ABRAJ
ENERGY SERVICES

Full Rig Mechanization:

ABRAJ Energy Services' Pioneering Approach To Safer, Smarter Drilling Operations



WHITE PAPER

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EXECUTIVE SUMMARY

Drilling rig operations rank among the most hazardous working environments in the oil and gas industry. Personnel injuries, human errors, and extended non-productive time (NPT) have long been accepted as an inherent cost of doing business. ABRAJ Energy Services is challenging this paradigm through full rig mechanization – a comprehensive approach that replaces manual, high-risk rig floor operations with remotely controlled, automated equipment systems.

ABRAJ was among the earliest drilling contractors in the Middle East and North Africa (MENA) region to deploy fully mechanized rigs, beginning operations in Oman in 2021 and subsequently expanding to Kuwait. ABRAJ currently operates six fully mechanized 1000HP AC rigs in Oman and one in Kuwait — seven fully mechanized 1000HP AC rigs in total. Each mechanized rig is equipped with an integrated suite of remotely controlled equipment, a proprietary interlock system comprising more than 27 safety interlocks per rig, AI-enabled CCTV zone monitoring cameras, and a drilling process automation platform.



In response to persistent industry-wide challenges around personnel safety and drilling efficiency, ABRAJ implemented a multi-pronged mechanization strategy that delivers:

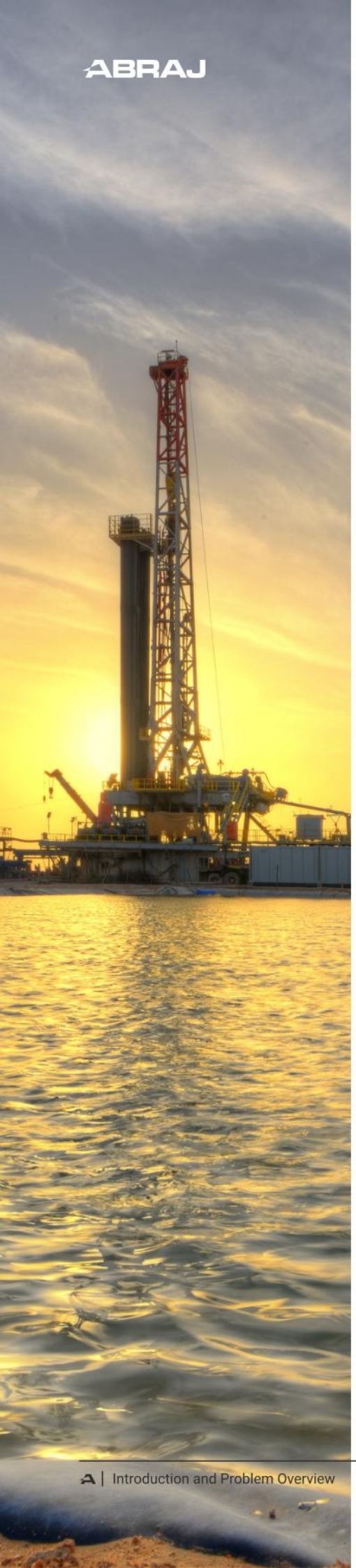
- **Hands-Free Operations:** Core rig floor activities during normal drilling operations – pipe handling, connection make-up and break-out, thread compound application, and mud bucket operations – are controlled remotely from the driller's cabin, removing personnel from the line of fire for those tasks.
- **Enhanced Safety:** More than 27 custom-designed tool-to-tool interlocks per rig that prevent human error, complemented by AI-enabled monitoring cameras that detect personnel entering a temporary no-go zone and alert the driller.
- **Reduced Manpower:** Fewer personnel required on the rig floor, directly reducing HSE exposure, injury probability, and associated labor costs.
- **Faster Rig Moves:** Carrier-based rig designs and wireless mast control that significantly reduce rig move times compared to conventional rigs.
- **Consistent Drilling Performance:** Process automation and sequencer technology reduce performance variability between drilling crews by encoding optimized, repeatable parameters into the rig control system. These capabilities are installed across the mechanized fleet and are being implemented progressively.

This white paper details the industry challenges that prompted ABRAJ's mechanization investment, the specific technical innovations implemented, the results and operational outcomes achieved, and the company's forward-looking vision for AI-integrated drilling operations.

"Our mechanized rigs represent a fundamental shift in how we approach drilling safety and performance. We don't just automate individual tools – we've reimagined the entire drilling operation to keep people out of harm's way while delivering better, more consistent results."

