LEL without being noticed within the area.

Overall, the spherical gas cloud method adopts a three-dimensional model to detect gas in the industry. The magnitude of the gas cloud varies based on the environment, facilities, equipment density, and spatial congestion. The typical assumptions being practiced in the industry are listed in Table 2.

TABLE 2. Typical performance targets for geographic gas detector mapping

Area Category	Target Flammable Gas Cloud Size (m)
Confined Space	4
Partially Confined Space	5
Open	10

Source: Towards Bespoke 3D Fire & Gas Mapping: Integration of Risk-Based Approach and CFD Modelling, Symposium Series No. 161, IChemE, 2016

For this research, a 5 m radius is chosen. This is the most stringent limit, assuming that the offshore production platform deck areas are mostly semi-enclosed, congested, and dense with equipment, but not confined.

ENCLOSED ENVIRONMENT OPTION - 5 M

The standard that is often referred to by the offshore oil and gas industry for gas detector spacing is Offshore Technology Report, OTO 93 002 – Offshore Gas Detector Siting Criterion, Investigation of Detector Spacing. This document is available and distributed by the UK Health and Safety Executive (UK HSE). The main fundamental gas detection philosophy, as stated in the report, is that when any gas cloud is sufficiently large, if ignited, it creates an explosion that causes significant damage. Thus, the cloud size should be detectable by the installed gas detection array (Kenexis 2024).

The UK HSE performed numerous studies to measure the resulting flame speeds and overpressures in experimental trials covering a range of conditions, including methane and propane hydrocarbon sources and blockage ratios ranging from 0% to 40%. From the experimental data, the UK HSE determined that for blockage ratios of 30%–40%,

typical for a congested offshore production platform, cloud sizes that are less than 6 m in diameter are not expected to cause overpressure damages resulting from the explosion. As a result of these findings, the UK HSE subsequently recommended employing a 5 m grid for offshore oil production.

The results from UK HSE studies are considered for offshore production platforms, where methane is the lightest hydrocarbon and the highest concern. In contrast, larger facilities, such as refineries, silos, or tank farms, may generate much larger clouds, although the likelihood to cause severe damage is reduced because of less confinement and obstruction.

For dense processing areas, 5 m grids are necessary, in highly confined areas or areas where the chemical of concern has a greater ability to cause damage. For open onshore process areas, a wider spacing of 10 m may be acceptable.

Figure 13 illustrates an ideal 5 m layout of gas detectors installed in a typical well-bay area on a remote unmanned offshore production platform.

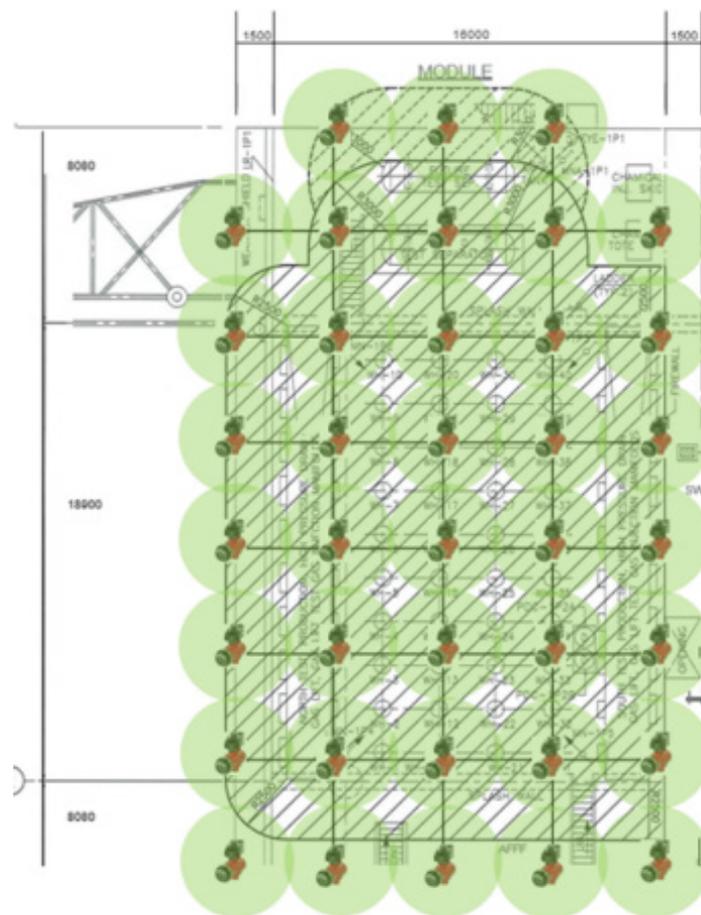


FIGURE 13. Recommended gas detector layout with 5 m spacing in the well-bay area of a typical offshore production platform

