Risk Analysis of Loss of Stability/Control During Jack-up Rig Moves: A Barrier Management Approach

1.0 Introduction and Event Definition

1.1 Overview of Jack-up Rig Move Operations

Jack-up rigs are Mobile Offshore Drilling Units (MODUs) specifically designed for their transportability and ability to operate in a self-elevated position. These units can be towed to a location, after which their legs are lowered to the seabed, and the hull is jacked up to a predetermined height above the sea surface, providing a stable platform for drilling or other offshore activities. The process of relocating a jack-up rig is a complex and multi-faceted operation, encompassing several distinct phases: meticulous pre-move planning and engineering, the physical transit of the rig (which can be a "wet tow" with the hull afloat or a "dry tow" aboard a heavy-lift vessel), precise positioning at the new site, controlled lowering of the legs to the seabed, the jacking up of the hull to the operational air gap, and finally, preloading of the foundations to ensure stability. These operations are inherently hazardous, and industry data suggests that incidents occurring during rig moves, particularly during the transition phases, are more frequent than those encountered when the rig is in its elevated, operational state.

1.2 Definition of the Undesired Event: "Loss of stability/control during rig move for a Jackup Rig"

For the purpose of this risk analysis, the undesired event is defined as: **An unintended situation where the jack-up rig deviates from its intended state of equilibrium or controlled movement during any phase of the rig move (including pre-move preparations, transit, leg lowering, seabed interaction, jacking, preloading, and final positioning), potentially leading to uncontrolled motions, listing, structural overstress, capsizing, or structural failure.** This definition encompasses both the loss of hydrostatic stability while the rig is afloat during transit and the loss of on-bottom or structural stability during jacking, preloading, or once elevated. It also includes the loss of positional control, which could lead to collisions or grounding.

The "Loss of stability/control" is not typically a singular, instantaneous failure but often represents the culmination of one or more antecedent failures or unmitigated threats across the various operational modes inherent in a rig move. The transitional phases, such as when the legs are first lowered to the seabed, the initial stages of jacking, and the critical preloading sequence, are particularly vulnerable periods where the rig's stability characteristics are dynamically changing. For instance, issues like slamming of spudcans on the seabed during leg lowering in heavy seas, or the development of Rack Phase Differential (RPD) due to uneven leg loading, can rapidly escalate into a loss of stability if not properly managed. Therefore, the definition must be sufficiently broad to capture these transient states and the diverse mechanisms that can lead to a loss of equilibrium or control.

1.3 Scope of the Risk Analysis

This risk analysis focuses specifically on jack-up rigs and covers the entire rig move operation, commencing from the initial preparations for departure from an existing location (or quayside) through to the point where the rig is securely installed, preloaded, and confirmed stable at the new operational site. The term "stability" within this analysis refers to:

- **Hydrostatic Stability:** The rig's ability to remain upright and resist overturning moments when afloat during transit.
- **Foundation Stability:** The ability of the seabed to support the leg loads without excessive or uncontrolled penetration (e.g., punch-through, rapid settlement) during jacking and preloading.
- **Structural Stability:** The ability of the rig's legs, hull, and jacking system to withstand the applied loads without failure or excessive deformation during all phases of the move. The term "control" refers to the ability to maintain the rig's intended position, heading, and operational parameters within defined safe limits.

1.4 Methodology: Barrier Management and Bowtie Analysis

The risk analysis presented herein employs the barrier management methodology. This approach systematically identifies potential threats that could lead to the defined undesired event, the potential consequences if the event occurs, and the safety barriers implemented to manage these risks. Barriers are categorized as:

- **Threat-Reducing Barriers:** Measures intended to prevent a threat from initiating the undesired event or to detect and control its escalation.
- **Consequence-Mitigating Barriers:** Measures intended to reduce the severity of the outcomes should the undesired event occur.

The structure of this analysis aligns with the principles of Bowtie analysis, which provides a visual representation of risk pathways from threats to consequences, with barriers depicted along these pathways.

A fundamental tenet of robust safety management is that barriers are not static entities. Their effectiveness can degrade over time due to various factors, including mechanical wear, procedural drift, or changes in personnel competency. Therefore, effective barrier management extends beyond initial identification and implementation; it necessitates ongoing verification, maintenance, performance monitoring, and auditing throughout the asset's lifecycle to ensure their continued integrity and reliability. This lifecycle perspective is integral to the philosophy underpinning this report.

2.0 Threat Analysis for Loss of Stability/Control During Rig Move

This section details specific threats that have the potential to cause a "Loss of stability/control during rig move for a Jackup Rig." For each threat, a set of threat-reducing barriers is identified, categorized into prevention, detection, and control measures.

2.1 Threat: Adverse Environmental Conditions Exceeding Operational

Limits

Threat Description: Encountering wind, wave, current, or tidal conditions during any phase of the rig move (transit, leg lowering, jacking, preloading) that surpass the rig's design specifications, approved operational limits as defined in the Rig Move Procedure (RMP), or the safe working limits of its equipment. Such conditions can induce excessive rig motions, impose loads beyond structural or jacking system capacity, or prevent the rig from maintaining its intended position or control, thereby leading to instability.

Threat Reducing Barriers:

- **Prevention:**
    - **Comprehensive Site-Specific Metocean Analysis:** Conducting detailed meteorological and oceanographic studies for the specific location and transit route. This involves analyzing historical weather data, seasonal trends, and extreme value statistics to understand the potential environmental conditions. This analysis is foundational for establishing realistic operational limits.
    - **Weather Routing and Forecasting Services:** Utilizing specialized marine weather forecasting services to obtain accurate and timely weather predictions for the planned transit route and operational window. This allows for route optimization to avoid the worst conditions.
    - **Established Weather-Related Operational Limits in Rig Move Procedure (RMP):** The RMP must clearly define specific, conservative go/no-go criteria for parameters such as wind speed, significant wave height, wave period, current velocity, and visibility for each critical phase of the rig move (e.g., commencing tow, leg lowering, jacking, preloading). These limits should be based on the rig's capabilities and the site-specific metocean analysis. For operations during hurricane season, guidance such as API RP 95J provides specific recommendations.
    - **Contingency Planning for Weather Downtime:** The RMP should include pre-identified sheltered locations or alternative contingency plans for securing the rig safely if adverse weather conditions are encountered or forecast to exceed operational limits during transit or installation.
    - **Adequate Towing Vessel Power and Configuration:** Ensuring the selected towing vessels have sufficient bollard pull and maneuverability to maintain control of the jack-up in the anticipated and potential adverse weather conditions.
- **Detection:**
    - **Onboard Environmental Monitoring Systems:** Continuous real-time monitoring of wind speed and direction (anemometers), wave conditions (e.g., wave radar, if fitted), and current speed and direction on the jack-up and/or lead tug.
    - **Regular Weather Forecast Updates:** Systematic reception, logging, and expert assessment of updated weather forecasts from reputable meteorological services throughout the operation.
    - **Vessel Motion Monitoring Systems:** Instrumentation to measure and display the rig's motions (pitch, roll, heave). Excessive or rapidly increasing motions can indicate worsening environmental conditions or that the rig is approaching its operational limits.
    - **Visual Observation by Experienced Marine Personnel:** Continuous visual assessment of sea state, vessel response, and weather development by the Tow

Master, OIM, and bridge watch officers.

- **Control:**
    - **Strict Adherence to Go/No-Go Criteria:** The Tow Master and OIM must rigorously enforce the pre-defined weather limits, making decisive calls to suspend or postpone operations if conditions approach or exceed these limits.
    - **Ballast Adjustments (Afloat Condition):** Utilizing the rig's ballast system to optimize stability characteristics (e.g., adjust draft, trim, metacentric height) in response to changing sea states, always operating within approved stability criteria and operational manual guidelines.
    - **Seeking Shelter or Course/Speed Alteration During Transit:** Implementing contingency plans by heading to a pre-identified sheltered location or altering the tow course and speed to mitigate the impact of adverse weather.
    - **Emergency Jacking or Leg Lowering (Site-Specific Contingency):** In certain shallow water situations and if structurally permissible and procedurally defined, partially lowering legs to the seabed to improve stability during unexpected severe weather. This is a high-risk maneuver and must be carefully assessed and planned.
    - **Maintaining Adequate Air Gap (Elevated Condition):** Ensuring the final air gap after jacking is sufficient to prevent wave impact on the hull during storm conditions, considering factors like maximum wave crest, storm surge, and potential settlement.

The suite of prevention, detection, and control barriers for adverse environmental conditions relies heavily on accurate information and robust equipment. However, their ultimate effectiveness hinges on the *timely and correct human decision-making process*. While detection systems provide crucial data on environmental parameters and rig response, it is the competent interpretation of this data by experienced personnel (Tow Master, OIM, Barge Master) and their decisive action based on pre-defined criteria (go/no-go limits in the RMP) that forms the most critical control. A failure in this human element—whether due to misjudgment, delayed response, or commercial pressures overriding safety limits—can entirely negate the benefits of technically sound prevention and detection measures, allowing the threat to escalate. The documented instances of incidents often point to procedural failures or errors in judgment, underscoring that the human component is a pivotal link in this barrier chain.

2.2 Threat: Seabed Instability and Geotechnical Hazards (Punch-Through, Rapid Penetration, Sliding)

Threat Description: Unexpected or inadequately assessed seabed conditions encountered during leg landing, jacking, or preloading operations. These hazards include, but are not limited to:

- **Punch-Through:** A sudden, uncontrolled penetration of one or more legs through a stronger soil layer into an underlying weaker layer.
- **Rapid Leg Penetration:** Legs penetrating the seabed at a rate faster than the jacking system can compensate, leading to tilting.
- **Uneven Seabed or Existing Depressions:** Encountering slopes, old spudcan footprints, or seabed debris causing eccentric loading on spudcans and uneven leg support.
- **Scour:** Erosion of seabed material around or beneath spudcans, potentially undermining foundation support over time or during preloading.
- **Sliding:** Lateral movement of a spudcan on a sloping or very weak seabed. Any of these

can cause sudden listing of the rig, overstressing of leg and jacking structures, damage to spudcans, and a catastrophic loss of stability.

Threat Reducing Barriers:

- **Prevention:**
  - **Comprehensive Site-Specific Geotechnical Investigation and Assessment (SSA):** This is the foremost preventive barrier. It involves conducting thorough soil borings, cone penetration tests (CPTs), and laboratory testing of soil samples to accurately characterize the seabed stratigraphy, soil strength parameters, and identify potential hazards such as 'strong over weak' soil profiles, shallow gas pockets, or variable soil conditions. The assessment should be performed in accordance with recognized industry standards like ISO 19905-1 or SNAME T&R B 5-5A.
  - **Detailed Leg Penetration Analysis (LPA) and Punch-Through Risk Assessment:** Utilizing the geotechnical data to perform engineering calculations that predict spudcan penetration depth, ultimate bearing capacity of the soil layers, and specifically assess the risk of punch-through or uncontrolled rapid penetration. This analysis identifies critical soil layers and informs preloading strategy.
  - **Appropriate Rig Selection:** Selecting a jack-up unit with spudcan design (e.g., standard, skirted, enlarged, or mat-supported for very soft soils) suitable for the anticipated seabed conditions identified in the SSA.
  - **Careful Spudcan Placement Strategy and Site Preparation:** Planning the exact spudcan touchdown locations to avoid known hazards like old spudcan footprints (which can cause eccentric loading or sliding), identified obstructions, areas of significant seabed slope, or pipelines. In high-risk punch-through areas, remedial measures like "Swiss cheese" operations (pre-drilling holes at spudcan locations to weaken a problematic crust) may be considered if deemed feasible and effective.
  - **Controlled Preloading Procedures in RMP:** The RMP must detail a stepwise preloading sequence, defining load increments, holding times at each step, and monitoring requirements. "Preloading in the water" (maintaining minimal air gap or even slight hull buoyancy) is a common strategy to reduce the free-fall distance and impact energy in case of a sudden leg penetration, thereby mitigating the severity of a punch-through event. Four-legged rigs may use alternate leg pair preloading (pre-driving).
- **Detection:**
  - **Leg Load Monitoring Systems:** Continuous, real-time monitoring of the load (vertical reaction) on each individual leg or spudcan during leg lowering, seabed contact, jacking, and throughout the preloading sequence. Unexpected drops or spikes in leg load can indicate seabed failure or punch-through.
  - **Penetration Monitoring Systems:** Accurate and continuous tracking of the penetration depth of each leg into the seabed. The rate of penetration is a key indicator; a sudden increase signifies potential instability.
  - **Hull Level, Trim, and List Monitoring:** Sensitive inclinometers and systems to continuously monitor the rig's levelness. Any deviation from level (tilt or list) beyond very small operational tolerances during jacking or preloading is a primary indicator of uneven leg settlement or a developing stability issue.
  - **Rack Phase Differential (RPD) Monitoring:** For rigs with truss legs, RPD sensors detect differential movement between chords of a leg, which can be caused by uneven spudcan loading due to seabed conditions or incipient punch-through.