– Eng. Saif Al Hamhami, CEO, ABRAJ Energy Services





INTRODUCTION AND PROBLEM OVERVIEW

The oil and gas drilling industry operates in one of the most hazardous working environments across all industrial sectors. Rig floor operations involve heavy equipment moving at high speeds, pressurized systems, and numerous simultaneous activities – all of which create significant risks for personnel. According to the International Association of Drilling Contractors (IADC), the drilling sector has historically recorded higher injury and fatality rates compared to many other heavy industries, despite continuous safety improvements over recent decades.

The operational challenges extend well beyond safety. In drilling operations, productive rig time can broadly be divided into drilling time — the actual making of hole — and flat time, covering the necessary activities performed when the bit is not making hole. Any unplanned lost time is typically captured separately as NPT. Only the third category creates measurable progress in the well delivery process; NPT and flat time consume rig hours without advancing the well. Every hour of NPT – whether caused by equipment failure, human error, or operational inefficiency – can cost operators tens of thousands of dollars, while excessive flat time on connections, tripping, casing running, and other non-drilling activities erodes well delivery performance just as effectively. Research published by the Society of Petroleum Engineers (SPE) has consistently identified human factors as a leading contributor to both NPT and extended flat time. Mechanization targets both: it reduces the human-error events that generate NPT, and it compresses the flat time associated with repetitive rig floor sequences.

Traditional drilling rigs require substantial crews working in close proximity to heavy machinery. While many conventional rigs are already fitted with hands-off tools such as iron roughnecks and pipe handling equipment, those tools still depend on continuous human intervention: crew members must guide, push, align, and stab pipe, apply thread compound, and step in whenever a tool does not engage as intended. Each of these interventions places workers in or near the "line of fire" – the zones immediately surrounding moving equipment where the risk of injury is highest. Industry statistics indicate that hand and finger injuries, struck-by incidents, and crush injuries on the rig floor account for a disproportionate share of drilling-related safety events.

Furthermore, conventional operations depend heavily on individual crew competency and manual coordination. Because each connection and each stand is executed through hand-guided sequences, the pace of work reflects the experience of the crew on shift: a driller with deep familiarity with a particular rig and field will typically complete a tripping operation faster than a crew newer to the equipment. This is a structural feature of manual work rather than a reflection on crew capability – any process that depends on human timing and judgement will show natural variation. That variation introduces uncertainty into the well delivery process and makes performance harder to forecast for both drilling contractors and their operator clients.

Against this backdrop, the concept of rig mechanization has emerged as a transformative approach: replacing manual, high-risk tasks with remotely operated equipment controlled from a safe distance. While individual mechanized components – such as iron roughnecks and automated pipe handling systems – have been available for decades, the integration of these systems into a fully mechanized rig represents a more recent and significant advancement that few drilling contractors have undertaken comprehensively.

"ABRAJ Energy Services is evolving beyond traditional service delivery. We're becoming a trusted solutions partner, bringing innovation and performance to the forefront of every operation."

– Eng. Saif Al Hamhami, CEO, ABRAJ Energy Services



ABRAJ Energy Services, Oman's leading drilling company with one of the youngest and most advanced fleets in the GCC, recognized early that partial mechanization was insufficient. The company embarked on a strategy to deploy fully mechanized rigs – complete packages in which the major rig floor operations are performed remotely, supported by integrated control software, custom-specified interlock systems, and AI-enabled CCTV camera systems for zone monitoring. The first fully mechanized ABRAJ rig entered operations in Oman in 2021. The mechanized fleet today comprises six fully mechanized 1000HP AC rigs in Oman and one in Kuwait — seven fully mechanized 1000HP AC rigs in total.

The following sections discuss the specific challenges that ABRAJ identified in conventional drilling operations and the comprehensive mechanization strategy implemented to address them.