ECONOMIC ANALYSIS

Three key economic parameters are used in evaluating whether the future drone project is economically viable:

1. Net present value (NPV)
2. Profit investment ratio (PIR)
3. Internal rate of return (IRR)

Based on historical factors, a cost escalation of 3.0% is applied from 2024, to compensate for escalating capital and direct operating costs. Oil price is estimated based on 2024 OPEC Oil Price Outlook, for this evaluation. The crude oil price assumption for 2024 is 90 USD/bbl, with an annual increase of 5 USD/bbl until 2038.

The economic analysis is also based on the volume of oil recovered by minimising the impact of spurious ESD and weather constraints, and not simply the total production of the platform. The assumptions used in the economic analysis are outlined as follows:

ONLY ONE REMOTE UNMANNED SATELLITE PLATFORM

This study considers only one specific unmanned satellite platform, and its production profile data is used for deriving the proposed solution and economic assumptions. The reason for using only one unmanned satellite platform is to simulate the simplest scenario at the smallest scale possible, with the expectation the economic analysis will still yield positive results.

PRODUCTION PROFILE SCREENING

One remote unmanned production platform for Company X will be used for this study. The asset’s estimated remaining life is approximately 15 years, prior to the cessation of production due to economic thresholds. The platform is producing approximately 2,000 bbl/day of oil in 2024, with an average production decline of 5% per year, until 2039, as depicted in Figure 14.

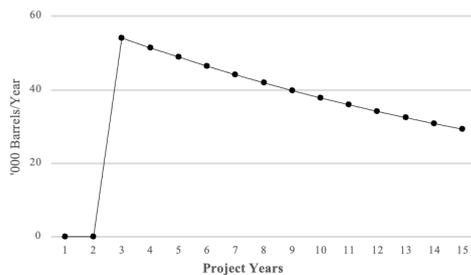


FIGURE 14. Projected production rate of Company X at one remote unmanned offshore platform

OIL PRODUCTION YEARS FROM 2024 ONWARDS, 15 YEAR PROJECTION

In this study, the oil and gas production concession for Company X, as permitted by Petronas Malaysia, is assumed to expire in 2039, according to the profit-sharing contract (PSC). This expiry date may be extended beyond 2039 in the event that Company X requests and performs due diligence on the economics and is subject to the Petronas agreement.

OIL RESERVOIRS DECREASING AT 5% PER YEAR

The decline in the oil reservoir is determined based on rigorous well tests and history-matching exercises performed by offshore production personnel, and later, the information is fed back to production technologists and sub-surface engineers for further history matching and analysis. The reconciled data and analysis are used by the organisation to develop business plans, determine budgets, and make reservations. The data is highly confidential owing to the sensitivity and potential impact on the company’s share value in the market. Hence, for this research, the decrease of 5% per year is selected for Company X’s unmanned production platform.

OIL PRICE AND PROJECTION

For the economic and sensitivity analyses, the current oil price and its projection up to the year 2039 are used, specifically 90 to 105 USD/bbl. Reliable sources in the oil and gas industry are referenced for this research, as shown in Figure 15.

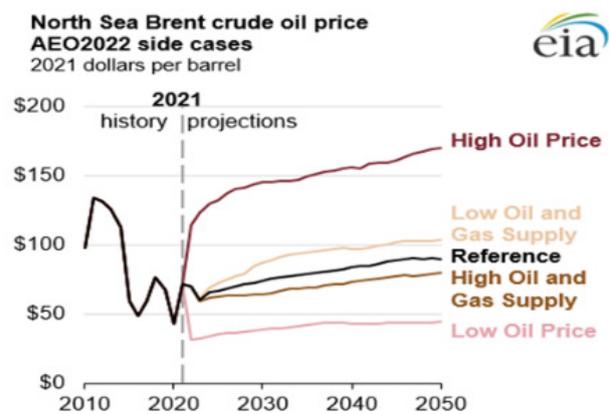


FIGURE 15. Crude oil price projection
Source: U.S. Energy Information Administration, Annual Energy Outlook (AEO 2022)

INFLATION RATE OF 3%

The inflation rate of 3% is determined based on Bank Negara Malaysia's latest available figures and assumptions.