    - **Acoustic/Sonar Monitoring (Advanced/Site-Specific):** In some critical cases, acoustic or sonar systems might be deployed to monitor seabed conditions around spudcans for scour development or significant soil displacement.
    - **ROV/Diver Inspections (Contingency):** Visual inspection of spudcan interaction with the seabed, particularly if issues are suspected or if operating near existing footprints or obstructions.
- **Control:**
    - **Emergency Stop of Jacking/Preloading:** Immediate cessation of all jacking and preloading operations if unexpected or excessive penetration rates, significant load imbalances between legs, or rig tilting beyond predefined limits are detected.
    - **Differential Jacking Capabilities:** The ability of the jacking system to adjust individual leg positions (jacking one leg up or down relative to others) to attempt to counteract tilting or manage uneven penetration. This must be done cautiously, respecting jacking system capacity and RPD limits to avoid overstressing legs or the jacking system itself.
    - **Rapid Ballast/Deballast Adjustments (if hull has buoyancy):** If preloading with minimal air gap, the ability to quickly adjust ballast (typically by dumping preload water) to reduce the load on a rapidly penetrating leg or to counteract a developing list.
    - **Punch-Through Recovery Procedures in RMP:** The RMP must contain pre-defined procedures for managing a punch-through event. This includes strategies for attempting to regain stability, minimizing further damage, and assessing the rig's condition. The primary control of minimizing air gap during preloading is crucial here.
    - **Spudcan Jetting Systems:** Some rigs are equipped with jetting systems in the spudcans that can be used to assist with leg extraction from sticky soils or, in some cases, to carefully manage penetration in certain soil types, though this is a specialized operation requiring expert geotechnical input.

The reliability of geotechnical assessments and SSAs, while being the cornerstone of prevention, is inherently subject to uncertainties. Soil conditions can exhibit significant spatial variability even over short distances, and the interpretation of geotechnical data involves engineering judgment. Furthermore, the complex interaction between spudcans and various soil types, especially layered soils or those prone to liquefaction, is an area of ongoing research and refinement in analytical modeling. This inherent uncertainty in fully predicting seabed behavior means that even with a diligent SSA, a residual risk of encountering unexpected conditions remains. Consequently, this elevates the importance of robust detection systems (such as real-time monitoring of leg loads, penetration, and hull level) and highly responsive control measures (including adaptive preloading procedures that can be modified based on observed behavior, and well-rehearsed emergency response capabilities). The strategy of "preloading in the water" or with minimal air gap is a direct acknowledgment of this residual risk, designed to mitigate the consequences should a sudden penetration occur.

2.3 Threat: Jacking System Malfunction or Failure

Threat Description: A mechanical, electrical, or hydraulic failure occurring within the jack-up rig's jacking system during leg lowering, hull raising/lowering, or holding operations. This can manifest as an inability to jack one or more legs, uncontrolled movement (run-off) of a leg, uneven jacking speeds between legs leading to tilting, or failure of braking or holding mechanisms. Such malfunctions can directly lead to a loss of stability or control.

Threat Reducing Barriers:

- **Prevention:**
  - **Rigorous Jacking System Design, Manufacture, and Certification:** Adherence to stringent design codes and standards (e.g., ABS, DNV rules) for all jacking system components, including gears, pinions, motors, brakes, and control systems. This includes requirements for material selection, manufacturing quality, and load testing. Prototype gear testing at 150% of rated load is a typical requirement.
  - **Comprehensive Preventive Maintenance Program (PMS):** Regular, scheduled inspection, lubrication, condition monitoring (e.g., oil analysis, vibration monitoring), and timely replacement of worn or life-limited jacking system components, as per Original Equipment Manufacturer (OEM) recommendations and classification society requirements.
  - **Pre-Move Jacking System Function Tests and Thorough Inspections:** Before commencing any rig move, conducting comprehensive operational checks of all jacking motors (electric or hydraulic), brakes (service and holding), control systems, limit switches, emergency stops, and RPD monitoring systems. This includes verifying torque settings on motors and ensuring brake functionality. Departmental checklists, such as those for electricians and mechanics, detail many of these specific checks.
  - **Competent and Trained Jacking System Operators and Maintenance Personnel:** Ensuring that all personnel responsible for operating and maintaining the jacking systems are adequately trained, certified (where applicable), and fully familiar with the specific system on the rig and its emergency procedures.
  - **Load Limitation Systems:** Design features or operational procedures to prevent overloading of the jacking system beyond its rated capacity.
- **Detection:**
  - **Rack Phase Differential (RPD) Monitoring System:** Continuous monitoring of the RPD on each leg (for truss leg jack-ups). An increasing or excessive RPD can indicate uneven leg loading due to seabed conditions, but also pinion slippage, climbing issues, or impending mechanical problems within the jacking mechanism itself, which could lead to overstress.
  - **Jacking Motor Current/Torque/Pressure Monitoring:** Real-time monitoring of electrical current for electric motors or hydraulic pressure/torque for hydraulic motors driving the pinions. Abnormal readings (e.g., sustained high current, pressure spikes, or significant variation between motors on the same leg or between legs) can indicate overload, binding, or malfunction.
  - **Leg Position, Speed, and Level Sensors:** Accurate and independent measurement of each leg's vertical position, jacking speed, and comparison between legs to detect discrepancies that might indicate uneven jacking or a problem with one or more jacking units. Hull level sensors also provide an indirect indication of jacking system performance.
  - **Audible and Visual Alarms:** Centralized alarm system on the jacking control console for critical parameters such as RPD limits exceeded, motor over-current/over-torque, brake failure, control system faults, or loss of power to jacking units.
  - **Jacking System Temperature Monitoring:** Monitoring temperatures of gearboxes and motors, as overheating can be an early indicator of mechanical problems or

excessive friction.

- **Control:**
    - **Emergency Stop Systems (E-stops):** Strategically located and easily accessible E-stop buttons that can immediately halt all jacking operations in the event of a detected malfunction or emergency.
    - **Automatic Brake Application on Power Loss or Failure:** Design of jacking system brakes (often spring-applied, power-released) to engage automatically and hold the leg securely if power is lost to the motors or a critical failure is detected.
    - **Mechanical Rack Chock System (if fitted and engaged):** A positive mechanical locking system that can be engaged with the leg racks to provide an independent means of securing the legs in position, particularly if the primary jacking system or brakes are compromised. Rack chocks are typically required for ocean tows.
    - **Procedures for Jacking with Reduced Pinion/Motor Capacity:** Specific, pre-approved operational procedures for continuing jacking operations under controlled conditions if some jacking units or motors fail but sufficient capacity remains to safely manage the operation, albeit potentially at reduced speed or with additional monitoring.
    - **Isolation of Failed Components:** The ability to mechanically and electrically/hydraulically isolate faulty jacking units or motors to prevent them from causing further damage or uncontrolled movement, and to allow operation with the remaining healthy units if procedures permit.
    - **Manual Brake Operation/Override (Emergency):** Procedures for manual operation or override of brakes in specific emergency scenarios, under strict supervision and control.

Rack Phase Differential (RPD) serves a dual role in safety. While often discussed in the context of detecting uneven seabed support or punch-through , it is also a critical indicator of the jacking system's own health and performance. If RPD develops due to a jacking system issue (e.g., a pinion slipping or a motor failing on one chord), it can induce significant uneven loading across the leg structure and the remaining jacking components. Mismanagement of RPD, or continuing to jack with excessive RPD, can itself lead to severe overstress on leg members and jacking gear, potentially causing a cascade failure within the jacking system. This creates a potential feedback loop where a minor jacking issue, if not detected and addressed via RPD monitoring and limits, could escalate into a major jacking system failure and subsequent loss of stability. Therefore, RPD monitoring is not just a passive measurement of external conditions but an active parameter in safeguarding the integrity of the jacking system itself.

2.4 Threat: Human Error and Procedural Non-Compliance During Critical Operations

Threat Description: Mistakes, errors in judgment, lapses in attention, or intentional deviations from established safe operating procedures by personnel during critical phases of the rig move. This includes, but is not limited to, errors in:

- Ballasting calculations or operations leading to incorrect trim, list, or stability margins.
- Navigation or vessel handling during transit or positioning.
- Leg lowering, seabed contact, and initial pinning operations.
- Jacking system operation (e.g., incorrect sequence, ignoring alarms, exceeding RPD limits).

- Preloading sequence, load monitoring, or air gap management.
- Emergency response actions or lack thereof. Such errors can directly compromise the rig's stability or ability to maintain control.

Threat Reducing Barriers:

- **Prevention:**
  - **Comprehensive, Clear, and Accessible Rig Move Procedures (RMP):** Well-documented, unambiguous, step-by-step procedures for all safety-critical tasks associated with the rig move. These must include operational limits, specific checklists for each phase, and clearly defined go/no-go criteria. Departmental pre-rig move checklists, such as those for the OIM, Barge Master, Electrician, and Mechanic, are vital components.
  - **Competency Assurance, Training, and Certification:** Robust training programs (including simulator-based training where beneficial for complex tasks like jacking or DP maneuvering) and rigorous competency assessment and verification for all personnel involved in safety-critical rig move operations. This applies to the OIM, Barge Master/Engineer, Tow Master, crane operators, jacking system operators, and bridge team.
  - **Pre-Move Briefings, Pre-Job Planning (PJP), and Tool-Box Talks (TBT):** Thorough discussion of the RMP, specific tasks, identified hazards, risk mitigation measures, roles, responsibilities, and emergency procedures before commencing the overall move and prior to each critical operational phase. PJP should begin weeks prior to the move and be revisited before new tasks.
  - **Human Factors Engineering (HFE) in System and Workplace Design:** Designing control stations, instrumentation displays (HMIs), alarm systems, and the general working environment to align with human capabilities and limitations, thereby minimizing the potential for error and optimizing human performance. This includes considerations of workload, visibility, accessibility, and information presentation.
  - **Safety Critical Task Analysis (SCTA) / Human Reliability Analysis (HRA):** Systematically identifying tasks where human error could lead to a major accident, analyzing potential failure modes (slips, lapses, mistakes, violations), and identifying Performance Influencing Factors (PIFs) to implement targeted risk reduction measures in procedures, training, or design.
  - **Management of Change (MOC) Procedures:** A formal, documented process for evaluating and controlling any deviations from standard procedures, equipment configurations, or personnel assignments, ensuring that any associated risks are assessed and mitigated before implementation.
  - **Adequate Manning Levels and Fatigue Management:** Ensuring sufficient qualified personnel are available to cover all critical roles without undue fatigue, particularly during extended or complex rig move operations. This includes adherence to work/rest hour regulations and proactive fatigue risk management strategies.
- **Detection:**
  - **Independent Verification and Second Checks for Critical Steps:** Requiring a second qualified and independent person to verify critical calculations (e.g., stability, preload amounts, ballast changes), critical valve line-ups, system settings, or key procedural steps before execution.
  - **Active Supervision and Monitoring of Operations:** Direct and vigilant

supervision by experienced and responsible personnel (OIM, Tow Master, Barge Engineer, Rig Manager) during all critical phases of the rig move, ensuring adherence to procedures and prompt identification of deviations or emerging hazards.
    - **Permit to Work (PTW) System:** A formal authorization system for controlling non-routine or high-risk tasks, ensuring that hazards have been identified, risks assessed, and necessary precautions (including human factors considerations) are in place and verified before work commences.
    - **Use of Procedural Checklists with Verifiable Sign-offs:** Implementing detailed checklists for critical operational sequences (e.g., pre-jacking, pre-float, preloading), requiring positive confirmation and sign-off by responsible personnel at key hold points or steps. The departmental pre-rig move checklists are a prime example of this barrier.
    - **Cross-Monitoring and Challenge by Team Members:** Fostering a team environment where crew members are encouraged and feel empowered to monitor each other's actions and challenge any observed deviations from procedure or unsafe practices (part of Crew Resource Management - CRM).
- **Control:**
    - **"Stop Work Authority" (SWA) Policy and Culture:** A clearly communicated and actively supported policy that empowers and obligates every individual on site to stop any job or operation they believe to be unsafe or not in accordance with procedures, without fear of reprisal.
    - **Defined Escalation Procedures for Problems and Deviations:** Clear, established channels and protocols for personnel to report operational problems, procedural difficulties, or unexpected situations to supervisors and management for resolution or guidance.
    - **Emergency Drills and Response Training:** Regular, realistic drills for foreseeable emergency scenarios (e.g., loss of stability, jacking system failure, man overboard, fire) to ensure that crews are proficient in executing emergency procedures effectively and efficiently under pressure.
    - **Contingency Procedures within the RMP:** Pre-defined alternative courses of action or recovery measures within the RMP for managing common deviations, equipment malfunctions, or unexpected events during the rig move.

While comprehensive procedures and rigorous training are undeniably vital preventive barriers against human error, their practical effectiveness can be significantly undermined if the prevailing organizational safety culture does not actively support and reinforce them. Principles such as "Blame fixes nothing," "Learning is vital," and "How you respond matters" are key tenets of a positive safety culture. If personnel fear punitive action for reporting errors, near misses, or difficulties in following procedures, these critical learning opportunities are lost, and unsafe conditions or practices may persist. A culture that encourages open reporting, views errors as opportunities for systemic improvement rather than individual blame, and supports decisive, safety-first responses from leadership is, therefore, a foundational meta-barrier. Such a culture fosters an environment where procedural adherence is valued, vigilance is maintained, and the other human-focused barriers can function as intended, rather than being bypassed or weakened by fear or complacency.

