Why Human Factors in Deep Water Drilling?

- In 2009, Gulf of Mexico
  - 316 wells drilled
  - 4 fatalities
  - 285 injuries
  - 133 fires or explosions
  - 11 spills of more than 50 barrels of oil

- In 2010, Macondo disaster

- Human error and human factors are contributing causes in over 50% of well control incidents
  - Cognitive errors and wrong actions
  - Communication failures
  - Excessive workload
  - Poor management practices
  - Poor information availability and presentation
  - Slow detection and response to kicks

(based on SINTEF data)
Human Factors Contributes to Over 50% of Incidents

SINTEF Data 2011
Over-Reliance on Procedures

- Focus on procedures
  - Developed prospectively to enhance safety
  - Applied retrospectively from incident analyses

- Drawbacks of procedures
  - Variations between installations – confusion, misapplication
  - Situations that lie outside of procedures – needs for reasoning
  - Script-following and confirmation bias – need for critical thinking

- So called “Human error / procedure violations” do not address, or even point to, where the underlying problems lie
  - Information overload
  - Situation uncertainty
  - Communication
  - Risk management and goal trade-offs
About Pacific Science & Engineering Group

From the lab… …to the user

- PSE develops innovative solutions that improve human performance in complex, high-consequence systems based on scientific principles and methods
  - Military command and control, industrial control rooms and operational workflows, supervisory control & automation, medical devices & health systems

- About 30 technical staff
  - Multi-disciplinary teams identified to meet the unique needs of each project
  - Professional licenses, certifications, and leadership in technical societies
  - Numerous professional awards and team recognitions from clients
About HTK International, L.C.

- HTKI provides operations consulting, petroleum engineering and skilled well site supervision around the globe.
- HTKI has successfully executed projects in over 25 countries and has over 60 years combined experience in drilling management worldwide consistently delivering top quartile results by offering innovative ideas, deploying the best available technology and utilizing top quality service providers.
- We use the right people with the right experience to bring you the right results.
Trident Project Objectives

- Develop a consistent method for identifying human factors issues in deepwater drilling
- Develop a database of human factors issues in well control
- Identify trends across incidents
- Provide a living repository of issues, incidents, and research literature
- Develop value from the database
  - Audit tools
  - Reporting schemes
  - Mitigations for high frequency human factors issues
Trident Value Proposition

Drilling Timeline

Plan  Implementation  Execution  Incident Investigation

Pre-Incident Audit Tool

Trident-Based Solutions
- Response Planner/Manager
- Handover/Shift Change Tool
  - Drillers’ Instructions
  - Real-Time Collaboration Tools

Post-Incident Investigation Tool

Trident Database
The insight for our Approach: Combine Risk Management and Human Factors

Risk Management
- Threats and barriers to influx and blow out
- Methods for implementing, maintaining, and verifying barriers

Risk Management “Bowtie”

Human Factors
- Decision cycle stages
- Socio-technical organizational structures and processes
- User goal trade-offs between efficiency and thoroughness

Decision Cycle
- Detect
- Interpret
- Decide
- Act

Prevention  Recovery
Our Approach:
1. Identify human factors “barriers”

- **Physical “containment” barriers**
  - Well control barriers that prevent the release of hydrocarbons, e.g. mud column, annular preventer

- **Technical, procedural, and organizational barriers**
  - Subordinate well control barriers that “shape” the performance of the containment barriers, e.g.
    - Design, maintenance, procedural steps for correct use, change management

- **Human factors barriers**
  - Subordinate well control barriers that “shape” the performance of containment barriers and that are influenced significantly by human factors considerations
    - Decision support for diagnosing well conditions
    - Intuitive controls for operating the BOP or recirculation processes
    - Training and drills/practice

- All barriers are good; they are barriers to threats and consequences due to a loss of well control
“Human Factors Barriers”? 