DISCOUNT FACTOR OF 15%

The discount factor (DF) of 15% is used herein because it is the most conservative value among the typical DFs used within the oil and gas industry for the production phase of the field development. Typical DFs range from 10% to 15% for production-related projects.

Discounting - Cost of Capital

- The discount rate used in evaluating an investment should be appropriate to the risk of the PROJECT, not the company.
- Discount rates should only account for market (or systematic) risk, not idiosyncratic (unsystematic or specific) risk.
- When is a risk "market" or "systematic", and when is it "specific" or "unsystematic"?
 - Exploration vs. Development vs. Production
 - Oil vs. Gas
 - Working interest vs. Revenue interest
 - Upstream vs. Midstream vs. Downstream
 - Country A vs. Country B vs. Country C
 - Leveraged vs. Equity

Industry Value Chain	Activity	Typical Discount Rates
Upstream	Exploration	15% - 20%
Upstream	Production	10% - 15%
Midstream	Power	8% - 12%
Midstream	Pipelines	8% - 12%
Midstream	Petrochemicals	12% - 18%
Refining & Marketing	Refining	12% - 18%

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HALLIBURTON

FIGURE 16. Discount rate assumed for petroleum economics, reported by Halliburton

Source: SPE Introduction to E&P. Petroleum Economics & Commercial, 28th November 2019 by Lamé Verre

ESTIMATED DOWNTIME DAYS DUE TO BAD WEATHER IN ONE (1) MONSOON MONTH

This assumption is based on Company X's historical full-year production loss management data between 2021 and 2023. An average of 7 days per calendar month during the northeast monsoon season, hampering the South China Sea east coast of peninsular Malaysia, is used as a conservative assumption for the platform suffering prolonged ESD. Company X's production engineers and operations engineers will make use of the existing hydrocarbon losses data used for periodical reporting and provide them to the drone project team for further analysis and solution proposals. Periodic hydrocarbon loss data is monitored daily and mandatory for hydrocarbon-producing operators worldwide. Thus, the data can be easily acquired and collated in-house.

MONSOON SEASON ESTIMATED FOR 5 MONTHS

The forecasted period for the Northeast Monsoon is from November to March. Based on this, the monsoon period is estimated to be approximately 5 months. This is the period where these unmanned platforms are exposed to prolonged shutdowns.

ANALYSIS IS BASED ON AN EXISTING OIL-PRODUCING PLATFORM (BROWNFIELD DEVELOPMENT)

For this research, the economic analysis is primarily based on an existing oil-producing platform referred to in the oil and gas industry as a brownfield development, which is expected to be affected by logistical challenges.

CAPITAL EXPENDITURE (CAPEX)

The projected economics of the drone project have been evaluated based on the 1st of January 2024 as the reference start date. The oil production is assumed until 2039, before the expiration of the PSC, providing 15 years of oil production. It is assumed that the production is shared between Company X and Malaysian government-owned Petronas. The project CAPEX is estimated at 3.2 million USD. The CAPEX breakdown for the drone project is shown in Table 3.

TABLE 3. CAPEX allocation for the drone project

CAPEX CATEGORY	Total (USD)
Hydrocarbon Production Loss Data Studies	0
Project Development (EPCIC) – Engineering	306,084
Project Development (EPCIC) – Procurement	2,358,421
Project Development (EPCIC) – Construction	74,937
Project Development (EPCIC) – Installation	166,547
Project Development (EPCIC) – Commissioning	156,232
Project Close Out	141,411
Total	3,203,632

OPERATING EXPENDITURE (OPEX)

Upon successful commissioning of the drone project, it will go into operational phase. Like other typical systems and equipment, it shall go into preventive maintenance and possible corrective maintenance if needed. This is intended

to prolong the lifespan of the whole drone system, enable on-demand availability, and maintain reliability. To ensure safe production operations, scheduled preventive maintenance is critical.