2.5 Threat: Collision During Transit or Maneuvering

Threat Description: The jack-up rig, while under tow or self-propelled (if applicable), or while maneuvering on or off location using tugs, collides with other vessels, fixed offshore installations (platforms, wind turbines), subsea infrastructure (pipelines, wellheads if legs are lowered prematurely), or navigational hazards (shoals, wrecks).
Threat Reducing Barriers:
- **Prevention:**
  - **Detailed Passage Planning and Route Hazard Identification:** Meticulous planning of the entire tow route, identifying all potential navigational hazards (e.g., shallow waters, wrecks, restricted areas), traffic separation schemes, proximity to other offshore installations, and environmentally sensitive areas. This includes review of nautical charts, pilot books, and local notices to mariners.
  - **Adequate Number, Capability, and Configuration of Towing Vessels:** Ensuring that the towing vessels selected have sufficient combined bollard pull, maneuverability, and appropriate towing gear for the size and displacement of the jack-up, the length and nature of the tow, and the prevailing and anticipated environmental conditions. This includes assessment of tug suitability.
  - **Established Communication Protocols and Bridge Resource Management (BRM):** Clear, concise, and understood communication procedures between the jack-up (Tow Master/OIM), the bridge teams of all towing vessels, and relevant external parties (e.g., Vessel Traffic Services (VTS), nearby platform OIMs). Effective BRM practices on all participating vessels are crucial.
  - **Competent and Experienced Bridge Team and Tow Master:** Ensuring that the Tow Master on the jack-up and the Masters and watch officers on the towing vessels are appropriately licensed, experienced in rig moving operations, and familiar with the specific challenges of the planned move.
  - **Maintaining Safe Speed and Closest Point of Approach (CPA) Limits:** Adherence to pre-agreed safe towing speeds appropriate for the sea state and proximity to hazards, and maintaining defined minimum CPA limits from other vessels and fixed objects.
  - **Use of Pilotage Services:** Engaging qualified maritime pilots in congested waters, port approaches, or areas with specific local navigational challenges.
  - **Daylight Operations for Critical Maneuvers:** Planning critical maneuvers, such as final approach to location or navigating narrow channels, to be conducted during daylight hours and in good visibility where practicable.
- **Detection:**
  - **Radar, AIS (Automatic Identification System), and ECDIS (Electronic Chart Display and Information System):** Proper use and monitoring of all available electronic navigation aids by competent watch officers for continuous situational awareness, target detection, and collision risk assessment.
  - **Diligent Visual Lookout:** Maintaining a dedicated and effective visual lookout on the jack-up (if manned during tow) and on all towing vessels at all times, by day and night.
  - **Vessel Traffic Services (VTS) Monitoring and Reporting:** Actively monitoring VTS broadcasts and complying with VTS reporting requirements and traffic instructions in designated areas.
  - **Proximity Alarms and Guard Zones:** Setting up electronic guard zones and proximity alarms on radar/ECDIS for critical navigational marks, charted obstructions, or nearby installations.

    - **Regular Position Verification:** Frequent checking of the rig's position against the planned track using multiple independent means (e.g., GPS, radar bearings/ranges).
- **Control:**
    - **Standard Collision Avoidance Maneuvers (COLREGs):** Strict adherence to the International Regulations for Preventing Collisions at Sea (COLREGs) by all vessels involved in the tow.
    - **Emergency Towing Procedures and Equipment:** Having well-understood procedures and readily available equipment for emergency towline deployment, adjustment, or release, and for using tugs to control the jack-up's heading and movement in an emergency. This includes having a spare emergency towline rigged.
    - **Use of Dynamic Positioning (DP) Capabilities (if available):** If the jack-up or key support vessels are DP-capable, utilizing DP for precise maneuvering during final positioning, holding station, or in confined waters, subject to DP system reliability and operational limits.
    - **Adherence to 500m Safety Zone Procedures:** Strict compliance with established procedures, communication protocols, and permissions when operating within the 500-meter safety zone of any offshore installation. This includes pre-entry checklists and positive confirmation from the installation.
    - **Anchor Handling Capabilities (for emergency anchoring if feasible):** While not primary for transit, having anchors ready for emergency deployment in shallow water might offer a last resort to arrest drift, if conditions and seabed permit.

A significant contributing factor to collisions involving vessels attendant to offshore installations, and by extension a risk during rig moves, is the distraction of bridge personnel with non-navigational tasks. Incidents have occurred where watchkeeping officers were engaged in administrative work, using computers for non-navigational purposes, or where lookouts were similarly distracted, leading to a loss of situational awareness and failure to detect developing collision courses. This underscores a critical human factors vulnerability: even with advanced navigational aids (detection barriers) and established maneuvering procedures (control barriers), if the human operators responsible for utilizing these barriers are not fully attentive to their primary safety-critical duties of navigation and lookout, the effectiveness of the entire barrier system against collision is severely compromised. Prioritization of navigational watchkeeping duties and fostering a culture of vigilance are essential.

2.6 Threat: Loss of Watertight Integrity During Transit (Wet Tow)

Threat Description: Ingress of seawater into the jack-up rig's hull through unsecured or failed openings (e.g., hatches, manholes, vents, doors), damaged seals, pipe penetrations, or structural failure of the hull plating during a wet tow. This can lead to a reduction in freeboard, progressive flooding of compartments, compromised hydrostatic stability, excessive list or trim, and potentially capsizing if not controlled.

Threat Reducing Barriers:

- **Prevention:**
    - **Thorough Pre-Tow Watertight Integrity Inspections and Securing:** Meticulous inspection of all hull openings, including hatches, manholes, vents, doors, and pipe penetrations, to ensure they are in good condition and properly secured (closed, dogged, gasketed). Consideration should be given to using additional securing

measures like clamp bars or welded strapping for critical openings if heavy weather is anticipated or if standard closures are suspect. All service lines on outer hull areas should be capped.

- **Hull Condition Survey and Maintenance:** Ensuring the hull structure is maintained in good condition, free from significant corrosion, wastage, or unrepaired damage that could compromise its watertightness. This is part of routine class surveys and pre-move inspections.
- **Detailed Stability Analysis for Tow Condition (Intact and Damaged):** Performing comprehensive stability calculations for the specific tow condition (draft, VCG, loading), including compliance with intact stability criteria (e.g., IMO MODU Code) and relevant damaged stability criteria. This assessment should consider the potential effects of flooding specific compartments.
- **Minimizing Liquid Variable Loads and Ensuring Tanks are Pressed Full or Empty:** Reducing free surface effects from slack tanks by either keeping necessary liquid ballast to a minimum and in designated tanks, or by ensuring tanks containing liquids are pressed completely full. Unused tanks should be empty.
- **Securing of Deck Cargo to Prevent Hull Damage:** Ensuring all deck cargo is properly secured to prevent shifting in heavy seas, which could damage hull fittings or structures, leading to water ingress.
- **Adherence to Load Line Requirements:** Ensuring the rig is not loaded beyond its assigned load line draft for the tow condition.

- **Detection:**
  - **Regular Tank Soundings and Void Space Inspections:** Implementing a schedule for frequent (e.g., every 2-12 hours depending on conditions and rig specifics) manual soundings of all hull tanks, void spaces, and cofferdams to detect any water ingress. Observations should be logged.
  - **Bilge Level Alarms and Water Ingress Detection Systems:** Utilization of fixed bilge alarms in machinery spaces and other critical compartments. Some rigs may have more sophisticated water ingress detection systems in void spaces.
  - **Continuous Monitoring of Rig Trim, List, and Freeboard:** Vigilant observation by the crew for any unexplained changes in the rig's trim, list, or a noticeable reduction in freeboard, which could indicate flooding.
  - **Hull Stress Monitoring Systems (if fitted):** Advanced systems that can detect abnormal hull stresses which might arise from flooding or structural damage.
- **Control:**
  - **Damage Control Plan and Procedures:** Having a well-defined, rig-specific damage control plan and readily accessible damage control equipment (e.g., portable pumps, shoring materials, patching kits, timber, wedges).
  - **Emergency Pumping Capabilities:** Ensuring that bilge and ballast pumps are operational and have sufficient capacity to manage potential rates of water ingress. Dedicated preload pumps might also be available.
  - **Compartment Isolation:** Procedures for isolating flooded compartments by closing watertight doors and valves to prevent progressive flooding.
  - **Contingency Plan for Severe Flooding and Stability Loss:** Pre-defined actions in the RMP or emergency response plan for severe flooding scenarios, which may include preparing for emergency leg lowering (if in suitable water depth and conditions allow), heading for the nearest port of refuge, or ultimately, rig abandonment.

- **Maintaining Communication with Towing Vessels and Shore Support:** Keeping all parties informed of the situation to coordinate assistance.

Research, notably the HSE Offshore Technology Report OTO 2000 059 , has indicated that previously accepted damage stability survivability criteria for jack-up units undergoing wet tows might not be adequate, particularly when considering certain environmental conditions and the dynamics of flooding. This finding suggests a potential systemic weakness in what was once considered a robust preventive barrier (i.e., design and certification standards based on older criteria). Such a revelation elevates the importance of operational barriers, such as exceptionally diligent pre-tow watertight integrity checks, conservative weather routing, and the maintenance of robust, well-rehearsed contingency plans for dealing with water ingress and potential stability loss. It implies that operators cannot solely rely on compliance with older standards and must proactively assess their units against newer research findings and potentially implement more stringent operational controls or enhance their emergency preparedness.

Table 1: Threats and Threat-Reducing Barriers for Loss of Stability/Control During Jack-up Rig Move

Threat ID	Threat Description	Prevention Barriers (Type, Snippets)	Detection Barriers (Type, Snippets)	Control Barriers (Type, Snippets)
T1	**Adverse Environmental Conditions Exceeding Operational Limits:** Encountering wind, wave, current, or tidal conditions during transit, jacking, or preloading that surpass the rig's design or procedural limits, leading to excessive motions, loads, or inability to maintain position/control.	- Comprehensive Site-Specific Metocean Analysis (Procedural, Engineering Study) - Weather Routing and Forecasting Services (Procedural, External Service) - Established Weather-Related Operational Limits in RMP (Procedural, Design Standard) - Contingency Planning for Weather Downtime (Procedural) - Adequate Towing Vessel Power and Configuration (Hardware, Procedural)	- Onboard Environmental Monitoring Systems (Hardware) - Regular Weather Forecast Updates (Procedural) - Vessel Motion Monitoring Systems (Hardware/Software) - Visual Observation by Experienced Marine Personnel (Human Action)	- Strict Adherence to Go/No-Go Criteria (Procedural, Human Action) - Ballast Adjustments (Afloat) (Procedural, System Operation) - Seeking Shelter/Course Alteration (Procedural) - Emergency Jacking/Leg Lowering (Contingency Procedure) - Maintaining Adequate Air Gap (Elevated) (Procedural)

Threat ID	Threat Description	Prevention Barriers (Type, Snippets)	Detection Barriers (Type, Snippets)	Control Barriers (Type, Snippets)
T2	**Seabed Instability and Geotechnical Hazards (Punch-Through, Rapid Penetration, Sliding):** Unexpected seabed conditions leading to uncontrolled leg penetration, rapid settlement, uneven leg loading, or sliding during leg landing, jacking, or preloading.	- Comprehensive Site-Specific Geotechnical Investigation and Assessment (SSA) (Procedural, Engineering Study) - Detailed Leg Penetration Analysis (LPA) and Punch-Through Risk Assessment (Procedural, Engineering Study) - Appropriate Rig Selection (Procedural) - Careful Spudcan Placement Strategy / Site Preparation (e.g., "Swiss cheese") (Procedural) - Controlled Preloading Procedures in RMP (e.g., minimal air gap) (Procedural)	- Leg Load Monitoring Systems (Hardware/Software) - Penetration Monitoring Systems (Hardware/Software) - Hull Level, Trim, and List Monitoring (Hardware/Software) - Rack Phase Differential (RPD) Monitoring (Hardware/Software) - Acoustic/Sonar Monitoring (Advanced/Site-Specific) (Hardware) - ROV/Diver Inspections (Contingency) (Procedural)	- Emergency Stop of Jacking/Preloading (Procedural, System Operation) - Differential Jacking Capabilities (System Operation, Procedural) - Rapid Ballast/Deballast Adjustments (if hull buoyant) (System Operation, Procedural) - Punch-Through Recovery Procedures in RMP (Procedural) - Spudcan Jetting Systems (System Operation, Procedural)
T3	**Jacking System Malfunction or Failure:** Mechanical, electrical, or hydraulic failure within the jacking system leading to uncontrolled leg movement, inability to jack, uneven jacking, or leg run-off.	- Rigorous Jacking System Design, Manufacture, and Certification (Design Standard, Procedural) - Comprehensive Preventive Maintenance Program (PMS) (Procedural) - Pre-Move Jacking System Function Tests and	- Rack Phase Differential (RPD) Monitoring System (Hardware/Software) - Jacking Motor Current/Torque/Pressure Monitoring (Hardware/Software) - Leg Position, Speed, and Level Sensors (Hardware/Software) - Audible	- Emergency Stop Systems (E-stops) (Hardware, Procedural) - Automatic Brake Application on Power Loss/Failure (Hardware Design) - Mechanical Rack Chock System (Hardware, Procedural) -