CHALLENGES IN CONVENTIONAL DRILLING OPERATIONS

ABRAJ's review of conventional drilling operations highlighted these critical problem areas that the mechanization program was designed to address:

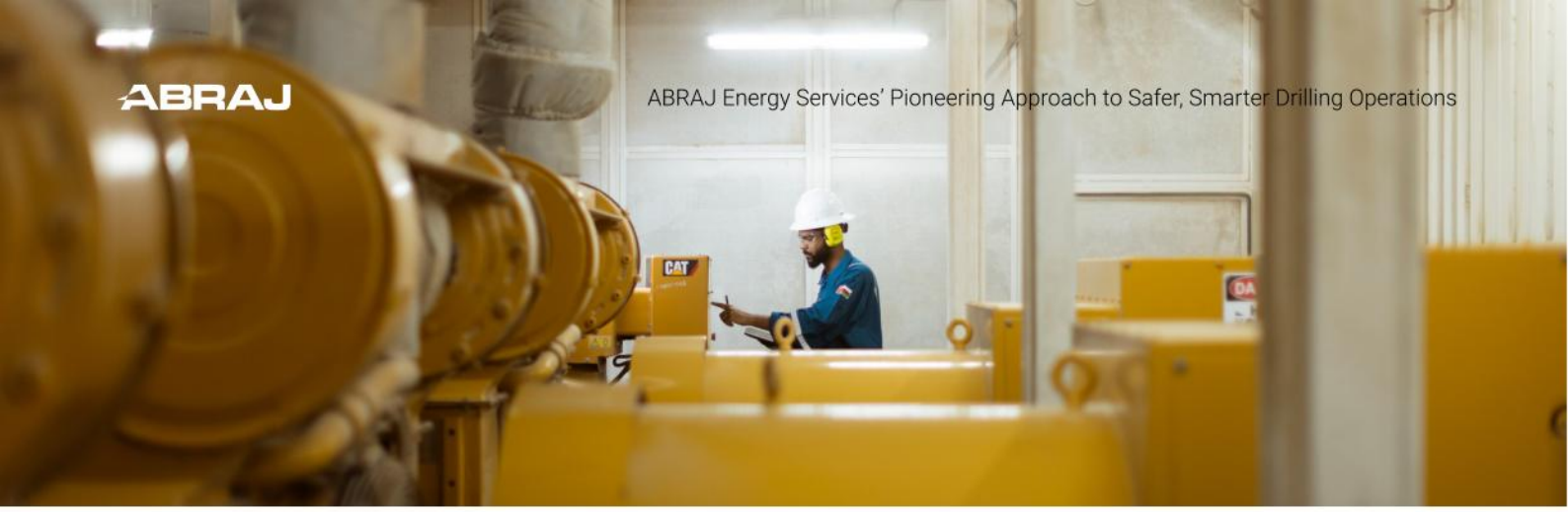
Personnel Exposure to High-Risk Zones

Conventional rigs require crew members to work directly on the rig floor in close proximity to the rotary table, top drive, and pipe handling equipment. Even where hands-off tools are fitted, personnel are still required to guide and align drill pipe, stab connections, operate manual tongs where those remain in use, apply thread compound, and intervene when a tool does not engage cleanly – placing them squarely in the line of fire. Rig floor injuries – particularly hand and finger injuries, struck-by incidents, and crush injuries – account for a disproportionate share of drilling-related safety events industry-wide.



Human Error and Inconsistent Performance

Conventional operations depend on individual crew competency and manually coordinated sequences, which introduces natural performance variability. A crew experienced with a specific rig and field will typically complete a tripping operation faster than a crew newer to the equipment – a structural characteristic of manual work rather than a reflection on crew capability. That variability makes the well delivery process harder to plan and forecast, and manual sequences leave more room for the timing and coordination errors that can result in equipment damage or wellbore problems. Human error remains one of the leading contributors to drilling incidents and NPT across the industry.



Extended Rig Move Times

Conventional rigs are typically designed as discrete components that must be individually loaded, transported, and reassembled at each new location. The disassembly and reassembly process is labor-intensive, requiring significant crane time and large crews. Rig moves can consume multiple days of non-productive time, directly extending the overall well delivery process and impacting project schedules, costs, and HSE exposure for the transport crew.

Hazardous Mast Operations

On conventional rigs, raising and lowering the mast is one of the highest-risk operations, requiring personnel to be in close proximity to the massive structure. The process typically involves manual controls operated near the base of the mast, with limited ability to observe the operation from a safe vantage point.

Limited Automated Safeguards

Conventional drilling operations often lack integrated software systems that connect equipment, monitor interactions between tools, and provide automated safeguards to prevent conflicting or dangerous equipment operations. Drillers rely primarily on their own experience and judgment, with minimal automated fail-safes to prevent human errors that can lead to equipment damage, well control incidents, or crew injuries.