- **Strict engineering definition of a barrier**
  - IADC: “Well barrier: Envelope of one or several dependent barrier elements preventing fluids or gases from flowing unintentionally from the formation into another formation or to the surface”
  - Norsk Oil and Gas: “If the primary well barrier is functioning as intended, it will be able to contain the pressurized hydrocarbons”

- **Broad risk management definition of a barrier**
  - IOGP: “Critical human tasks are defined as those activities people are expected to perform as barriers against the occurrence of an incident, or to prevent escalation in the event an incident does occur. They include activities required to support or maintain physical and technological barriers”
  - IOGP: “Review HF barriers and controls”
  - Energy Institute: “Barriers: may be physical barriers: fences, guards, bunds, protective clothing, safety devices or 'administrative' barriers – checking procedures, permits-to-work, supervision.”
Human Factors Barriers for Kick Detection

- **Detect**
  - Sensors for aiding situation awareness? Displays? Vigilance?

- **Interpret**

- **Decide**
  - Collaboration? Authority?

- **Act**
  - Controls? Timing? Feedback?

- **Total**
  - 117 Human factors barriers for kick detection
  - Many replicated across different user roles
Each major branch of the bowtie (threats and consequences) can be organized into component topics:

- Critical decision
  - Detect, Interpret, Decide, Act
- Training and certifications
- Maintenance and inspection
- Planning
- Equipment
Consistent and thorough analysis of human factors issues throughout the well control bowtie

- Major branches
  - Threats and consequences
- Component topics
  - Decision cycle, training, maintenance, planning, equipment
- Consistent analysis within each component
Our Approach:
2. Analysis of Loss of Well Control Incidents

- **Objective**
  - Analyze incidents using the kick detection human factors barriers
  - Identify trends in weak and strong barriers

- **Identify incidents**
  - BSEE, BOEM, and other sources
  - 30 deep water incidents

- **Analysis**
  - Code incidents for presence/absence of HF barriers
  - Identify “hot spots” of frequent absences

- **Note**: incidents are not maintained as entities
  - Instead, their factors are coded and summed across incidents

- **These statistics can be used to**
  - Identify problematic factors for deeper investigation
  - Develop better risk management processes
Incidents in the Database

The majority of incidents are recent.
Example of Incident Coding

- “At this time, the trip tank was full, and it was emptied into the active system. During this operation, two stands of drill pipe accidentally fell out of the racking fingers and across the drill floor. The driller assisted the drill crew in replacing the pipe into position. At about 2145 hours, after the pipe was back in position, the driller was proceeding into the doghouse when he noticed that the trip tank was filling rapidly. He ran in one more stand and asked the mud man and assistant driller to verify that the flow was not coming from the mud pumps.”

<table>
<thead>
<tr>
<th>Human Factors Barrier</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vigilant and not physically distracted</td>
<td>Absent</td>
</tr>
<tr>
<td>Vigilant and not mentally distracted</td>
<td>Present</td>
</tr>
<tr>
<td>Detected kick early</td>
<td>Absent</td>
</tr>
<tr>
<td>Shut in the well early</td>
<td>Absent</td>
</tr>
<tr>
<td>Raised the issue early</td>
<td>Absent</td>
</tr>
<tr>
<td>Raised the issue late</td>
<td>Present</td>
</tr>
<tr>
<td>Investigated the issue early</td>
<td>Absent</td>
</tr>
<tr>
<td>Investigated the issue late</td>
<td>Present</td>
</tr>
</tbody>
</table>
Frequently Absent Human Factors Barriers

- **Detect**
  - PVT and pressure sensors are implemented throughout the system – for good SA
    - 14/30 absent
  - Vigilant and not overconfident in barriers
    - 10/30 absent
  - Evidence of an influx detected early
    - 15/30 absent

- **Interpret**
  - Multiple explanations considered early
    - 10/30 absent

- **Decide**
  - Raised issue to the team early
    - 14/30 absent
  - Correctly calibrated confidence in barriers – User not overconfident of barriers
    - 18/30 absent

- **Act**
  - Well shut in prior to discussion with team members
    - 13/30 absent
  - Evidence of an influx investigated early
    - 15/30 absent
  - Well shut in early
    - 22/30 absent
Major Themes

- Poor communication of risks
  - E.g. Tool pusher did not know accumulator lines were detached from BOP
  - E.g. Did not know that insufficient mud was aboard to kill a kick
  - Potential solutions: Better handoffs, daily meetings, usage of onshore monitoring