Threat ID	Threat Description	Prevention Barriers (Type, Snippets)	Detection Barriers (Type, Snippets)	Control Barriers (Type, Snippets)
		Inspections (Procedural) - Competent and Trained Jacking System Operators and Maintenance Personnel (Human Factor, Procedural) - Load Limitation Systems (Hardware/Software Design)	and Visual Alarms for jacking system parameters (Hardware/Software) - Jacking System Temperature Monitoring (Hardware)	Procedures for Jacking with Reduced Pinion/Motor Capacity (Procedural) - Isolation of Failed Components (Procedural, System Design) - Manual Brake Operation/Override (Emergency Procedure)
T4	**Human Error and Procedural Non-Compliance During Critical Operations:** Mistakes, lapses, or deliberate deviations from established procedures by personnel during ballasting, navigation, leg lowering, jacking, preloading, or emergency response.	- Comprehensive, Clear, and Accessible Rig Move Procedures (RMP) (Procedural) - Competency Assurance, Training, and Certification (Human Factor, Procedural) - Pre-Move Briefings, PJP, and Tool-Box Talks (TBT) (Procedural, Human Factor) - Human Factors Engineering (HFE) in System and Workplace Design (Design Standard) - Safety Critical Task Analysis (SCTA) / Human Reliability Analysis (HRA) (Procedural,	- Independent Verification and Second Checks for Critical Steps (Procedural, Human Action) - Active Supervision and Monitoring of Operations (Human Action) - Permit to Work (PTW) System (Procedural) - Use of Procedural Checklists with Verifiable Sign-offs (Procedural) - Cross-Monitoring and Challenge by Team Members (Human Factor, CRM)	- "Stop Work Authority" (SWA) Policy and Culture (Procedural, Human Factor) - Defined Escalation Procedures for Problems and Deviations (Procedural) - Emergency Drills and Response Training (Procedural, Human Factor) - Contingency Procedures within the RMP (Procedural)

Threat ID	Threat Description	Prevention Barriers (Type, Snippets)	Detection Barriers (Type, Snippets)	Control Barriers (Type, Snippets)
		Engineering Study) - Management of Change (MOC) Procedures (Procedural) - Adequate Manning Levels and Fatigue Management (Procedural, Human Factor)		
T5	**Collision During Transit or Maneuvering:** The jack-up rig colliding with other vessels, fixed installations, or submerged obstructions during sea passage or when maneuvering on/off location.	- Detailed Passage Planning and Route Hazard Identification (Procedural) - Adequate Number, Capability, and Configuration of Towing Vessels (Hardware, Procedural) - Established Communication Protocols and BRM (Procedural, Human Factor) - Competent and Experienced Bridge Team and Tow Master (Human Factor) - Maintaining Safe Speed and CPA Limits (Procedural) - Use of Pilotage Services (Procedural, External Service) - Daylight Operations for	- Radar, AIS, and ECDIS Systems (Hardware/Software) - Diligent Visual Lookout (Human Action) - Vessel Traffic Services (VTS) Monitoring and Reporting (Procedural, External Service) - Proximity Alarms and Guard Zones (Hardware/Software) - Regular Position Verification (Procedural)	- Standard Collision Avoidance Maneuvers (COLREGs) (Procedural) - Emergency Towing Procedures and Equipment (Procedural, Hardware) - Use of Dynamic Positioning (DP) Capabilities (if available) (System Operation) - Adherence to 500m Safety Zone Procedures (Procedural) - Anchor Handling Capabilities (Emergency) (System Operation, Procedural)

Threat ID	Threat Description	Prevention Barriers (Type, Snippets)	Detection Barriers (Type, Snippets)	Control Barriers (Type, Snippets)
		Critical Maneuvers (Procedural)		
T6	**Loss of Watertight Integrity During Transit (Wet Tow):** Ingress of seawater into the hull through unsecured openings, damaged seals, or structural failure during a wet tow, leading to reduced freeboard, compromised stability, and potential capsizing.	- Thorough Pre-Tow Watertight Integrity Inspections and Securing (Procedural, Human Action) - Hull Condition Survey and Maintenance (Procedural) - Detailed Stability Analysis for Tow Condition (Intact and Damaged) (Procedural, Engineering Study) - Minimizing Liquid Variable Loads / Pressing Tanks Full (Procedural) - Securing of Deck Cargo to Prevent Hull Damage (Procedural) - Adherence to Load Line Requirements (Procedural)	- Regular Tank Soundings and Void Space Inspections (Procedural, Human Action) - Bilge Level Alarms and Water Ingress Detection Systems (Hardware/Software) - Continuous Monitoring of Rig Trim, List, and Freeboard (Human Action, Hardware) - Hull Stress Monitoring Systems (if fitted) (Hardware/Software)	- Damage Control Plan and Procedures (Procedural) - Emergency Pumping Capabilities (Hardware, Procedural) - Compartment Isolation (Procedural, System Design) - Contingency Plan for Severe Flooding and Stability Loss (Procedural) - Maintaining Communication with Towing Vessels and Shore Support (Procedural)

3.0 Consequence Analysis for Loss of Stability/Control During Rig Move

Should the threat-reducing barriers fail and a "Loss of stability/control during rig move for a Jackup Rig" event occur, several severe consequences can ensue. This section details these potential outcomes and the consequence-mitigating barriers designed to prevent escalation or lessen their impact.

3.1 Consequence: Rig Capsizing / Sinking

Consequence Description: The most catastrophic outcome of a loss of stability event, involving the complete overturning (capsizing) or foundering (sinking) of the jack-up rig. This typically results in the total loss of the multi-million dollar asset, poses an immediate and extreme threat of multiple fatalities to personnel onboard, and can lead to significant environmental pollution from released inventories. Historical jack-up accidents have demonstrated the devastating potential of capsizing events.

Consequence Mitigating Barriers:

- **Prevention (of escalation to full capsize once instability is evident):**
  - **Rapid and Effective Execution of Damage Control Procedures:** If instability is due to flooding, the immediate and correct implementation of damage control measures, such as activating bilge/ballast pumps to dewater breached compartments, counter-flooding intact compartments to correct list/trim (as per approved damage stability booklet), or isolating damaged sections to prevent progressive flooding, can arrest the escalation towards capsize.
  - **Emergency Ballasting/De-ballasting Systems and Procedures:** Quick and decisive use of the rig's ballast systems to attempt to restore positive stability or reduce the angle of heel. This requires readily available power for pumps and clear procedures for emergency ballast operations.
  - **Jettisoning of Significant Deck Load (Extreme and Last Resort Measure):** In dire circumstances, and if procedures exist and conditions permit safe execution without further endangering the rig or personnel, the controlled jettisoning of heavy deck loads might be considered to improve stability. This is a highly complex and risky action.
  - **Emergency Leg Lowering/Pinning (if applicable and feasible):** If the instability occurs in suitable water depth and conditions, and the jacking system is operational, attempting an emergency lowering of legs to gain seabed support could prevent capsize. This is highly dependent on the specific scenario.
- **Detection (of imminent capsize or conditions leading to it):**
  - **Continuous Monitoring of List/Heel Angle and Rate of Change:** Utilizing inclinometers (electronic and manual) and visual references to continuously track the angle of list/heel and, crucially, the rate at which it is increasing. A rapidly increasing angle is a strong indicator of imminent capsize.
  - **Alarms for Critical List Angles/Downflooding Points:** Pre-set audible and visual alarms that activate when the rig reaches critical list angles specified in the stability booklet, or when downflooding points are close to immersion.
  - **Monitoring of Draft, Freeboard, and Rate of Water Ingress:** Closely monitoring changes in draft and freeboard, and estimating the rate of water ingress if flooding is the cause, to assess the time available before stability is critically lost.
- **Control (managing the capsize event to save lives and mitigate further harm):**
  - **Well-Defined and Regularly Drilled Emergency Evacuation Procedures:** Having clear, concise, and well-rehearsed procedures for abandoning the rig via lifeboats, life rafts, or other means (e.g., personal descent devices, transfer to standby vessel). Drills must cover various scenarios and ensure familiarity with all evacuation equipment.
  - **Effective Search and Rescue (SAR) Operations Activation:** Prompt notification and activation of internal (e.g., Fast Rescue Craft from standby vessel) and external (e.g., Coast Guard, other vessels in vicinity) SAR resources.
  - **Provision and Use of Personal Survival Equipment:** Ensuring all personnel onboard have access to, and are trained in the use of, appropriate personal survival

equipment, including lifejackets, immersion suits (especially in cold waters), and personal locator beacons (PLBs).
    - **Automatic Activation and/or Manual Deployment of EPIRB:** Ensuring the Emergency Position Indicating Radio Beacon (EPIRB) activates automatically upon immersion or can be manually deployed to transmit a distress signal and location to rescue authorities.
    - **Standby Vessel Presence and Capability:** Having a dedicated standby vessel in close proximity during critical rig move phases, equipped and crewed for rescue operations.

The progression from initial instability to full capsize can be alarmingly rapid, particularly if critical buoyancy is lost or a significant overturning moment develops quickly. This severely constrains the time window available for effective consequence mitigation, whether that involves attempts to save the rig or, more critically, to ensure the safe evacuation of all personnel. This reality places an immense premium on the *readiness, reliability, and effectiveness of pre-planned emergency response procedures and associated equipment*. Furthermore, it underscores the critical need for rapid, decisive, and correct decision-making by the rig leadership (OIM, Barge Master) under conditions of extreme stress and urgency. Delays or errors in initiating evacuation or deploying survival systems can have fatal consequences. Therefore, the "preventive" aspects of consequence mitigation—such as rigorous emergency drills, meticulous maintenance of life-saving appliances, and clear command structures for emergencies—are paramount.

3.2 Consequence: Structural Damage to Rig (Hull, Legs, Jacking System)

Consequence Description: The jack-up rig sustains significant structural damage to its primary components, such as bending, buckling, or fracture of leg chords or bracings; damage or deformation of spudcans; failure or severe damage to jacking houses, gearboxes, pinions, or motors; or breaches and deformation of the hull structure. This damage can result from excessive loads imposed during uncontrolled movements, impacts (e.g., severe punch-through, hard leg slamming on the seabed, collision with other objects), or from overstressing due to uneven leg support or excessive RPD.

Consequence Mitigating Barriers:

- **Prevention (of minor damage escalating to major failure or preventing reoccurrence):**
    - **Post-Incident Damage Assessment Procedures:** Implementing immediate and thorough procedures to assess the extent of any structural damage after an event (e.g., a hard seabed contact, a minor punch-through, excessive RPD occurrence, or unexpected impact). This assessment determines if further operations can continue safely, require modification, or if the rig needs to be taken out of service. ABS, for example, requires a damage survey after a tow before putting the rig on location.
    - **Operational Adjustments to Reduce Stress on Damaged Components:** If minor, manageable damage is identified, modifying operational procedures (e.g., adjusting jacking sequence to favor undamaged legs, redistributing variable loads, seeking calmer sea conditions for transit) to reduce stress on the affected components and prevent further damage.
    - **Preservation of Evidence and Data Logging:** Ensuring that all relevant data from

monitoring systems (leg loads, RPD, hull stresses, motions) leading up to and during the damaging event is preserved for detailed engineering investigation.

- **Detection (of the extent and nature of structural damage):**
  - **Comprehensive Visual Inspections:** Conducting thorough visual checks by competent personnel of all accessible affected areas (legs, spudcans if visible, jacking houses, hull connections) after any suspected overload, impact, or unusual operational event.
  - **Non-Destructive Testing (NDT):** If significant stress, impact, or deformation is suspected, employing appropriate NDT methods (e.g., ultrasonic testing (UT), magnetic particle inspection (MPI), dye penetrant testing (DPT)) to check for cracks, internal flaws, or material degradation in critical structural members, welds, and jacking system components.
  - **Strain Gauges / Structural Health Monitoring Systems (if fitted):** Utilizing data from permanently installed or temporarily deployed strain gauges or other structural monitoring systems that can indicate yielding, overstress, or fatigue damage in key structural elements.
  - **Dimensional Checks and Alignment Surveys:** Measuring critical dimensions and checking alignments of leg guides, jacking systems, or other components if deformation is suspected.
- **Control (managing the damaged state to ensure safety and limit further loss):**
  - **Approved Temporary Repair Procedures:** If minor and repairable damage occurs, implementing class-approved temporary repair measures that allow the rig to safely transit to a suitable repair facility or, in some limited cases, to complete the current move under strictly defined operational restrictions.
  - **Securing Damaged Areas:** Taking immediate measures to secure any loose or compromised components to prevent further damage, hazards to personnel, or pollution.
  - **Contingency Towage Plan to Repair Yard:** Having a pre-considered plan for safely towing a structurally damaged rig to a designated repair yard, which may involve different tug requirements or stability considerations.
  - **Down-rating Operational Capacity or Imposing Stricter Limits:** If permanent, non-critical damage has occurred but is deemed manageable for continued (though restricted) service, formally down-rating the rig's operational capacity (e.g., reduced environmental limits, payload restrictions) based on engineering assessment and class approval.
  - **Consultation with Classification Society and MWS:** Engaging with the classification society and Marine Warranty Surveyor (MWS) to report damage, agree on assessment methods, and approve any repair plans or continued operation with damage.