Location and Access Constraints

Conventional rig layouts require large, heavily prepared locations and wide access roads to accommodate the number of individual loads involved in a rig move. Location preparation – civil works, access roads, and subsequent site restoration – is a direct cost to the operator. In geographically constrained or environmentally sensitive areas, the required location footprint and road dimensions can become a limiting factor on where a rig can be deployed at all.

Power Consumption and Fuel Efficiency

Conventional rig power systems frequently run more generating capacity online than the rig's actual load requires, with engines running regardless of demand. The result is avoidable fuel consumption, higher emissions per well, and accelerated engine wear – costs that accumulate for every day the rig is on location.

Identifying these challenges was the first step toward improvement. ABRAJ recognized that addressing them would require not incremental upgrades to individual components, but a comprehensive, systems-level approach to mechanization. The next section outlines the strategy and best practices ABRAJ has implemented across its mechanized rig fleet.

ABRAJ'S MECHANIZATION STRATEGY AND BEST PRACTICES

ABRAJ implemented a comprehensive mechanization strategy across its AC rig fleet – spanning 1000HP rigs in Oman and Kuwait – focusing on remote equipment control, integrated safety systems, software automation, and optimized rig design:

1. Fully Mechanized Equipment Suite

At the core of ABRAJ's approach is a suite of remotely controlled equipment that removes the need for personnel on the rig floor during normal drilling operations. Every major tool is operated from the driller's cabin via the rig's integrated control system, creating what ABRAJ's team describes as a "cockpit"-like operating environment. The specific control platform differs by rig manufacturer across the fleet, but the operating principle is consistent: primary control of the rig floor sits with the driller in the cabin.

"It's like being a pilot. The driller sits in his cabin with control of the rig floor equipment, so during drilling operations we keep the crew away from the moving machinery."

— Ismail Al Habsi, Drilling Superintendent, ABRAJ Energy Services



The table below sets out representative mechanized equipment installed on ABRAJ's mechanized rigs. Primary control is the driller's principal means of operating the tool during normal drilling operations. Secondary control is the backup or local means of operating the same tool, used during maintenance, commissioning, or if primary control is unavailable.

Equipment	Primary Control	Secondary Control
Power Catwalk	Driller Cabin – Integrated Rig Control System	Wire Less Control & Local Control
BX Elevator	Driller Cabin – Integrated Rig Control System	–
Top Drive System	Driller Cabin – Integrated Rig Control System	–
Lower Guide Arm (LGA)	Driller Cabin – Integrated Rig Control System	–
Iron Roughneck AR-80	Driller Cabin – Integrated Rig Control System	Wireless Control
Pipe Doper (Automatic)	Driller Cabin – Integrated Rig Control System	–
Power Slip PSF-14	Driller Cabin – Integrated Rig Control System	–
Mud Bucket (Mechanized)	Driller Cabin – Integrated Rig Control System	Local Control
Pipe Cat / Pipe Stabber	Driller Cabin – Integrated Rig Control System	–
Mast (Raise / Lower / Scope)	Wireless Remote Control from Safe Distance	Local Control

Individual tools within this suite remove specific manual tasks that were previously points of HSE exposure. The automatic pipe doper applies thread compound to each connection and retracts without human intervention, replacing the practice of a crew member applying compound by brush – a repetitive task that exposed workers to hand and finger injuries. The mechanized mud bucket likewise replaces a manual installation and removal task at the connection. In each case the hands-on activity is removed from the rig floor rather than simply made easier to perform.

Two distinct layers should be separated here. The mechanized equipment itself provides remote control of each individual tool from the cabin. The sequencer is an additional software layer, installed on some units in the fleet, that chains those individual tool commands into one combined operation. Where the sequencer is active, a tripping operation runs as a single automated sequence: the operator activates the pipe cat from the console, the drill pipe is pushed onto the rig floor, the BX Elevator lifts it, the Lower Guide Arm (LGA) centers it over the rotary table. The slips engage the drill pipe and transfer the string load from the top drive to the rotary table, allowing the top drive to disconnect from the current stand. The Iron Roughneck makes up the connection, and the Top Drive hoists the assembled string – without a crew member entering the rig floor.

2. Custom-Designed Tool-to-Tool Interlock System

Each ABRAJ mechanized rig features more than 27 individual interlocks designed to prevent conflicting equipment operations and human error. Critically, these interlocks are not standard manufacturer offerings – they were designed and specified by ABRAJ's engineering team based on lessons learned from historical incidents, near-misses, and human error patterns across the drilling industry.