- Delayed response to kick or influx
  - E.g. Waiting to shut in the well until investigations were complete
  - E.g. Delay in detecting PVT anomaly
  - Potential solutions: Better data presentations, better diagnosis support

- Poor efficiency/thoroughness trade-off decisions (ETTO)
  - E.g. insufficient follow-up on anomalous cementing test results;
  - E.g. failure to install or check for installation of by-pass valves;
  - E.g. failure to check pressures prior to removing a barrier
  - Potential solutions: Better understanding of when and where efficiency is appropriate, better risk management processes

- Insufficient sensors to support situation awareness
  - E.g. lack of pressure sensor under BOP ram led to failure to detect gas bubble
  - Potential solutions: Better sensing
Incident Analysis Conclusions

- Major themes are not too surprising
  - Good thing – means the analysis makes sense

- Underscores the importance of high frequency HF issues
  - Communication
  - Decision making
  - Thoroughness-Efficiency trade-offs (corner cutting)
  - Sensors for situation awareness

- Leverage
  - Frequently absent human factors barriers are good places to focus further efforts:
    - Audits and reviews
    - Mitigation projects
Our Approach:
Summary: Steps in Trident Development

TRIDENT DEVELOPMENT PROCESS

- **Human Factors (HF)** barriers are identified within well control bowties.
- **Performance-shaping & Decision-shaping Factors** are identified within the HF barriers.
- **Incidents** are analyzed against the HF barriers and trends are identified.
- **Research** literature is mapped into the database.
- **Feedback** refines each step.

**TRIDENT DATABASE**
(interactive, integrated, searchable)

**WELL CONTROL BOWTIES**
(defined & identified)

**HUMAN FACTOR BARRIERS**
(Barriers that are influenced significantly by Human Factors)

**HUMAN FACTOR RESEARCH**
(literature, key words)

**PERFORMANCE SHAPING FACTORS**
Factors that influence human performance

**HUMAN FACTORS**
- **DETECT**
- **INTERPRET**
- **DECIDE**
- **ACT**

**DECISION LOOP**
Factors that affect decision making in well control

**ANALYZE**
(identify trends/themes)

**CODE**
(presence of decision shaping factors)

**WELL CONTROL INCIDENTS**
(collected)

**OIL & GAS INFORMATION**

**HUMAN FACTOR INFORMATION**

**TRIDENT INFORMATION**
Value Proposition – Leveraging the Results of the Human Factors Barriers Incident Analysis

Drilling Timeline

Plan

Implementation

Execution

Incident Investigation

Pre-Incident Audit Tool

Trident-Based Solutions
  • Response Planner/Manager
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Post-Incident Investigation Tool

Trident Database
Phase 1 Deliverables

- Report of project development and findings
  - OTC-15 conference paper and presentation
- Database of human factors barriers
  - Bowtie of threats and barriers with human factors barriers identified
  - Criticality ratings of barriers for human factors consequence and involvement
  - Literature mapped to human factors barriers
- Analysis of incidents in terms of human factors barriers
  - Identification of trends – both strong and weak human factors barriers
  - Demonstration of approach using Macondo
- Value proposition and strategy for phase 2
  - Audit tool
  - Incident investigation tool
  - Demonstration projects – Trident-based solutions
Phase 1 Completion

- Relax deep water criterion to include more public incidents
  - There are many more BSEE/BOEM incidents if we include more shallow water incidents (currently set at >500 ft.)

- Revise human factors barriers
  - Version 2.0

- Re-analyze all incidents for strong and weak human factors barriers
Proposed Phase 2 Work

- Extend the Trident analysis methodology developed in phase 1 to additional well control threats and consequences (task 8: factors and mitigations)
- Develop a prototype solution to a common human factors issue identified during phase 1 (task 8: factors and mitigations)
- Add new incident data to the Trident database (task 9: tool development)
- Refine the Trident database for use as a review and audit tool (task 9: tool development)

- 12 months, beginning in May 2015
Trident-Based Solutions

- Decision support tools
  - Response planning and management
  - Supervision and change awareness dashboards
  - Complex, team situation awareness

- Human-system integration
  - User interface usability
  - User-task workflow
  - System performance assessment

- Scientifically-principled design
  - Department of Defense and process control experience
Map and numerous decision support tools to aid in the monitoring of an air space and the evaluation of potentially threatening aircraft
Response Planner and Manager for Air Warfare - Adaptable to Well Control

- Decision support for managing responses to threatening aircraft
  - Diagnosis
    - What to do to decide?
    - What to do if it’s a threat?
    - What to do if it’s a non-threat?
  - What has been done?
    And when?
  - What to do next?