Assuming the drone will serve the whole balance of the expected asset lifetime, a proposed long-term service maintenance contract or price agreement is recommended. This is intended to ensure a seamless preventive maintenance campaign, without the need to go through the standard procurement process for every preventive campaign mobilisation.

The frequency of preventive maintenance is proposed to be 6 months per campaign. This is assuming that no corrective maintenance is required. The annual preventive maintenance cost is approximately 128,000 USD per year. This cost is insignificant compared with the assurance of effective and efficient oil production, and not being hampered by spurious ESD during the monsoon season.

The proposed operating expenditure (OPEX) for managing the drone system is shown in Table 4.

TABLE 4. Preventive maintenance cost breakdown (per campaign)

Preventive Maintenance Cost (per Campaign Every 6-Monthly)					
No.	Line item	Price/Qty (RM)	Quantity	Unit	Sub-total (RM)
1.	Drone engineer	4,500	20	day	90,000
2.	Drone technician	3,000	20	day	60,000
3.	Manpower mobilisation & demobilisation cost	30,000	1	lot	30,000
4.	Tools and equipment rental	6,500	25	day	162,500
5.	Consumables (rollers, test gas, etc.)	20,000	1	lot	20,000
6.	Spare drone batteries	5,000	8	set	40,000
7.	Integrated HMI module and controller - software update	7,500	1	lot	7,500
8.	Licence and remote product after-sales support	200,000	1	year	200,000
Total in RM					610,000
Total in USD					128,421

REMOTE UNMANNED OFFSHORE PLATFORM WITH THE IMPLEMENTED DRONE PROJECT

Based on the previously described scenario and assumptions, the drone project is expected to be economically viable and yield significant value while improving safety. The discounted cumulative cash flow at a 10% DF demonstrates the maximum capital overlay of approximately 3.52 million USD, which is expected to occur in the 2nd year of the project. The payback period is approximately 2.7 years. This is the point where the cash flow becomes positive again, around the 3rd quarter of 2025. Based on the 10% DF, the expected terminal cash surplus is approximately 23.34 million USD. These results are shown in Figure 17.

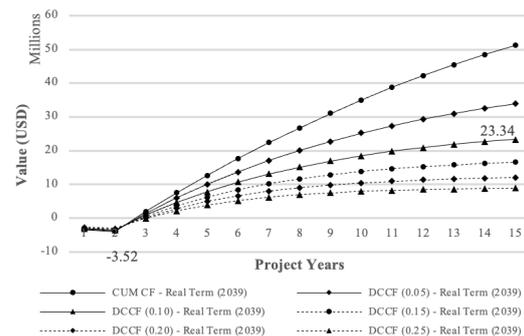


FIGURE 17. Discounted cumulative cash flow projection of the drone project by 2039

KEY ECONOMIC PARAMETERS

Three economic parameters are used to decide whether the drone project is economically viable. They are the NPV, PIR, and IRR. All three parameters are discussed in this section, and subsequently, a separate sensitivity analysis is discussed.

NET PRESENT VALUE (NPV)

Referring to Figure 18, the NPV remains positive even for a 25% DF. At a moderate DF of 10%, the NPV value is estimated to be 11.35 million USD.

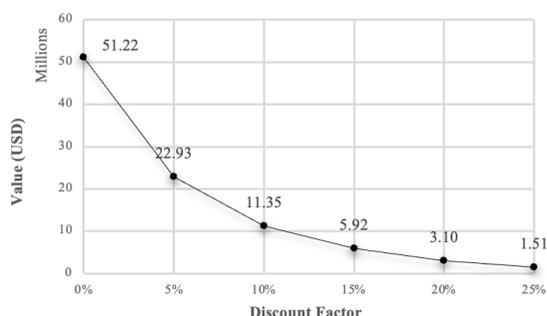


FIGURE 18. NPV profile of platform X with the drone project

PROFIT INVESTMENT RATIO (PIR)

The PIR is estimated to be 6.63 based on a 10% DF, which is considered a healthy PIR value. Even at the most conservative DF of 25%, the PIR value remains above 1.0, with an estimated value of 2.93, as shown in Figure 19.