An important consideration is that structural damage incurred during one phase of a rig move, even if seemingly minor at the time (e.g., leg slamming during lowering in rough seas , or minor deformation from a previous footprint interaction), can create a latent failure condition. This pre-existing weakness, if undetected or unaddressed, can significantly lower the threshold for more severe structural failure during a subsequent, more demanding phase of the operation (such as full preloading which imposes maximum design loads on the legs and foundations) or when the rig later encounters harsh environmental conditions. This highlights the critical importance of conducting thorough post-event inspections and damage surveys even if an incident appears to have had limited immediate consequences. Failure to identify and rectify such latent damage effectively weakens a key preventive barrier against future catastrophic failure.

3.3 Consequence: Personnel Injury / Fatality

Consequence Description: Crew members or other personnel onboard the jack-up rig or support vessels suffering physical harm, ranging from minor injuries to fatalities. These can occur due to various mechanisms associated with a loss of stability or control, such as:

- Falls from height (e.g., if the rig lists suddenly or personnel are working at elevation without proper fall protection).
- Being struck by falling, shifting, or swinging objects (e.g., unsecured equipment, derrick components, cargo) due to uncontrolled rig motions.
- Crushing injuries if caught between moving parts of the rig or between the rig and another structure during uncontrolled movements or collision.
- Injuries sustained during emergency evacuation attempts in chaotic conditions.

Consequence Mitigating Barriers:

- **Prevention (of injury occurring during the instability event itself, before or during evacuation):**
    - **Designated Safe Muster Areas/Temporary Safe Refuges (TSRs):** Clearly identified, structurally sound, and easily accessible locations onboard where personnel should gather during an instability event before a decision to evacuate is made. These areas should offer protection from immediate hazards.
    - **Thorough Securing of All Loose Equipment and Stores:** Rigorous procedures for ensuring all tools, equipment, spare parts, and stores are properly stowed and sea-fastened before commencing any rig move phase, to prevent them from becoming dislodged and creating impact or trip hazards during uncontrolled motions.
    - **Restricted Access to Potentially Hazardous Areas:** Implementing physical barricades (e.g., safety chains, gates) and clear signage to restrict personnel access to areas that could become particularly hazardous during a loss of stability event (e.g., deck areas with low freeboard prone to green water, areas near legs or jacking machinery during uncontrolled movements, exposed locations).
    - **Personal Fall Protection Systems (PFPS):** Ensuring that personnel working at height or in locations where there is a risk of falling overboard are equipped with and correctly using appropriate PFPS (harnesses, lanyards, anchor points).
- **Detection (of personnel in danger or injured):**
    - **Personnel Accountability Systems (e.g., POB boards, electronic muster systems):** Rapidly deployable systems to account for all personnel onboard during an emergency, ensuring no one is missing or trapped.
    - **CCTV Monitoring in Critical Areas:** Where installed, using CCTV to monitor critical work areas or muster stations to help identify personnel who may be in danger or injured.
    - **Buddy System and Communication Checks:** Implementing a buddy system for personnel working in isolated or hazardous areas, with regular communication checks.
- **Control (managing injuries and facilitating rescue):**
    - **Effective Emergency Evacuation Systems:** Ensuring all life-saving appliances (LSA), including lifeboats, life rafts, and escape chutes/devices, are fully

operational, regularly inspected and maintained, readily accessible, and sufficient for the total number of personnel onboard (POB). Crew must be thoroughly trained in their deployment and use.
  - **First Aid and Medical Emergency Response Plan and Facilities:** Having trained medical personnel (e.g., medic), adequate medical supplies, and established procedures for providing immediate first aid and medical treatment for injuries sustained during an incident. This includes protocols for medical evacuation (medevac) if required.
  - **Man Overboard (MOB) Procedures and Rescue Equipment:** Specific, well-drilled procedures and readily available equipment (e.g., rescue boats, MOB recovery devices, lifebuoys) for responding to MOB incidents, which are a heightened risk during instability events or abandonment.
  - **Appropriate Personal Protective Equipment (PPE):** Mandating the correct use of task-appropriate PPE by all personnel, including hard hats, safety glasses/goggles, impact-resistant gloves, steel-toed safety boots, and, critically during abandonment or risk of immersion, approved lifejackets and immersion suits (especially in cold water environments).
  - **Clear and Unambiguous Emergency Alarms and Communication:** Ensuring that emergency alarms (e.g., general alarm, abandon rig alarm) are distinct, audible throughout the rig, and understood by all personnel. Clear communication of instructions during an emergency is vital.

The effectiveness of even the best-designed evacuation systems (a critical control barrier for personnel safety) can be severely compromised if personnel are unable to safely reach them. During a rapid loss of stability event, conditions onboard can become chaotic, with the rig listing heavily, uncontrolled motions, and potential for structural damage creating new obstacles. If escape routes are blocked, for instance by dislodged equipment or damaged walkways and grating systems , the ability to execute a timely and orderly evacuation is jeopardized. Furthermore, lack of clear, calm, and authoritative instruction from leadership during such an escalating crisis can lead to confusion and panic, further hindering effective use of evacuation facilities. This highlights a crucial interplay: "preventive" consequence mitigation barriers (such as maintaining clear and protected escape routes, ensuring all equipment is secured, and robust emergency leadership training) are vital for the successful functioning of "control" consequence mitigation barriers like lifeboats and life rafts.

3.4 Consequence: Environmental Pollution (e.g., oil/fuel spill)

Consequence Description: The unintentional release of hydrocarbons (such as diesel fuel, lubricants, hydraulic oils) or other hazardous materials (e.g., drilling fluids, chemicals) into the marine environment. This can occur as a result of a hull breach due to collision or grounding, damage to onboard tanks during severe listing or capsizing, or failure of equipment containing these substances during the loss of stability event. The Montara incident, involving a jack-up, led to a significant oil spill and gas leak.

Consequence Mitigating Barriers:

- **Prevention (of spill occurring from a damaged or unstable rig):**
  - **Robust Hull and Tank Design Standards:** Construction according to classification society rules that include requirements for hull strength and tank protection (e.g., double hull for certain fuel tanks, strategic location of hazardous material storage away from collision-prone areas).

    - **Emergency Shutdown Systems for Fuel/Oil Transfer Operations:** Automated or manual systems to quickly stop any ongoing fuel, lubricant, or hydraulic oil transfer operations if a leak is detected or significant structural damage occurs, minimizing the volume that could be spilled.
    - **Tank Isolation Valves and Systems:** Provision of remotely or locally operable isolation valves for fuel, oil, and chemical tanks, allowing damaged tanks or pipework to be quickly isolated to prevent further discharge.
    - **Regular Inspection and Maintenance of Tank Structures and Associated Pipework:** Ensuring tanks and their piping systems are free from corrosion or defects that could lead to leakage under stress or impact.
- **Detection (of spills occurring):**
    - **Regular Visual Sheen Monitoring:** Procedures for rig crew to conduct regular visual observation of the water surface around the rig for any signs of oil sheen or other pollutants, especially after any incident or during transfer operations.
    - **Tank Level Monitoring Systems with Leak Detection Alarms:** Utilizing tank gauging systems that can provide alarms for unexpected or rapid drops in tank levels, which could indicate a leak or breach.
    - **Deck Drainage and Coaming Containment Monitoring:** Regular inspection of deck coamings, scuppers, and drainage systems designed to contain minor deck spills, ensuring they are clear and that any contained pollutants are identified.
    - **Airborne or Satellite Surveillance (for larger, ongoing incidents):** External resources that can be used to detect and track larger spills.
- **Control (managing the spill to minimize environmental impact):**
    - **Shipboard Oil Pollution Emergency Plan (SOPEP) or Rig-Specific Spill Response Plan:** Having a comprehensive, approved, and regularly drilled spill response plan onboard. This plan outlines procedures for reporting, assessment, containment, and recovery of spills.
    - **Availability and Readiness of Onboard Spill Response Equipment:** Ensuring the rig is equipped with an adequate inventory of appropriate spill response equipment, such as containment booms, skimmers, sorbent materials, and dispersants (if their use is approved for the operating area and conditions). Equipment must be regularly inspected and maintained.
    - **Clear Notification Procedures to Authorities and Spill Response Organizations:** Established protocols for promptly notifying relevant coastal state authorities, classification societies, and contracted Tier 2/3 spill response organizations in the event of a spill that exceeds onboard capabilities.
    - **Trained Spill Response Team Onboard:** Designated and trained personnel onboard responsible for initiating first-response actions according to the SOPEP.
    - **Containment Boom Deployment Capabilities:** Procedures and capability (potentially using support vessels) to deploy containment booms around the rig to limit the spread of a surface spill, if sea conditions permit.

While a well-equipped rig with a comprehensive SOPEP and trained crew represents a crucial set of control barriers for pollution, the practical effectiveness of these measures is often severely limited by the prevailing environmental conditions, particularly the sea state, and by the speed at which a significant spill can spread. If the primary loss of stability event is itself caused by or occurs during adverse weather, the same conditions (high winds, rough seas) will greatly hamper or even prevent the deployment of booms, the operation of skimmers, and other surface containment and recovery efforts. This reality underscores the paramount importance of the *preventive* barriers: those aimed at preventing the loss of stability in the first place, and those designed to maintain hull and tank integrity even if the rig sustains damage. Robust structural design, secure tank arrangements, and effective damage control to prevent breaches are therefore even more critical for environmental protection in challenging offshore environments.

3.5 Consequence: Collision with Other Assets (Fixed Platforms, Subsea Infrastructure, Other Vessels)

Consequence Description: If the loss of control or stability occurs during transit, or while maneuvering in proximity to other offshore assets (e.g., fixed production platforms, subsea wellheads or pipelines, other vessels), the jack-up rig could drift or move uncontrollably, resulting in a collision. Such a collision could cause severe damage to both the jack-up and the other asset, potentially leading to further hydrocarbon releases (if a platform or pipeline is struck), structural failures, and a high risk of injuries or fatalities to personnel on both units involved. This consequence is distinct from Threat 2.5 (Collision During Transit or Maneuvering), as here the collision is a *result* of the jack-up having already lost stability or control, rather than collision being a primary cause of that loss.

Consequence Mitigating Barriers:

- **Prevention (of collision occurring once the jack-up has lost stability/control):**
    - **Emergency Anchoring or Mooring Capabilities (if feasible and prepared):** If the jack-up is equipped with anchors and the water depth/seabed conditions permit, attempting an emergency deployment of anchors to arrest the rig's drift or uncontrolled movement. This requires anchors to be ready for quick release and is highly situational. Similarly, if mooring lines can be rapidly deployed to nearby strong points (e.g., tugs, fixed structures if designed for it), this might offer some control.
    - **Effective Use of Attendant Support Vessels for Emergency Towing or Pushing:** Directing available tugboats or other capable support vessels to attempt to regain control of the drifting jack-up, push it away from hazards, or hold it in position, provided they have sufficient power and maneuverability and can safely approach the out-of-control rig.
    - **Emergency Shutdown and Evacuation of Nearby Facilities:** Pre-established communication channels and protocols for alerting nearby fixed platforms or mobile units of the imminent collision risk, allowing them to initiate emergency shutdown (ESD) of production, blowdown of systems, and prepare for or commence personnel evacuation if necessary.
    - **Broadcast of Navigational Warnings (SECURITE/PAN-PAN/MAYDAY):** Transmitting urgent navigational warnings to alert other maritime traffic in the vicinity about the out-of-control jack-up and its potential drift path.
- **Detection (of an impending collision trajectory):**
    - **Continuous Positional Monitoring of the Drifting Rig:** Utilizing the jack-up's own GPS (if operational) and radar tracking by support vessels or nearby installations to continuously monitor the path, speed, and predicted trajectory of the out-of-control rig relative to fixed hazards or other vessels.
    - **Urgent Communication with Potentially Affected Assets:** Establishing and maintaining direct communication (e.g., VHF radio) with any platforms, installations, or vessels that are identified as being on a potential collision course, providing

updates on the situation and coordinating defensive actions.
    - **Visual Tracking and Plotting:** Maintaining a visual lookout and manually plotting the drifting rig's movement relative to fixed charts and known hazards, especially if electronic systems are compromised.
- **Control (managing the collision impact and its immediate aftermath):**
    - **"Brace for Impact" Procedures:** If collision is unavoidable, broadcasting instructions for personnel on both the jack-up and the potentially impacted asset to move to designated brace-for-impact locations, adopt protective postures, and secure loose items to minimize injury.
    - **Post-Collision Damage Assessment and Emergency Response Activation:** Immediately after a collision, activating emergency response plans on both affected assets to assess structural damage, check for personnel injuries, control any resultant hazards (fire, flooding, hydrocarbon release), and initiate rescue or medical assistance as needed.
    - **Coordinated Emergency Response Between Multiple Assets:** If a collision involves another operational facility, establishing joint communication and coordinating emergency response efforts (e.g., firefighting, spill response, medical support) between the jack-up and the other asset's emergency teams.
    - **Maintaining Stability of Both Assets Post-Collision:** Focusing efforts on maintaining or restoring stability to both the jack-up and any other vessel or platform involved, to prevent further escalation of consequences.