Top section shows actions for commercial air. Bottom section shows actions for threats. The X-axis indicates distance from own ship and when actions are appropriate. The yellow bars indicate which section is appropriate for the situation – in this case, both. Grayed out actions have been taken. Times indicate how long ago an action was taken. Amplifying details about the aircraft are available elsewhere.
Supervision and Change Awareness Dashboard

**Approach**
- Identify operator information requirements by user role
- Identify information feeds and design Janus architecture
- Develop, deliver, and assess a functional prototype (TRL 7)

**Problem**
- Huge number of systems and displays to monitor
- Different user roles need different data

**Objectives**
- Identify and present key system information to operators from fused system data
- Provide drill-down access to primary displays

**Transition customers**
- US Navy communications managers
- US Navy command and control
- Industrial process control manufacturer
Questions?
Response Planner and Manager for Kicks

Watch altitude, verify within air corridor: 1:45
Verify territorial waters: 1:00
Minimize RCS/IRCS: 5:00

Level I warning: 0:30
CIWS to auto / ready self-defense systems
Level II warning
Cover
Execute EW packages: 0:50
Level III warning
Illuminate
Report to senior
Alert stinger detachment
Deploy decoys
Fire flares / warning shot
Engage / do not engage decision
Dashboard Tool for Key Drilling Information

- Title bar
- Key Indicators
- Illustration
- Timeline illustration
- Tool bar
Summary of Kick Detection Decision Barriers, 1 of 2

- **Detect: anomalies are detected quickly**
  - PVT and other sensor data
    - Well control anomaly is detected in a timely manner
    - PVT sensor suite is maintained and active
    - PVT sensor suite maintenance status is understood by users
    - PVT data displays are maintained, active, and available for the looking to users
    - Camera feeds from key system components are maintained and available to users
    - Set point alerts on the PVT system are active and presented effectively
  - Vigilance
    - Users are not distracted by events, thoughts, or shift changes
    - Users are not fatigued and fit for duty
    - Users are not overconfident, but actively vigilant for anomalies
  - Anomaly detection
    - Anomalies are detected early (less than 5 barrels gained), late (less than 20 barrels gained), or not detected

- **Interpret: anomaly data is interpreted and diagnosed**
  - Information representation
    - Net flow is represented effectively
    - Potential confounds are represented and accounted for
    - Models of flow are available for effective comparison against reality
    - Trends and changes are represented effectively
  - Training
    - Users are adequately trained to interpret and diagnose situations
  - Critical thinking
    - Critical background information about drilling conditions and prior kicks are known to the users
    - Critical background information about system status (including integrity tests) are known to the users
    - Support for considering multiple alternative explanations is provided
    - Multiple explanations are considered early
    - Anomalies are not dismissed without good reason
Summary of Kick Detection Decision Barriers, 2 of 2

- **Decide**: process of coming to a team decision
  - Users raised anomaly issues to others early (less than 5 barrels gained), late (less than 20 barrels gained), or not raised
  - Users had accurate confidence in existing physical barriers
  - Users were included in diagnosis discussion early, including drilling supervisor and onshore support

- **Act**: shut in the well and investigated the situation
  - Decision process and authority to act is clear and understood
  - Well is shut in prior to investigation of the situation
  - Well is shut in early (less than 5 barrels gained), late (less than 20 barrels gained), or not shut in
  - Flows and pressures are checked effectively
  - False alarms do not lead to complacence and are considered for their implications to the situation and drilling process
Detect (48 barriers)

