REAL TIME MONITORING

Recommended Best Practices for Offshore Well Construction
1. Introductions
2. Why RTM – Case for Action
3. Clarification on OESI Report
4. What is the Central Purpose of RTM?
5. What Minimum Requirements Serve that Central Purpose?
   1. Pressure Testing Practices
6. Examples
8. Questions
PhD in Chemical Physics

20+ Years with Royal Dutch Shell
- 2003 – 2012 Global Team Lead for Real Time Operations Centers (RTOC)
- Built global network of RTOC hubs and satellites, incl. RTOC Houston
- Built DART remote directional drilling centers

5 Years with The University of Texas at Austin
- Lancaster Professor in Petroleum Engineering
- Director of RAPID (Rig Automation and Performance Improvement in Drilling) Consortium
- Co-PI of OESI

Houston Chronicle, Sept 19, 2010

"A lot of oil companies use their real-time operating centers in a passive mode, collecting data, being able to do post-mortem analysis. We use them to interact with the rig in real time to keep it actively out of trouble," said van Oort, performance improvement manager for wells at Shell Upstream America, during a tour of the company’s real-time operations center in West Houston.

While no one claims such centers could have prevented the deadly April 20 blowout at BP’s Macondo well, they are getting a closer look as oil companies face pressure regulators and the public ensure the safety of offshore drilling.

This summer, in fact, began building a 24-hour real-time operations center in its west Houston campus. Expected to be complete by year-end, it will continuously monitor all the company’s drilling and completions in the Gulf of Mexico company spokesman Darren Rea said. Others could follow suit.

Major oil companies, including Exxon Mobil Corp., Chevron Corp., and ConocoPhillips say they real-time well data to keep tabs on offshore drilling projects, especially big and costly deep-water wells. The information, collect by sensors on drilling rig and inside wells and be to land by satellites, allows...
SHELL RTOC & DART CENTERS

RTOC New Orleans (left) and DART center Houston (top)
Images from SPE 97059 and SPE 163526
UT AUSTIN RTCC & DRILLING SIMULATOR

RTCC UT Austin used for historical and real-time data analysis by students

Monitoring capability for 9 wells concurrently

Site for RTM training of BSEE staff in summer 2017
UT REAL-TIME COLLABORATION CENTER
Real-time rig-activity detection helps identify and minimize invisible lost time

Case-based reasoning study in Louisiana well basin

Drilling Unconventional Shale Wells Remotely

Evolution of Real Time Operations Monitoring: from Concept to Global Implementation Technology

Nonproductive Time (NPT) Reduction Delivered Through Effective Failure Investigations

Application of Predictive Real-Time Wellbore Stability Monitoring on a Deepwater EOR Unit

Real-Time ECD Simulation and Management Using a Remote Operations Center

EVO RTM PUBLICATIONS
INTRO—NZ

• Flow assurance planning and design for four-well lower-tertiary program in GOM

• Managed installation and commissioning of Soft Torque systems on >70 rigs

• Responsible for operations, analytics, and application development for largest drilling RTOC (148 rigs concurrent)
  • Developed software for kick detection, rig performance analytics. Tested and deployed on thousands of wells.
  • Invented new BOP and Iron Roughneck Testing Tools (SPE 178776)

• Founder—Operators Group for Data Quality and Co-Founder DSATS DQA
  • IADC is considering adopting standard contract amendment based on language developed by NZ at Chesapeake
  • IADC proposed contract language is very similar to what is proposed in OESI recommendations
CASE FOR ACTION - 1

1) Flow out greater than flow in

2) DP pressure increasing with pumps shut down

3) Increasing static pressure

Graphs & data courtesy James Pappas, RPSEA
CASE FOR ACTION - 2

Source: Deepwater Horizon Study Group
Performance-based regulatory framework

- Focus on risk-based regime
- Allow industry to determine relevant use of RTM based on levels of risk and complexity

RTM = BAST. BSEE to monitor spectrum of RTM technologies and best practices

- Use internal group (e.g. ETAC) or external group (e.g. OESI)

Involve all stakeholders in development of risk-based goals and standards for offshore oil & gas processes

- Specifically work with API, IADC, etc.