"These interlocks did not come from the manufacturer. They came from ABRAJ's own experience — incidents, operational errors, and lessons learned in the field over the years. We turned those lessons into engineering controls: interlocks that stop human error from becoming an incident."

— Saud Al Ghafri, Operations Manager, ABRAJ Energy Services

The interlock system monitors the status of all connected equipment in real time and prevents actions that could create hazardous conditions. The following are representative examples drawn from the wider set of more than 27 interlocks fitted to each rig:

Condition	Prevented Action	Safety Rationale
IBOP closed on rig floor	Mud pump cannot start	Prevents pressurizing the string with crew below, avoiding mud splash hazards
Pressure present in string	IBOP cannot open	Prevents uncontrolled release of pressurized fluid onto the rig floor
Elevator bails extended	Rotating Link Adapter (RLA) cannot be rotated	Prevents extended bails and elevator from being swung into surrounding equipment or personnel

By building interlock logic on actual incident data and near-miss reports rather than generic safety protocols, ABRAJ has created a system that directly targets the root causes of the industry's most common human-error incidents.

One distinction is worth stating clearly: an interlock is a hard-wired or software-enforced control that prevents an unsafe action from being executed at all. The AI camera system described in the next section is not an interlock. It is a safety monitoring device that supports the zone management system by detecting and alerting, leaving the decision to halt operations with the driller.

3. AI-Powered Zone Management System

Complementing the interlock system, ABRAJ has deployed an AI-enabled CCTV camera system on its mechanized rigs. The rig floor is designated a Red Zone during normal operations. When equipment moves — for example, during Top Drive System (TDS) travel — the affected area temporarily becomes a Temporary No-Go Zone, and AI-enabled CCTV monitors it for personnel intrusion.

The system uses digital cameras with artificial intelligence algorithms to detect human movement within predefined coordinates. Our current AI-enabled CCTV layer triggers alarms on the driller's console. The direction is to integrate it with the interlock system so that an unsafe act or condition detected by the AI-enabled CCTV can automatically stop the operation.

It can also detect whether personnel are wearing the required personal protective equipment (PPE), including helmets and gloves, providing an additional layer of compliance monitoring.



4. Drilling Process Automation and Sequencer Technology

ABRAJ's mechanized rigs are equipped with a process automation platform that allows drilling teams to pre-program optimal drilling parameters for each well section. Once activated, the platform performs repetitive drilling tasks – such as tag bottom, back-ream, and other routine activities – according to pre-defined, optimized specifications. An important qualification applies throughout this section: these functions are installed and available on ABRAJ's mechanized rigs, but they are being rolled out progressively and not all features are fully implemented in field operations today. What follows describes designed capability and trial results rather than universal current practice across the fleet.

The significance of process automation extends beyond the automation of individual steps. In conventional drilling, performance varies considerably between crews. Encoding field-specific best practices into the control system itself reduces that variability, so that the rig executes operations to the same optimized parameters regardless of who is at the controls.

Building on the automation platform, ABRAJ has implemented sequencer technology that combines multi-step rig floor operations into a single command. By pressing one button, the driller initiates a combined activity: the pipe cat delivers a joint, the LGA guides it to center, and the iron roughneck makes up the connection. This has been trialled on ABRAJ rigs and field data has been captured. It is not yet applied to all tripping operations across the fleet.

5. Optimized Rig Design and Faster Rig Moves

ABRAJ's mechanization extends beyond the rig floor to encompass the entire rig design and transport system:

- **Smaller Rig Footprint:** ABRAJ's rig footprint is approximately 30% smaller than a comparable conventional rig; overall location requirement is approximately 15% smaller (per SPE-225133-MS), reflecting reduced auxiliary layout needs. This can reduce location preparation time, civil works costs, and environmental impact for operators and makes deployment feasible on constrained locations where a conventional layout may not fit.
- **Carrier-Based Transport System:** Major components – the mast, substructure, drawworks, BOP control unit, main HPU, and rig-move HPU – are combined into integrated carrier units that move as single loads. This consolidation dramatically reduces the number of truck loads, crane lifts, and personnel required, shortening total rig-move time and reducing HSE exposure during transitions.
- **Wireless Mast Operations:** Mast raising, lowering, scope-in, and scope-out are all controlled wirelessly from a safe distance, eliminating one of the most hazardous phases of rig-up operations.