- PVT and pressure sensors
  - Barrier: PVT and pressure sensors are implemented throughout the system
  - Barrier: PVT and pressure sensors are operational early (< 5 barrels gained)
  - Barrier: PVT and pressure sensors are operational late (< 20 barrels gained)
  - Barrier: PVT and pressure sensors are maintained

- Data displayed to users
  - PVT and pressure sensor data display are available to the user
    - 5 barriers: Driller, mud logger, company man, on shore center, any front line team member
  - PVT and pressure sensor data display are maintained
    - 5 barriers: Driller, mud logger, company man, on shore center, any front line team member

- PVT and pressure sensor data are presented clearly
  - 5 barriers: Driller, mud logger, company man, on shore center, any front line team member

- Visual inspection of the separator and pits are available to the user for the looking
  - Note: The user has a view of the separator and pits from his current location without having to move to another room (may be a direct view, camera or other technology)
  - 5 barriers: Driller, mud logger, company man, on shore center, any front line team member

- Alerts are provided to notify users of pit gains
  - 5 barriers: Driller, mud logger, company man, on shore center, any front line team member
Detect (48 barriers)

- **Vigilance**
  - User is not physically distracted
    - Note: The user is not distracted by some physical event, such as falling pipe or a person; the user is not physically away from the workstation
    - 5 barriers: Driller, mud logger, company man, on shore center, any front line team member
  - User is not pre-occupied
    - Note: The user is not mentally preoccupied by personal issues
    - 5 barriers: Driller, mud logger, company man, on shore center, any front line team member
  - User is not over-confident of barriers
    - Note: The user feels confident of barriers (may be false confidence) and therefore is not monitoring the situation closely - see critical thinking for misinterpretation of situation based on over-confidence
    - 5 barriers: Driller, mud logger, company man, on shore center, any front line team member

- **User is not fatigued**
  - Note: The user is not fatigued due to a long shift (end of shift) or due to taking a double shift
  - 5 barriers: Driller, mud logger, company man, on shore center, any front line team member

- **Detection timing**
  - Barrier: Indication of a reservoir influx detected early
    - Note: Evidence of the kick was detected prior to 5 barrels of influx (could be a pit gain or other indicator)
  - Barrier: Indication of a reservoir influx detected late
    - Note: Evidence of the kick was detected prior to 20 barrels of influx (could be a pit gain or other indicator)
  - Barrier: Indication of a reservoir influx detected very late
    - Note: Blow out; not truly a barrier, but good information to capture
Interpret (39 barriers)

- Effective representations were available to the user
  - Net flow available
    - Note: A measure of net flow was available to the user
    - 5 barriers: Driller, mud logger, company man, on shore center, any front line team member
  - Outside factors in net flow available
    - Note: Outside factors that affect net flow, e.g. heave, crane, mode of operation, tripping, mud weight change are available to the user and/or taken into account in computations of net flow
    - 5 barriers: Driller, mud logger, company man, on shore center, any front line team member

- Fingerprinting of connection flows available to the mud logger
  - Barrier: Fingerprinting of connection flows available to the mud logger

- Change and trend awareness available
  - Note: Trends in variables, such as pressure and mud weight, are represented, and significant changes are highlighted. Multiple grain sizes of trend data are available, e.g. 5 second data and 1 second data
  - 5 barriers: Driller, mud logger, company man, on shore center, any front line team member

- Training
  - Note: The user is trained in the use of the display and how to interpret the data
  - 5 barriers: Driller, mud logger, company man, on shore center, any front line team member
Interpret (39 barriers)

- Relevant background information is available: formation, drilling status, well conditions, and tests
  - 5 barriers: Driller, mud logger, company man, on shore center, any front line team member

- Support for critical thinking
  - Multiple explanations considered early
    - Note: Regardless of when/if the well was shut in, the user considered multiple explanations for the indication of a reservoir influx or situation, early (less than 5 barrels of influx)
    - Barrier: Multiple explanations considered early by any frontline team member
  - Multiple explanations considered late
    - Note: Regardless of when/if the well was shut in, the user considered multiple explanations for the indication of a reservoir influx or situation, late (less than 20 barrels of influx)
    - Barrier: Multiple explanations considered late by any frontline team member