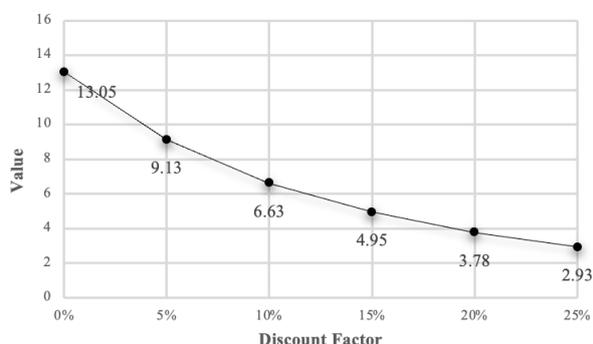


FIGURE 19. PIR profile of platform X with the drone project

INTERNAL RATE OF RETURN (IRR)

Figure 20 shows an IRR value of 65.9% for a 10% DF. Assuming the most conservative DF value of 25%, the IRR value remains at a healthy figure of 46.0%.

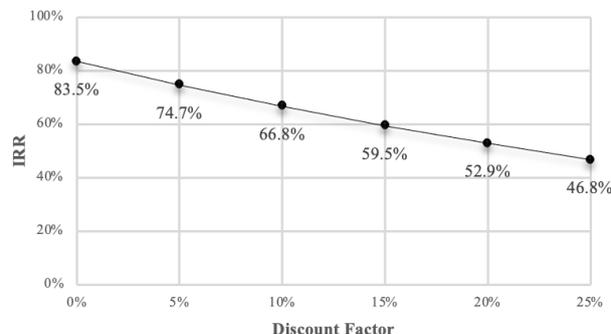


FIGURE 20. IRR profile of platform X with the drone project

Overall, the analysis indicates that the project is a promising investment, with very robust viability, even considering a steep DF of 25%.

KEY ECONOMIC PARAMETERS OF THE SENSITIVITY ANALYSIS

This section discusses the key parameters used in the sensitivity analysis. A range of ±30% is applied to four main inputs, namely the crude oil price, oil production profile, CAPEX, and OPEX.

The crude oil price is known to be volatile. For example, the crude oil price plunged to below 20 USD/bbl in 2020, due to the sudden abundance of shale oil.

Production profiles for any given platform are also susceptible to abrupt changes. Multiple possibilities can occur, including sand formation collapse, sand screen collapse, wellhead failure due to integrity issues, and forced shut-in for safety reasons. On the positive side, any production enhancement, such as scale squeeze activities, secondary lifts, reperforation, and recompletion works, can help enhance the production profile.

CAPEX must also be considered in the sensitivity analysis. However, for this drone project, the bulk of the CAPEX cost comes from the FLIR cameras. Considering that the FLIR cameras are final products and not commodity items, it is safe to assume that the cost will not fluctuate significantly. Nevertheless, for this sensitivity analysis, the case will be simulated for comparison purposes.

In terms of OPEX, the cost is assumed to be stable and only affected by inflation. The main factor affecting this cost is the manpower and tools rental, which comprise approximately 45% of the overall OPEX cost.

NET PRESENT VALUE (NPV) SENSITIVITY ANALYSIS

The production profile and crude oil price factors overlap each other, as seen on the NPV sensitivity analysis chart (Figure 21), indicating almost identical NPV sensitivity. The NPV is most sensitive to the changes in these two factors, but even with a 30% reduction in crude oil price or production profile, NPV remains positive. It is most robust against OPEX changes, with minimal NPV deviation (~10%).

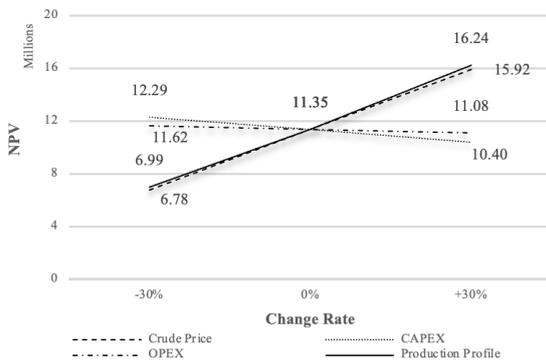


FIGURE 21. NPV sensitivity analysis of platform X with the drone project

PROFIT INVESTMENT RATIO (PIR) SENSITIVITY ANALYSIS

The production profile and crude oil price factors overlap each other, indicating identical PIR sensitivity. At a 30% reduction in the production profile and crude oil price, almost the same sensitivity gradient is observed with a 30% increase in CAPEX, but still with a positive impact. At a 30% reduction in CAPEX, more sensitivity is observed, with an increased gradient. The OPEX changes at ±30% have an insignificant impact on the PIR numbers, as demonstrated in Figure 22.