6. Environmental and Camp Safety Enhancements

The mechanization package includes several additional innovations that address environmental and camp safety:

- **Automatic Diesel Transfer Shutoff:** Prevents diesel spills during transfer from the main tank to the day tank, protecting the environment and ensuring regulatory compliance.
- **Fuel Management System:** Automatically controls power load distribution across the rig's generators, shutting down unnecessary engines when demand is low and bringing them back online as needed. This reduces fuel consumption, lowers emissions, and extends engine life.
- **Centralized Fire and Gas Detection:** The main camp and minicamp feature a centralized fire and gas detection system linked to a single monitoring platform, replacing the legacy design where each cabin had independent sensors. This enables faster emergency detection and coordinated response.
- **Improved Camp Design:** Enhanced room and office design with high-quality accessories, contributing to improved living conditions and crew welfare.

RESULTS AND OUTCOMES

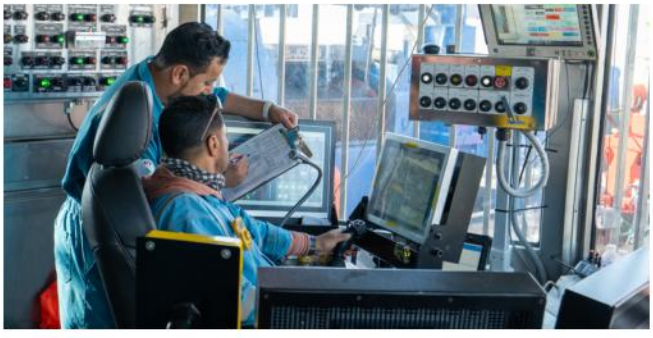
Implementing these mechanization best practices across ABRAJ's fleet in Oman and Kuwait has yielded significant, measurable improvements:

Safety Performance

- **Hands-Free Rig Floor Operations:** Rig floor operations during normal drilling activities are conducted hands-free for the core pipe handling and connection sequences, reducing the number of crew members exposed in the line of fire. The driller controls the drilling process from the cabin via 7–11 cameras and the rig's integrated control system.
- **Human Error Prevention:** Over 27 custom interlocks per rig actively prevent the categories of human error that historically cause the industry's most serious incidents. Conflicting equipment operations – such as activating the mud pump with the IBOP closed – are physically prevented by the interlock system.
- **AI-Enhanced Zone Monitoring:** The AI-enabled camera system provides real-time monitoring and alerting when personnel enter a temporary no-go zone, adding an intelligent detection layer beyond traditional physical barriers. The system detects and alerts; the decision to halt operations remains with the driller.
- **Reduced Personnel Exposure:** Reduced rig floor headcount directly translates to fewer personnel exposed to hazards, lower probability of injury, and reduced HSE incident rates.

Operational Efficiency

- **Faster Rig Moves:** The carrier-based transport system, which combines multiple major components into single loads, has significantly reduced rig move durations compared to conventional rigs. Minimal crane use during rig moves further reduces both time and HSE exposure.
- **Consistent Well Delivery:** Process automation and sequencer technology are designed to make well delivery performance consistent regardless of individual crew experience levels, effectively encoding the expertise of the most capable drillers into the operation. These capabilities are installed across the mechanized fleet and are being implemented progressively.
- **Reduced Tripping Time:** One-button combined activities for tripping operations – where pipe delivery, centering, and connection makeup occur automatically in sequence – have been trialled on ABRAJ rigs with field data captured, showing reduced tripping times and the elimination of timing errors between individual equipment commands. Application across all tripping operations is progressing.
- **Lower Location Costs:** The rig footprint is approximately 30% smaller than a comparable conventional rig; overall location requirement is approximately 15% smaller (per SPE-225133-MS), reflecting reduced auxiliary layout needs. This reduces location preparation time, civil works costs, and environmental impact for operators.