The presence of other operational offshore assets (platforms, subsea templates, pipelines, other MODUs or vessels) in close proximity to a jack-up rig's planned transit route or location significantly amplifies the potential severity and complexity of a loss of stability or control event. A drifting, out-of-control jack-up poses a substantial threat in such congested environments. This heightened potential for cascading failures and multi-asset involvement means that rig move planning in these areas demands an additional, more stringent layer of *preventive barriers*. These should focus intensely on *preventing the initial loss of control or stability of the jack-up itself*. This may involve adopting wider safety margins for environmental conditions, imposing more restrictive go/no-go criteria, utilizing more powerful or dedicated escort tugs throughout all critical maneuvering phases, and ensuring exceptionally robust contingency plans are in place for any deviation from the planned operation. The risk assessment for such moves must explicitly account for the increased consequence potential due to proximity to third-party assets.

Table 2: Consequences and Consequence-Mitigating Barriers for Loss of Stability/Control During Jack-up Rig Move

Consequence ID	Consequence Description	Prevention Barriers (Post-event, to prevent escalation) (Type, Snippets)	Detection Barriers (To detect onset/presence) (Type, Snippets)	Control Barriers (To manage/mitigate impact) (Type, Snippets)
C1	**Rig Capsizing / Sinking:** Complete loss of stability leading to overturning or sinking, total asset	- Rapid Execution of Damage Control Procedures (Procedural, System Operation) -	- Continuous Monitoring of List/Angle of Loll & Rate of Change (Hardware, Human Action) -	- Emergency Evacuation Procedures (Lifeboats, Rafts) (Procedural, Hardware) -

Consequence ID	Consequence Description	Prevention Barriers (Post-event, to prevent escalation) (Type, Snippets)	Detection Barriers (To detect onset/presence) (Type, Snippets)	Control Barriers (To manage/mitigate impact) (Type, Snippets)
	loss, severe environmental impact, high risk of multiple fatalities.	Emergency Ballasting/De-ballasting Systems (System Operation, Procedural) - Jettisoning of Deck Load (Extreme Measure, Procedural) - Emergency Leg Lowering/Pinning (Contingency Procedure)	Alarms for Critical List Angles/Downflooding Points (Hardware/Software) - Monitoring of Draft, Freeboard, Rate of Water Ingress (Human Action, Hardware)	Search and Rescue (SAR) Operations Activation (Procedural, External Service) - Personal Survival Equipment (Lifejackets, Immersion Suits) (Hardware) - EPIRB Activation (Hardware, Procedural) - Standby Vessel Presence and Capability (Hardware, Procedural)
C2	**Structural Damage to Rig (Hull, Legs, Jacking System):** Bending/buckling of legs, spudcan damage, jacking system failure, hull breaches due to excessive loads or impacts.	- Post-Incident Damage Assessment Procedures (Procedural) - Operational Adjustments to Reduce Stress (Procedural) - Preservation of Evidence and Data Logging (Procedural)	- Comprehensive Visual Inspections (Human Action) - Non-Destructive Testing (NDT) (Procedural, Specialized Equipment) - Strain Gauges / Structural Health Monitoring Systems (if fitted) (Hardware/Software) - Dimensional Checks and Alignment Surveys (Procedural)	- Approved Temporary Repair Procedures (Procedural, Engineering Support) - Securing Damaged Areas (Procedural, Human Action) - Contingency Towage Plan to Repair Yard (Procedural) - Down-rating Operational Capacity (Procedural, Engineering Assessment) - Consultation with

Consequence ID	Consequence Description	Prevention Barriers (Post-event, to prevent escalation) (Type, Snippets)	Detection Barriers (To detect onset/presence) (Type, Snippets)	Control Barriers (To manage/mitigate impact) (Type, Snippets)
				Class/MWS (Procedural)
C3	**Personnel Injury / Fatality:** Physical harm to crew due to falls, being struck by objects, crushing injuries, or during emergency evacuation.	- Designated Safe Muster Areas/Temporary Safe Refuges (TSRs) (Design, Procedural) - Thorough Securing of All Loose Equipment and Stores (Procedural) - Restricted Access to Potentially Hazardous Areas (Procedural, Physical Barriers) - Personal Fall Protection Systems (PFPS) (Hardware, Procedural)	- Personnel Accountability Systems (POB boards, e-muster) (Procedural, Hardware/Software) - CCTV Monitoring in Critical Areas (Hardware) - Buddy System and Communication Checks (Procedural, Human Factor)	- Effective Emergency Evacuation Systems (LSA) (Hardware, Procedural) - First Aid and Medical Emergency Response Plan/Facilities (Procedural, Resources) - Man Overboard (MOB) Procedures and Rescue Equipment (Procedural, Hardware) - Appropriate Personal Protective Equipment (PPE) (Hardware, Procedural) - Clear Emergency Alarms and Communication (Hardware, Procedural)
C4	**Environmental Pollution (e.g., oil/fuel spill):** Release of hydrocarbons or hazardous materials due to hull breach, tank damage, or equipment failure.	- Robust Hull and Tank Design Standards (Design Standard) - Emergency Shutdown Systems for Fuel/Oil Transfer (System Design, Procedural) -	- Regular Visual Sheen Monitoring (Procedural, Human Action) - Tank Level Monitoring Systems with Leak Detection Alarms (Hardware/Software) - Deck	- Shipboard Oil Pollution Emergency Plan (SOPEP) / Rig Spill Plan Activation (Procedural) - Availability/Readiness of Onboard

Consequence ID	Consequence Description	Prevention Barriers (Post-event, to prevent escalation) (Type, Snippets)	Detection Barriers (To detect onset/presence) (Type, Snippets)	Control Barriers (To manage/mitigate impact) (Type, Snippets)
		Tank Isolation Valves and Systems (System Design, Procedural) - Regular Inspection/Maintenance of Tanks & Pipework (Procedural)	Drainage and Coaming Containment Monitoring (Procedural, Human Action) - Airborne or Satellite Surveillance (Large Spills) (External Service)	Spill Response Equipment (Hardware, Procedural) - Clear Notification Procedures to Authorities/Spill Orgs (Procedural) - Trained Spill Response Team Onboard (Human Factor, Procedural) - Containment Boom Deployment Capabilities (Hardware, Procedural)
C5	**Collision with Other Assets (Fixed Platforms, Subsea Infrastructure, Other Vessels):** Drifting or uncontrolled jack-up collides with nearby assets, causing mutual damage, potential pollution, and risk to personnel.	- Emergency Anchoring or Mooring Capabilities (System Operation, Procedural) - Effective Use of Attendant Support Vessels for Emergency Control (Procedural, Resource Coordination) - Emergency Shutdown and Evacuation of Nearby Facilities (Procedural, Inter-Asset Coordination) - Broadcast of Navigational	- Continuous Positional Monitoring of Drifting Rig (Hardware/Software, Human Action) - Urgent Communication with Potentially Affected Assets (Procedural, Human Action) - Visual Tracking and Plotting (Human Action)	- "Brace for Impact" Procedures (Procedural) - Post-Collision Damage Assessment and Emergency Response Activation (Procedural) - Coordinated Emergency Response Between Multiple Assets (Procedural) - Maintaining Stability of Both Assets Post-Collision (Procedural, System Operation)

Consequence ID	Consequence Description	Prevention Barriers (Post-event, to prevent escalation) (Type, Snippets)	Detection Barriers (To detect onset/presence) (Type, Snippets)	Control Barriers (To manage/mitigate impact) (Type, Snippets)
		Warnings (Procedural)		

4.0 Barrier Integrity and Management

The identification of threats, consequences, and their respective barriers is a critical first step in risk management. However, the continued effectiveness of these barriers relies on a robust system for ensuring their integrity throughout the lifecycle of the jack-up rig and its operations. This involves defining performance expectations, diligent maintenance, competent personnel, and regular verification and review processes.

4.1 Ensuring Barrier Effectiveness

The concept of Safety Critical Elements (SCEs) is central to ensuring barrier effectiveness. SCEs are those parts of an installation (hardware, software, or procedural) whose failure could cause or contribute substantially to a major accident, or whose purpose is to prevent or limit the effect of a major accident. For each SCE identified within the context of rig move stability, clear Performance Standards must be established. These standards define the required functionality, availability, reliability, survivability, and any critical interactions with other systems or human elements that the barrier must achieve to be considered effective.
Verification and validation processes are then necessary to ensure that these barriers are designed, installed, tested, and capable of functioning as intended under all relevant conditions. Classification societies like DNV and ABS play a significant role in this verification process, offering services for design review, certification of equipment, and approval of operational procedures related to safety critical functions. This includes verifying that equipment meets recognized standards (e.g., DNVGL-ST-N001 for marine operations, ISO 19905-1 for site-specific assessments). For instance, inspections and maintenance documentation are crucial for accountability and tracking issues.

4.2 Maintenance of Physical Barriers

Physical barriers, such as the jacking system, ballast system, mooring equipment, emergency power generators, and navigation systems, require diligent maintenance to remain effective.

- **Preventive Maintenance Systems (PMS):** A comprehensive PMS, aligned with OEM recommendations and class requirements, must be in place for all critical equipment. This includes scheduled inspections, lubrication, replacement of wear-and-tear components, and functional testing.
- **Corrosion Control and Structural Integrity Programs:** Jack-up rigs operate in harsh marine environments, making them susceptible to corrosion and material degradation. Regular inspections (visual and NDT), maintenance of protective coatings (e.g., three-coat systems of primer, high-build epoxy, polyurethane topcoat), and cathodic protection systems are essential to maintain the structural integrity of the hull, legs (especially splash zones), and spudcans. Preload tanks are particularly prone to

microbiologically influenced corrosion (MIC) if not properly preserved.
- **Testing of Detection and Alarm Systems:** Periodic functional testing of all detection and alarm systems critical to stability management is mandatory. This includes bilge alarms, fire and gas detection systems (which can be indicative of escalating events), RPD monitors, jacking motor overload alarms, and navigation equipment alarms.

4.3 Management of Human and Procedural Barriers

Human actions and adherence to procedures are fundamental barriers. Their integrity depends on several organizational factors:
- **Regular Review and Update of Procedures:** Rig Move Procedures (RMPs), emergency response plans, operational checklists, and stability manuals must be living documents. They require regular review (e.g., annually or after significant operational changes/incidents) to ensure they remain current, accurate, user-friendly, and incorporate lessons learned from industry incidents or internal experience.
- **Ongoing Competency Assessment and Refresher Training:** Initial training and certification are not sufficient. Regular competency assessments, refresher training, and emergency drills are necessary to ensure that all personnel (OIM, Barge Master, Tow Master, jacking operators, crane operators, bridge teams) remain proficient in their safety-critical tasks and emergency response roles. This includes understanding PIFs and CRM principles. IADC WellSharp Plus incorporates human factors into technical well control training, a model that could be adapted for rig move critical tasks.
- **Human Factors Audits and Integration:** Periodically conducting specific Human Factors audits or integrating HF considerations into general safety audits can help assess how effectively human factors are being managed in practice. This includes evaluating workload, HMI effectiveness, procedural usability, and communication pathways.
- **Safety Culture Monitoring and Improvement Programs:** Actively monitoring and fostering a positive safety culture that encourages procedural adherence, proactive hazard reporting, learning from errors (without a blame culture), and empowers individuals to exercise Stop Work Authority is crucial for the reliability of human and procedural barriers.

4.4 Role of Marine Warranty Surveyors (MWS)

Marine Warranty Surveyors (MWS) provide an independent third-party technical review and approval of high-value and high-risk marine operations, including jack-up rig moves. Their role in the context of rig move stability typically involves:
- Review and approval of the Rig Move Procedure (RMP), site-specific assessments (SSA), geotechnical reports, leg penetration analyses (LPA), mooring plans (if applicable), and towing vessel suitability.
- Verification that operations are planned in accordance with industry standards, regulations, and best practices.
- Physical inspection of the rig and support vessels prior to the move.
- Attendance during critical phases of the rig move (e.g., jacking, preloading, critical tow maneuvers) to witness operations and verify compliance with approved procedures and safety criteria.
- Issuing a Certificate of Approval if all conditions are met, which is often a requirement for insurance coverage.

The MWS acts as a crucial overarching verification layer, or a *meta-barrier*, by independently checking the adequacy and implementation of many of the operator's technical and procedural barriers. However, the inherent effectiveness of the MWS function itself is dependent on several factors: the competence and experience of the individual surveyor, the quality and completeness of information provided by the rig operator and their contractors, and a clearly defined and sufficiently detailed scope of work for the MWS. A superficial or "tick-box" approach to marine warranty surveying, as cautioned against in some industry discourse , can significantly undermine its value as a robust independent barrier. For the MWS to be truly effective, it must involve a deep, critical review of all relevant documentation and a diligent verification of actual site conditions and operational practices, rather than merely confirming procedural compliance on paper. The MWS should challenge assumptions and ensure that risks are genuinely managed to ALARP.