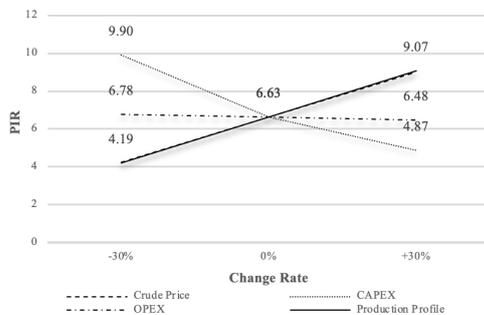


FIGURE 22. PIR sensitivity analysis of platform X with the drone project

INTERNAL RATE OF RETURN (IRR) SENSITIVITY ANALYSIS

The IRR sensitivity for the production profile and crude oil price are overlapping. At a 30% reduction, the production profile and crude oil price have almost the same sensitivity gradient as that observed with a 30% reduction in CAPEX, while maintaining a positive impact. At a 30% increase in CAPEX, production profile and crude oil price have less sensitivity, with a reduced gradient. Similar to PIR, changes in OPEX have an insignificant impact on the IRR values. The analysis results are shown in Figure 23.

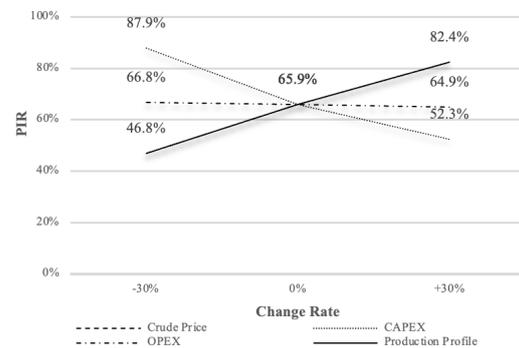


FIGURE 23. IRR sensitivity analysis of platform X with the drone project

IMPACT ON THE NPV, PIR, AND IRR BASED ON THE CRUDE OIL PRICE RANGE OF 20 TO 35 USD

Based on the screening analysis, the crude oil price range between 20 to 35 USD indicates a significant reduction in all three economic parameters at reasonable DFs.

The main highlight is the decrease in NPV to -0.78 million USD at a DF of 15%. From the previous analysis using a 10% DF, the NPV remains positive but marginal, with a value of 0.36 million USD. This poses a remarkably substantial risk in terms of the other sensitivity factors, such as changes in the CAPEX or even the OPEX. This marginal NPV is not robust, and the project can be easily derailed by the progression of a negative NPV value, as demonstrated in Figure 24.

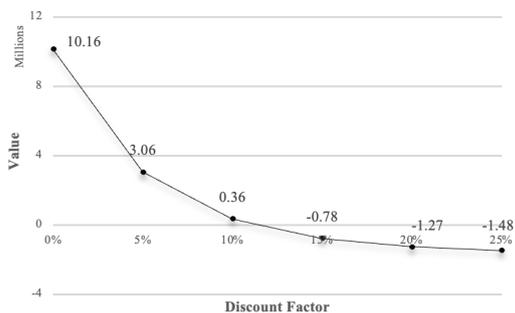


FIGURE 24. NPV values at various DFs for platform X with the drone project - crude oil price range of 20 to 35 USD

The PIR decreases to 0.90 at the DF of 10%. For a project to break even and be viable, the PIR value must be above 1.0, meaning that for every dollar invested, the return will be more than 1.0 USD. For this project to stand any chance of investment the DF needs to be below 9%, which is relatively optimistic compared with the normal practice of a 10% DF, as shown in Figure 25.