Operational and Financial Impact Summary

Metric	Conventional Rig	ABRAJ Mechanized Rig
Rig floor personnel during drilling	Multiple crew members in line of fire	Reduced — core operations performed remotely from the cabin
Safety interlocks	Limited	27+ custom interlocks per rig
Rig floor monitoring	Visual observation only	AI-powered cameras with real-time alerts
Pipe handling	Manual – hands-on	Fully mechanized pipe cat, LGA, elevator
Pipe doping	Manual brush application	Automatic pipe doper – no human contact
Mast raise/lower	Manual controls near mast	Wireless remote control from safe distance
Rig footprint	Large conventional layout	Rig footprint approximately 30% smaller than a comparable conventional rig; overall location requirement approximately 15% smaller (per SPE-225133-MS), reflecting reduced auxiliary layout needs.
Rig move design	Individual component transport	Carrier-based combined loads
Drilling automation	Driller experience-dependent	Process automation platform with pre-programmed parameters (progressive rollout)
Tripping operations	Sequential manual commands	One-button sequencer automation (trialled; field data captured)

As of 2026, ABRAJ's mechanized fleet comprises six fully mechanized 1000HP AC rigs in Oman and one in Kuwait — seven fully mechanized 1000HP AC rigs in total. The mechanization platform is continuously refined based on operational feedback and field data. The company is also exploring expansion into Saudi Arabia, Algeria, and additional markets.

Looking Ahead: Integrated Solutions, AI, Predictive Maintenance, and Continuous Innovation

ABRAJ's current mechanized rigs represent a foundation upon which the company is building progressively more advanced capabilities. Several innovations are currently under development:

- **Integrated Service Solutions:** ABRAJ is extending its offering beyond the rig itself toward integrated service delivery – bundling services such as cementing with the drilling rig under a single scope. Integrating these services reduces interface management for the operator, removes handover delays between contractors, and shortens the overall well delivery process.
- **AI-Enabled Equipment Safety:** ABRAJ is developing the capability for individual pieces of mechanized equipment to autonomously detect human presence within their operating envelope and stop operations independently – shifting from centralized zone monitoring to distributed, equipment-level safety intelligence.
- **Smart Predictive Maintenance:** Mechanized equipment will monitor its own operational parameters – oil contamination levels, vibration patterns, temperature trends – and alert maintenance teams when service is actually needed, replacing calendar-based maintenance with condition-based intelligence.
- **Behavioral Analytics:** AI camera systems are being extended to analyze crew behavioral patterns, identifying individuals or teams that may require additional training or support, enabling a data-driven approach to crew performance management.
- **Machine Learning for Drilling Optimization:** As the system accumulates drilling data from multiple wells and formations, machine learning algorithms will analyze parameters and outcomes to recommend optimized settings for future wells, creating an institutional knowledge base that continuously improves.

> **"Mechanized rigs enable intelligent drilling — using machine learning to analyze field data and recommend optimum drilling parameters."**
>
> — Saud Al Ghafri, Operations Manager, ABRAJ Energy Services



CONCLUSION

ABRAJ Energy Services' full rig mechanization program demonstrates that the persistent challenges of drilling safety, human error, and operational inconsistency can be fundamentally addressed through a comprehensive, systems-level approach to rig design and automation. By moving beyond individual component upgrades to a fully integrated mechanized platform, ABRAJ has achieved a step-change improvement in both safety and efficiency.
The following best practices, distilled from ABRAJ's approach, offer guidance for drilling contractors and operators evaluating rig mechanization:

Mechanize Comprehensively

Individual automated components deliver incremental benefits, but the transformative gains – in safety, consistency, and efficiency – come from integrating the core rig floor operations into a unified, remotely controlled system. Partial mechanization leaves significant risk and inefficiency on the table.

Design Interlocks from Incident Data

Off-the-shelf equipment configurations cannot address the specific safety requirements of every operating environment. Building interlock logic based on actual incident data, near-miss reports, and operational experience creates significantly more effective safety systems than generic manufacturer defaults.

Invest in Software and Automation

An extensible software platform that connects all equipment, enables process automation, and supports data analytics provides the foundation for continuous optimization. Sequencer technology and process automation platforms reduce competency variability and encode best practices into every operation.

Optimize Beyond the Rig Floor

Mechanization benefits extend to rig design, transport, camp safety, and environmental performance. Carrier-based transport, wireless mast operations, automatic diesel shutoff, and centralized detection systems all contribute to the overall value proposition.

Build for Continuous Innovation

The most impactful mechanization programs are designed as extensible platforms that support future capabilities. AI integration, machine learning, predictive maintenance, and behavioral analytics represent the next frontier – and require a software and sensor foundation that must be built today.

Through proactive investment, customized engineering, and a commitment to continuous improvement, ABRAJ Energy Services has established a new benchmark for mechanized drilling operations in the Middle East. The company's experience demonstrates that safer, more efficient, and more consistent drilling is not aspirational – it is achievable today with the right strategy and execution.

For more information, please visit our website.



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