4.5 Auditing and Review of Barrier Effectiveness

To ensure long-term risk control, barrier systems must be subject to periodic auditing and review:

- **Regular Safety Case Reviews:** For jurisdictions operating under a safety case regime (e.g., UK, Norway, Australia), the safety case for the jack-up rig (which includes rig move operations) must be periodically reviewed and updated. This process inherently involves reassessing major accident hazards, the barriers in place, and their ongoing effectiveness.
- **Incident Investigation and Dissemination of Lessons Learned:** All stability-related incidents, accidents, and significant near misses must be thoroughly investigated to identify root causes, including failed or degraded barriers (technical, human, or procedural). The findings and corrective actions must be documented, implemented, and, where appropriate, shared across the company fleet and with the wider industry to prevent recurrence. Organizations like IOGP facilitate such lesson sharing.
- **Performance Monitoring of Barriers:** Establishing Key Performance Indicators (KPIs) related to the health and function of critical barriers can provide early warning of degradation. Tracking these KPIs allows for proactive intervention before a barrier fails.

Table 3: Key Performance Indicators (KPIs) for Barrier Integrity Monitoring (Examples)

Barrier Category	Specific Barrier Example	Potential KPI for Monitoring Effectiveness	Target/Acceptable Range	Monitoring Frequency
Geotechnical Assessment & Site Entry	Comprehensive Site-Specific Assessment (SSA) / Leg Penetration Analysis (LPA)	- % of SSAs/LPAs completed and approved by MWS at least 'X' days prior to rig move commencement. - Number of SSA/LPA recommendations outstanding or not implemented at time of rig move.	- 100% completed/approved >14 days prior. - Zero critical recommendations outstanding. - Variance < 15% (example).	Per rig move

Barrier Category	Specific Barrier Example	Potential KPI for Monitoring Effectiveness	Target/Acceptable Range	Monitoring Frequency
		 - Variance between predicted and actual leg penetration > Y% (post-move analysis).		
Jacking System Integrity	Preventive Maintenance of Jacking System	- % of safety-critical jacking system PMS tasks completed on schedule. - Number of jacking motor/brake failures or near misses per 1000 jacking hours. - Average RPD values recorded during routine jacking (non-critical soil).	- >98% on schedule. - < X failures/near misses per year. - RPD within OEM limits.	Monthly / Per jacking cycle
Procedural Adherence & Human Performance	Rig Move Procedure (RMP) Checklists	- % completion and sign-off of critical RMP checklists. - Number of Stop Work Authority (SWA) activations related to procedural deviations during rig moves. - Number of human error-related near misses/incidents during rig moves.	- 100% completion. - SWA encouraged, investigate all. - Decreasing trend.	Per rig move / Quarterly
Weather Preparedness	Adherence to Weather-Related Operational Limits	- Number of instances where operations continued beyond defined weather limits. - Accuracy of	- Zero instances. - Forecast accuracy within +/- Z% for key parameters.	Per rig move / Continuous during move

Barrier Category	Specific Barrier Example	Potential KPI for Monitoring Effectiveness	Target/Acceptable Range	Monitoring Frequency
		weather forecasts vs. actual conditions experienced (post-move review).		
Watertight Integrity (Wet Tows)	Pre-Tow Watertight Integrity Inspections	- % completion of pre-tow watertight integrity checklist with all items verified. - Number of reported deficiencies in watertight closures found during inspection.	- 100% completion. - Zero critical deficiencies unresolved before tow.	Per wet tow
Emergency Response Readiness	Emergency Evacuation Drills (Abandon Rig)	- Average time to complete full muster and prepare first lifeboat for launching during unannounced drills. - % of crew successfully completing emergency response competency assessments.	- < X minutes. - 100% competency.	Quarterly / Annually
MWS Effectiveness	MWS Review and Approval	- Number of MWS recommendations implemented. - Feedback score from rig team on clarity and practicality of MWS recommendations.	- >95% recommendations implemented or risk-assessed equivalent. - >4 out of 5.	Per rig move

5.0 Key Recommendations for Risk Reduction

Based on the comprehensive risk analysis of "Loss of stability/control during rig move for a Jackup Rig," the following key recommendations are proposed to further enhance safety and mitigate risks associated with these critical operations:

- **5.1 Enhance Rig Move Procedure (RMP) Robustness:**
  - **Mandate Detailed, Task-Specific Checklists:** Develop and implement highly detailed, task-specific checklists with unambiguous go/no-go criteria for all critical phases of a rig move. This includes pre-move preparations, leg lowering and raising sequences, each stage of jacking (e.g., initial lift, jacking to preload height, jacking to final air gap), each step of the preloading operation, and transit in confined or congested waters. These checklists should be integral to the RMP and require formal sign-offs at hold points.
  - **Integrate Human Factors Analysis into RMPs:** The findings from Human Reliability Analysis (HRA) and Safety Critical Task Analysis (SCTA) should be directly translated into the RMP. This means procedures should be designed to minimize identified human error traps, simplify complex decision-making, and provide clear guidance for managing PIFs relevant to each task.
  - **Clarify Decision-Making Authority:** The RMP must explicitly define the roles, responsibilities, and ultimate decision-making authority for each critical step and for all go/no-go decisions, particularly at critical junctures where operational parameters approach limits or unexpected conditions arise. This clarity is essential to avoid confusion or delays in high-pressure situations.
- **5.2 Strengthen Site-Specific Assessment (SSA) Processes:**
  - **Holistic SSA Scope:** Ensure SSAs rigorously evaluate not only the ultimate limit states (e.g., storm survival when elevated) but also the transient conditions and dynamic effects during installation (leg lowering, seabed impact, initial jacking) and removal. This may require more sophisticated analytical techniques beyond quasi-static checks for certain conditions.
  - **Advanced Punch-Through Risk Management:** Improve methodologies for assessing and mitigating punch-through risk, especially in geotechnically complex or uncertain soil conditions. This should include consideration of advanced numerical modeling techniques and, where appropriate and feasible, proactive mitigative measures such as "Swiss cheesing" or specialized spudcan designs, based on thorough cost-benefit and risk-reduction analyses.
  - **Mandate Independent Peer Review for High-Risk SSAs:** For rig moves to locations with known significant geotechnical challenges, novel environmental conditions, or when using rigs near their operational envelope, an independent peer review of the SSA and LPA by qualified geotechnical and structural specialists should be mandated.
- **5.3 Invest in and Optimize Advanced Detection and Monitoring Systems:**
  - **Promote Wider Adoption and Effective Use of Real-Time Monitoring:** Encourage the wider adoption and ensure the effective utilization of integrated, real-time monitoring systems for critical parameters such as Rack Phase Differential (RPD), individual leg loads, leg penetration rates, hull stresses (if instrumented), and key environmental conditions. Data should be clearly displayed to operators in an actionable format.
  - **Develop Clear Alarm Philosophies and Operator Response Protocols:** For all monitoring systems, develop and implement clear, unambiguous alarm philosophies that define alarm setpoints, priorities, and required operator responses. Ensure operators are thoroughly trained on these protocols to avoid alarm fatigue or incorrect actions.

- **5.4 Intensify Focus on Human Performance and Competency:**
  - **Implement Scenario-Based Simulator Training:** Where feasible, implement high-fidelity, scenario-based simulator training for key rig move personnel (OIM, Barge Master/Engineer, Tow Master, Jacking System Operators). Training should focus on decision-making under pressure, management of off-normal situations (e.g., unexpected leg penetration, jacking system malfunctions, rapid weather deterioration), emergency response coordination, and effective Crew Resource Management (CRM).
  - **Strengthen Competency Assurance Programs:** Enhance competency assurance programs for all personnel involved in safety-critical rig move tasks. This should go beyond basic certification and include regular verification of practical skills, understanding of site-specific procedures, RMP content, and emergency response duties.
  - **Conduct Regular Human Factors Workshops and Reviews:** Periodically conduct workshops and reviews specifically focused on identifying and mitigating Performance Influencing Factors (PIFs) pertinent to jack-up rig move operations. These should involve operational personnel to capture "work-as-done" insights.
- **5.5 Improve Interface Management and Communication:**
  - **Standardize Communication Protocols and Interface Documents:** Develop and implement standardized communication protocols, including terminology and reporting structures, and formal interface documents that clearly delineate responsibilities and information flow between all parties involved in a rig move (rig owner/operator, drilling contractor, MWS, Tow Master, support vessel Masters, shore-based engineering and logistics support).
  - **Comprehensive Pre-Move Interface Meetings:** Ensure pre-move meetings explicitly address and document interface responsibilities, communication plans, and joint contingency plans, particularly for operations involving multiple contractors or complex interactions (e.g., tandem tows, positioning near existing infrastructure).
- **5.6 Foster Proactive Barrier Management and Continuous Learning:**
  - **Establish a Formal System for Barrier Performance Tracking:** Implement a system for formally identifying all safety-critical barriers (technical, operational, human) relevant to rig move stability, defining their performance standards, and regularly tracking their performance and integrity status (e.g., through KPIs as exemplified in Table 3).
  - **Ensure Thorough Investigation and Industry-Wide Sharing of Lessons from Stability Incidents:** Mandate thorough, root-cause focused investigations of all stability-related near misses and incidents. The emphasis should be on identifying failed, inadequate, or missing barriers. Crucially, lessons learned and effective corrective actions should be robustly implemented within the organization and actively shared across the industry through forums like IOGP, IADC, and regulatory bodies to promote collective learning and prevent recurrence.

By systematically implementing these recommendations, the offshore industry can further reduce the risks associated with jack-up rig moves, enhancing the safety of personnel, protecting valuable assets, and safeguarding the marine environment.

Works cited

1. Offshore Oil Rig: A Comprehensive Guide - JOUAV,

https://www.jouav.com/blog/offshore-oil-rig.html 2. Jack-Up Rig - Drilling & Well Completion - Simply Explained | Home Page, https://www.tidjma.tn/en/glossary/o-g-jack-up-rig-7813/ 3. Jackup Safety: Q&A with ABS - Rigzone, https://www.rigzone.com/news/jackup_safety_qa_with_abs-02-mar-2015-137455-article/?pgNum=2 4. Rig Move - Standards - DrillingForGas, https://www.drillingforgas.com/en/drilling/standards/rig-move-standards 5. Jack-Up Rigs Operational Aspects (Offshore Drilling) | PDF - Scribd, https://www.scribd.com/presentation/192666187/Jack-up-Rigs-Operational-Aspects-Offshore-Drilling 6. ABS Leads Industry in Addressing Jackup Safety Through Targeted R&D, https://ww2.eagle.org/content/dam/eagle/publications/whitepapers/ABS_Jackup_Safety_White_Paper.pdf 7. Beyond box-ticking: safe and efficient jack-up operations - DNV, https://www.dnv.com/article/beyond-box-ticking-safe-and-efficient-jack-up-operations-49148/ 8. Barrier management - DNV, https://www.dnv.com/energy/topics/barrier-management/ 9. Barrier Management - American Bureau of Shipping, https://ww2.eagle.org/en/Products-and-Services/offshore-energy/exploration/Barrier-Management-Advisory.html 10. The bowtie method - Barrier Based Risk Management Knowledge base - Wolters Kluwer, https://www.wolterskluwer.com/en/solutions/enablon/bowtie/expert-insights/barrier-based-risk-management-knowledge-base/the-bowtie-method 11. 5 Steps to Create a Comprehensive Bow Tie Analysis | Prometheus Group, https://www.prometheusgroup.com/resources/posts/5-steps-to-create-a-comprehensive-bow-tie-analysis 12. Jackup Rig Accident Personal Injury Attorneys - BoatLaw, LLP, https://www.boatlaw.com/types-of-accidents/jackup-rig-accidents/ 13. Manage risk of damage to grating systems (walkways and deck ..., https://www.hse.gov.uk/safetybulletins/grating-systems.htm 14. Marine Safety Forum – Safety Flash 15-18, https://www.imca-int.com/media/hwsnwauu/msf-safety-flash-15-18.pdf 15. Site Specific Assessment of Jack-up Rigs - Zentech Inc, https://www.zentech-usa.com/post/site-specific-assessment-of-jack-up-rigs 16. Jack-up and geotechnical engineering - DNV, https://www.dnv.com/services/jack-up-and-geotechnical-engineering-9466/ 17. www.bsee.gov, https://www.bsee.gov/sites/bsee.gov/files/notices-to-lessees-ntl/hurricanes/ntl2008-g10.pdf 18. Jackup Moving (Oilfield Seamanship Series, Volume 2) - 2nd Edition ..., https://shop.witherbys.com/jack-up-moving-2nd-edition-oilfield-seamanship-series/ 19. www.iadc.org, https://www.iadc.org/wp-content/uploads/2015/04/rr049-Review-of-the-Jack-Ups_-Safety-in-Transit.pdf 20. Jack-Up Rig Safe Handling Procedure - Elite Offshore Academy, https://eliteoffshore.com/jack-up-rig-safe-handling-procedure/ 21. Risk of collision with offshore installations from attendant vessels - HSE, https://www.hse.gov.uk/safetybulletins/risk-collision-offshore-installations-attendant-vessels.htm 22. UK regulator says too many vessels risk collision with offshore installations - Rivieramm, https://www.rivieramm.com/news-content-hub/uk-regulator-says-too-many-vessels-risk-collision-with-offshore-installations-84198 23. general ocean tow recommendations for jackup drilling units, https://iadc.org/wp-content/uploads/2015/04/ocean-tow-guidelines.pdf 24. @ECRTD-UK: https://www.eajournals.org/ Enabling Formal Safety Assessment Method in Jack-Up Rig Operations, https://www.eajournals.org/wp-content/uploads/Enabling-Formal-Safety-Assessment-Method-in-Jack-Up-Rig-Operations.pdf 25. Rig Move Risk Assessment | PDF | Geotechnical Engineering - Scribd, https://www.scribd.com/doc/118926343/Rig-move-risk-assessment 26. OTC-6125