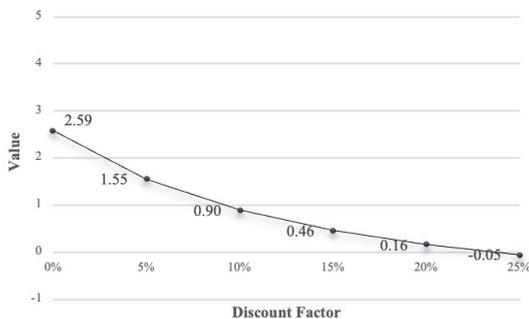


FIGURE 25. PIR values at various DFs for platform X with the drone project - crude oil price range of 20 to 35 USD

The IRR decreases to 12.4% at a DF of 10%, indicating a very slow return on investment, as shown in Figure 26.

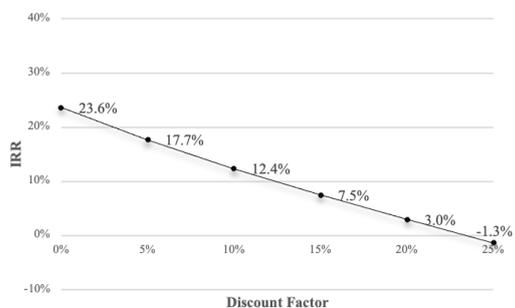


FIGURE 26. IRR values at various DFs for platform X with the drone project - oil price range of 20 to 35 USD

Overall, these parameters indicate that the project is significantly less enticing and has a high probability of not proceeding. At the DF of 15%, the NPV dropped to a negative value of -0.78 million USD. The PIR of 0.46 is less than 1, indicating that it is not a worthwhile investment, and the IRR value of 7.6% indicates a significantly slow return.

Hence, if the crude oil price dips between this range, the drone project is not viable.

CONCLUSION AND RECOMMENDATION

This research considers the feasibility of remotely resetting the ESD signal for unmanned offshore platforms via drone verification. The results theoretically prove that remote ESD signal reset is feasible for remote offshore unmanned production platforms, enabling safe verification conducted at the site by drones instead of humans. Ultimately, the implementation of a drone project is still expected to receive significant pushback from industry experts and regulating bodies.

An initial survey is recommended to gather information from seasoned offshore production personnel regarding their actions when faced with ESD situations. It is also necessary to gauge the respondents' perception and reception of this research topic. This survey feedback can subsequently be used to further improve the drone solution.

The proposed drone solution is developed based on existing well-established industry standards for fire and gas mapping and design, developed by industry experts such as Petronas, ISA, IMO, DNV, and NFPA. Instead of creating a new standard or methodology, we used the established methods and standards for initial guidance and proof of concept. This approach may also improve the chances of industry acceptance.

Moreover, simulations should be conducted to demonstrate that drones can provide superior FOI coverage. This is necessary to ensure that remote ESD reset can be performed without human presence or verification.

In terms of economics, this drone project is suitable for both new and aged offshore facilities, demonstrating high project viability. For example, the drone project begins to exhibit a negative NPV at only 20 to 35 USD per barrel of oil. Beyond this oil price threshold, or at the current oil price, assuming the facilities have a decent oil production rate (approximately 500 bbl/day), the drone solution is expected to provide a significantly high economic return. Ideally, this drone project can be installed during the platform's construction to minimise the expensive offshore installation costs.

In terms of addressing production loss or deferment, this drone project significantly improves the chances of rapidly restarting the platform due to a spurious ESD signal. This is historically true for water operations in Malaysia, where personnel cannot be dispatched safely until the adverse weather subsides. This waiting period causes significant production losses, whereas drones can perform verification in a small fraction of the time.

This research does not suggest that drones can replace the existing mounted FGS. The proposed solution is complementary to the existing FGS on the offshore production platform. This drone project solution is intended for use in the absence of a human presence due to logistical challenges. Ultimately, humans, such as the offshore installation manager, still have the final decision in performing the remote ESD reset aided by this drone project recommendation after performing a remote verification exercise.

Overall, drone solutions are expected to face challenges, reservations, and negative feedback from industry, but with sufficient knowledge sharing and constructive debate, they may have the potential for global-scale adoption.

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DECLARATION OF COMPETING INTEREST

None.

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