- Anomaly not dismissed
  - Note: The anomaly was not dismissed as “normal” phenomena, such as u-tubing, breathing, ballooning
  - Barrier: Anomaly not dismissed by the frontline team

- Alternative explanation support
  - Note: The user has display support for considering alternative explanations of data and conditions. For example, a display allowed the user to compare the current data against signature data for multiple alternatives, such as kicks, u-tubing, ballooning
  - 5 barriers: Driller, mud logger, company man, on shore center, any front line team member

- Training on critical thinking
  - Note: The user was trained how to conduct critical thinking and on how to use any critical thinking support displays
  - 5 barriers: Driller, mud logger, company man, on shore center, any front line team member
Decide (15 barriers)

- User raised issue early
  - Note: Regardless of when/if the well was shut in, the user raised the issue to the decision-making team PRIOR to five barrels of influx
  - Barrier: Any frontline team member raised issue early

- User raised issue late
  - Note: Regardless of when/if the well was shut in, the user raised the issue to the decision-making team PRIOR to twenty barrels of influx
  - Barrier: Any frontline team member raised issue late

- Correct confidence in barriers
  - Note: The user has the correct confidence in the status of barriers and behaves accordingly in terms of critical thinking, investigation, and decision making, such as an early decision to shut in the well if there are indications that some barriers are weak
  - Barrier: The team had correct confidence in barriers

- User was included in discussions early
  - Note: Regardless of when/if the well was shut in, the user was included in discussion of the indication of a reservoir influx or situation PRIOR TO FIVE BARRELS of influx so that this user’s perspective could be taken into account for critical thinking, investigation, and decision making
  - 5 barriers: Driller, mud logger, company man, on shore center, any front line team member

- User was included in discussions late
  - Note: Regardless of when/if the well was shut in, the user was included in discussion of the indication of a reservoir influx or situation prior to twenty barrels of influx so that this user’s perspective could be taken into account for critical thinking, investigation, and decision making
  - 5 barriers: Driller, mud logger, company man, on shore center, any front line team member

- Distributed decision making
  - 5 barriers: Driller, mud logger, company man, on shore center, any front line team member
Act (15 barriers)

- Decision process and authority is clear
  - Authority to shut in the well is understood
    - Note: The process for deciding to shut in the well, as well as other decisions regarding an anomaly or situation, is clear; user knows whether he/she has authority to act
    - 5 barriers: Driller, mud logger, company man, on shore center, any front line team member
  - Driller shut in the well prior to discussion with others
    - Barrier: Driller shut in the well prior to discussion with others

- Investigated the situation early
  - Conduct pressure tests
    - Barrier: team member conducted pressure tests early
      - Note: Driller or other front line team member shut in the well, turned off pumps, and checked PRESSURES prior to five barrels of influx
  - Flow check
    - Barrier: Team member checked flow early
      - Note: Regardless of when/if the well was shut in, the Driller or other front line team member turned off pumps and checked for continuing flow prior to five barrels of influx
  - Visually inspect pits
    - Barrier: team member visually inspected the pits early
      - Note: Regardless of when/if the well was shut in, the Driller or other front line team member visually inspected the pits for faulty sensors or other issues with the tank system prior to five barrels of influx
Act (15 barriers)

- Investigated the situation late
  - Conduct pressure tests
    - Barrier: team member conducted pressure tests late
      - Note: Driller or other front line team member shut in the well, turned off pumps, and checked PRESSURES prior to 20 barrels of influx
  - Flow check
    - Barrier: Team member checked flow late
      - Note: Regardless of when/if the well was shut in, the Driller or other front line team member turned off pumps and checked for continuing flow prior to 20 barrels of influx

- Visually inspect pits
  - Barrier: team member visually inspected the pits late
    - Note: Regardless of when/if the well was shut in, the Driller or other front line team member visually inspected the pits for faulty sensors or other issues with the tank system prior to 20 barrels of influx

- Well shut in
  - Barrier: Well shut in early
    - Note: The well was shut in prior to five barrels of influx
  - Barrier: Well shut in late
    - Note: The well was shut in prior to 20 barrels of influx
  - Barrier: blow out
    - Note: not a barrier, but useful data