On-Bottom Stability of Jackups, 1989 - Stewart Technology Associates, https://stewart-usa.com/wp-content/uploads/2018/10/OTC-6125-On-Bottom-Stability-of-Jackups-1989.pdf 27. Jack-up barge punches through sandy bottom - Itic-insure.com, https://www.itic-insure.com/our-publications/the-wire/jack-up-barge-punches-through-sandy-bottom-158872/ 28. Back Analyses of Jack-up Rig Penetration for Punch Through Case - ResearchGate, https://www.researchgate.net/publication/344106414_Back_Analyses_of_Jack-up_Rig_Penetration_for_Punch_Through_Case 29. Functional requirements for stability of jack up drilling rigs on working position, https://www.researchgate.net/publication/26594532_Functional_requirements_for_stability_of_jack_up_drilling_rigs_on_working_position 30. Soil-Structure Interaction During Preloading of Jackup MODU's in Different Soil Conditions, https://www.jurispro.com/files/articles/devoy-soil.pdf 31. IADC/SPE 88001 Jack-Up Mobilization in a Complex ... - OnePetro, https://onepetro.org/SPEAPDT/proceedings-pdf/04APDT/04APDT/4078607/spe-88001-ms.pdf 32. operation with jack-up, https://www.ugtu.net/sites/default/files/ukh_08_j5_a3_offshore_drilling_with_ju_32s_22_10_14.pdf 33. Jack Up Unit Location Assessment | PDF | Risk | Geotechnical Engineering - Scribd, https://www.scribd.com/document/685889671/Jack-Up-Unit-Location-Assessment 34. Jack-Up Preloading Procedure - Elite Offshore Academy, https://eliteoffshore.com/jack-up-preloading-procedure/ 35. (PDF) GENERAL GUIDANCE FOR THE DESIGN, FABRICATION ..., https://www.researchgate.net/publication/322583136_GENERAL_GUIDANCE_FOR_THE_DESIGN_FABRICATION_AND_INSTALLATION_OF_JACK-UP_PLATFORMS 36. Offshore Rig Moving Engineering & Consultancy | ABL Group, https://abl-group.com/abl/loss-prevention/marine-warranty-survey/mws-rig-moving/ 37. Jack Up Guidelines | PDF | Water Transport - Scribd, https://www.scribd.com/document/128176892/Jack-Up-Guidelines 38. Guidelines For Site Specific Assessments of Jack-Ups | PDF | Insurance - Scribd, https://www.scribd.com/document/360836818/Guidelines-for-Site-Specific-Assessments-of-Jack-ups 39. Factors influencing the correct positioning of offshore jack up rigs - ResearchGate, https://www.researchgate.net/publication/343224783_Factors_influencing_the_correct_positioning_of_offshore_jack_up_rigs 40. Preloading | Oil and Gas Drilling Glossary | IADCLexicon.org, https://iadclexicon.org/preloading/ 41. JACK UP UNITS - PCA-CPA, https://files.pca-cpa.org/pcadocs/2017-06/2.%20Ukraine%20-%20Revised%20Memorial%20-%20Exhibits/2.%20Ukraine%20-%20Revised%20Memorial%20-%20Exhibits/UA-791.pdf 42. Pre-spud Checklist # 1 - DrillingForGas, https://www.drillingforgas.com/en/checklists/pre-spud/pre-spud-checklist-1 43. Jack-Up Drilling Units - IADC, https://iadc.org/wp-content/uploads/SFEL_Jack-Up_for-web.pdf 44. Department Pre Rig Move Checklists | PDF | Crane (Machine ..., https://www.scribd.com/document/175699930/Department-Pre-Rig-Move-Checklists 45. RPD System – SMEC Oil & Gas, https://smecoilandgas.com/rpd-system 46. Jack-up vessel preload reliability study - TU Delft Repository, https://repository.tudelft.nl/file/File_a18c35af-0783-4f58-aa20-3b80abb93016 47. 7 Common Jack-Up Rig Accidents and How To Prevent Them - Jones Act Lawyer, https://www.jonesact.com/blog/7-common-jack-up-rig-accidents-and-what-drilling-companies-should-do-to-prevent-them/ 48. Jacking Systems | PDF | Buoyancy | Fatigue (Material) - Scribd, https://www.scribd.com/document/708592589/Jacking-Systems-2 49. Industrial Vehicle Guide:

Helping to Ensure Safety and Efficiency During Rig Moves, https://www.hpinc.com/industrial-vehicle-guide-helping-to-ensure-safety-and-efficiency-during-rig-moves?__hstc=51891126.73bd3bee6fa385653ecd7c9674ba06f0.1741132800262.1741132800263.1741132800264.1&__hssc=51891126.1.1741132800265&__hsfp=79048079 50. Human performance | IOGP, https://www.iogp.org/workstreams/safety/safety/human-performance/ 51. Well control | IOGP, https://www.iogp.org/workstreams/safety/well-control/ 52. Getting to Grips with Human Factors in Drilling Operations | Request PDF - ResearchGate, https://www.researchgate.net/publication/295087719_Getting_to_Grips_with_Human_Factors_in_Drilling_Operations 53. Enabling Formal Safety Assessment Method in Jack-Up Rig Operations - R Discovery, https://discovery.researcher.life/download/article/8e20d707026938eba311221241904376/full-text 54. Lifting and hoisting safety | IOGP, https://www.iogp.org/workstreams/safety/safety/lifting-and-hoisting-safety/ 55. IOGP Life Saving Rules for Oil & Gas Safety | EcoOnline US, https://www.ecoonline.com/en-us/blog/the-iogp-life-saving-rules-for-safety-in-the-oil-and-gas-industry/ 56. International Association of Drilling Contractors North Sea Chapter HUMAN FACTORS Guidance on MODU/MOU Safety Case Content, https://iadc.org/wp-content/uploads/2019/07/Human-Factors-Guidance-on-MODU-MOU-Safety-Case-Content.pdf 57. SPE-187241-MS Integrating Human Factors into Petroleum Engineering's Curriculum: Essential Training for Students - OnePetro, https://onepetro.org/SPEATCE/proceedings-pdf/17ATCE/17ATCE/D021S011R002/3927532/spe-187241-ms.pdf/1 58. IADC WellSharp Plus - International Association of Drilling Contractors, https://iadc.org/accreditation/wellsharp-plus/ 59. (PDF) How Can the Petroleum Industry Benefit From Human Reliability Analysis? - ResearchGate, https://www.researchgate.net/publication/267459480_How_Can_the_Petroleum_Industry_Benefit_From_Human_Reliability_Analysis 60. The human factor – cost-effective safety critical task analysis - Risktec, https://risktec.tuv.com/knowledge-bank/the-human-factor-cost-effective-safety-critical-task-analysis/ 61. ANCHOR HANDLING MANUAL - Marine Safety Forum, https://www.marinesafetyforum.org/wp-content/uploads/2018/08/Anchor-Handling-Manual-Template-MSF-Rev01a-Oct15.doc 62. The human element in maritime operations - DNV, https://www.dnv.com/services/the-human-element-in-maritime-operations-245177/ 63. Guide for Dynamic Positioning Systems - American Bureau of Shipping, https://ww2.eagle.org/content/dam/eagle/rules-and-guides/current/other/191-guide-for-dynamic-positioning-systems-2024/191-dps-guide-feb24.pdf 64. On Linking of Task Analysis in the HRA Procedure: The Case of HRA in Offshore Drilling Activities - MDPI, https://www.mdpi.com/2313-576X/4/3/39 65. Fabrication site construction safety practices project - IOGP, https://www.iogp.org/workstreams/safety/safety/construction/ 66. Pre Loading Checklist Form Template - Jotform, https://www.jotform.com/form-templates/pre-loading-checklist 67. Checklists - DrillingForGas, https://www.drillingforgas.com/en/?view=category&id=143 68. Pre Job Safety Meeting for Jacking Operation - YouTube, https://www.youtube.com/watch?v=EIJWnSYeEss 69. Rig Move & Installation Procedure | PDF | Geotechnical Engineering - Scribd, https://www.scribd.com/document/805916397/Rig-Move-Installation-Procedure 70. Jack-Up (Self-Elevating) Installations: Floating Damage Stability Survivability Criterion - IOGP Safety Zone, https://safetyzone.iogp.org/safetyalerts/alerts/Detail.asp?alert_id=49 71. Offshore Information Sheet No 6/2007 - Jack-up (self-elevating) installations: floating damage stability survivability criterion - International Association of Drilling Contractors, https://iadc.org/wp-content/uploads/2015/04/Jack-up-Installations-Floating-Damage-Stability.pdf 72. Review of the Jack-Ups - International Association of Drilling Contractors, https://iadc.org/wp-content/uploads/2015/04/rr049-Review-of-the-Jack-Ups_-Safety-in-Transit.pdf 73. Jackup Rigs Analysis and Design | PDF | Offshore Drilling - Scribd, https://www.scribd.com/document/338636853/Jackup-Rigs-Analysis-and-Design 74. A Case Study on the Corrosion of an Aging Jack-Up Drilling Rig - MDPI, https://www.mdpi.com/2077-1312/13/3/495 75. Part III – Subdivision, Stability and Freeboard – July 2024 - PRS, https://prs.pl/wp-content/uploads/modu_p3.pdf 76. DRILLSHIP MAXVCG AND STABILITY CALCULATION - Ship Design, https://www.mermaid-consultants.com/drillship-maxvcg-and-stability-calculation.html 77. Jack-Up Rig Accident Lawyers | Arnold & Itkin - Offshore Injury Attorneys, https://www.offshoreinjuryfirm.com/offshore-injuries/jack-up-rig-accidents/ 78. Cathodic Protection of Jack-up Rigs - Havtil, https://www.havtil.no/contentassets/29e2662209804c23870d29941032717f/cathodic-protection-of-jack-up-rigs.pdf 79. Rigging Up/Down - IADC.org - International Association of Drilling Contractors, https://iadc.org/safety-meeting-topics/rigging-updown/ 80. Idc 37 Rig Move Plan | PDF - Scribd, https://www.scribd.com/document/601786897/IDC-37-RIG-MOVE-PLAN 81. annual report - 2016 2017 - NOPSEMA, https://www.nopsema.gov.au/sites/default/files/documents/2021-07/Report%20-%20NOPSEMA%20Annual%20Report%202016-17%20-%20Web%20version.pdf 82. NOPSEMA - Annual Report 2017–18, https://www.nopsema.gov.au/sites/default/files/documents/2021-03/A638600.pdf 83. Drilling and well - DNV, https://www.dnv.com/energy/services/subsea-facilities/drilling-and-well/ 84. DNVGL_ST_N0001 FULL.pdf - SlideShare, https://www.slideshare.net/slideshow/dnvglstn0001-fullpdf/260209265 85. DNV-RP-C104: Self-elevating Units - HVL, https://home.hvl.no/ansatte/gste/ftp/MarinLab_files/Litteratur/DNV/DNV_p10.pdf 86. ISO 19905-1:2023 - Jack-ups - Standards New Zealand, https://www.standards.govt.nz/shop/iso-19905-12023 87. What is Marine Warranty Survey? - Virtue Marine, https://www.virtuemarine.nl/post/what-is-marine-warranty-survey 88. Marine Warranty Survey (MWS) | World-Leading Surveyors - ABL Group, https://abl-group.com/abl/loss-prevention/marine-warranty-survey/ 89. Guidelines for marine lifting operation noble denton | PDF - SlideShare, https://www.slideshare.net/slideshow/guidelines-for-marine-lifting-operation-noble-denton/12972481 90. Safety case content and level of detail - NOPSEMA, https://www.nopsema.gov.au/sites/default/files/documents/Safety%20Case%20Guidance%20revised.pdf 91. A NNU A L REPORT 2018–19 - NOPSEMA, https://www.nopsema.gov.au/sites/default/files/documents/2021-03/A698325.pdf 92. IADC/SPE Managed Pressure Drilling & Underbalanced Operations Conference & Exhibition - IADC.org, https://iadc.org/event/iadc-spe-managed-pressure-drilling-underbalanced-operations-conference-exhibition-2/