Encourage API to work with OEMs, drilling contractors, industry trade groups to establish BOP CBM pilot project

- API publication goal
WHAT THE OESI REPORT IS

It is a follow-up to the NAS study

It is a document issued by OESI, not BSEE

It is a document commissioned and paid for by BSEE

It is a document reviewed by BSEE

- BSEE changes & additions were partially included, at the discretion of OESI
WHAT THE OESI REPORT IS NOT

It is not a BSEE document

It is not a BSEE guideline or regulation

It is at BSEE’s discretion for the ultimate RTM rule-making to:

- Adopt the OESI recommendations in their entirety
- Adopt the OESI recommendations partially
- Not adopt any of the OESI recommendations
BEFORE WE GET STARTED – 1. CHARLIE’S CONCERNS

• You cannot remove ultimate authority and final decisions from the rig.
  • A: RTM is not about removing ultimate authority and final decisions from the rig. It is a tool to provide decision-makers (at the rig and elsewhere) with the information to make better decisions faster.

• When establishing RTM you must establish a team work culture and the shore base must be seen by operations as part of the team there to help them.
  • A: Agreed. This is essential if RTM is going to succeed in a company willing to adopt it.

• I do not think the regulator wants to own operations and operational liability. So not sure what they would do with actual real time data.
  • A: This is up to the regulator to decide what role they want to play & liability they want to adopt.

• Only those involved with planning and executing the well can understand and interpret the RTM data correctly. The data has no value out of context.
  • A: Here, there is a disagreement of opinion. Many data points and trends have value with limited context: an LOT test either reaches expected maximum pressure or it does not; a casing or negative test is essentially pass/fail; a pressure/flow trend (e.g. backflow on connections) can show a well either to be ballooning or kicking; the Macondo pressure trends are revealing with limited context, etc.
BEFORE WE GET STARTED — 2. CHARLIE’S CONCERNS

• The best value from RTM is the culture change and the planning, executing, the morning meetings, and debriefing the well as a team (onshore & offshore).
  • A: Agreed, again for a company willing to adopt RTM and go through the culture change

• The other best value is the way decision making changes to allow for team input. The last best value is the second set of eyes helping the operational team on the rig
  • A: A disagreement of opinion, but if adopting RTM has served the first two purposes, then tangible benefits and improvements have been achieved.

• Lastly in many situations and many well control incidents the rig is NOT drilling. So some of the RTM data is not going to be available, some cannot be available, and the “drilling” analysis cannot be used in these situations.
  • A: Cf. Macondo data: data can still be gathered, transmitted and analyzed, even when the well is not drilling

• There is still not a big data bandwidth available in many cases offshore. If it is available — many drilling data systems have failed under the weight of this data and the inability to interpret it — especially real time.
  • A: RTM in its current form is mostly about the gathering and transmission of current data, and not high-frequency data that would tax bandwidth. Data requirements can (and are currently) being met with readily available bandwidth
BEFORE WE GET STARTED — 3

• Why is RTM Required?
  • It is considered BAST and is recommended by NAS (National Academy of Science)
  • When used effectively, it can reasonably help prevent or mitigate catastrophic events

• Will RTM Replace Rig Decision Making?
  • No, RTM cannot have all information available to rig staff. It should be considered supplementary only
  • RTM enables rig staff augmentation in an efficient manner when required

• Do I need to build a RTM Center or War Room?
  • No, there is no prescribed method for HOW to manage RTM. Each organization should determine what methods best support their goals and objectives with respect to the risk inherent to each project.

• Do I need to have people watching my rigs 24/7?
  • No, that is wasteful. Most monitoring can and should be done by exception and SMEs should be called upon when needed instead of watching 24/7

• Will BSEE be big brother, always watching for mistakes?
  • We recommend that BSEE have the option to monitor as they see fit. However, to best use their resources and to minimize the burden on industry, they should manage by exception and trust the operator in most circumstances

• Does BSEE need to know EVERYTHING I’m doing?
  • No. BSEE should not be concerned with your performance, that is up to you. BSEE should only concerned with a small subset of activities and events that are reasonably related to protection of life, health, property, and the environment.
EVENTS OF INTEREST
(I.E. THINGS THAT ARE CONSIDERED CRITICAL TO LIFE, HEALTH, PROPERTY, AND THE ENVIRONMENT)

a. Wellbore Positioning
b. Blowout Preventer (BOP) Testing
c. Casing/Liner Pressure Testing
d. Formation Integrity Test (FIT)
e. Leak Off Test (LOT)
f. Positive and Negative Pressure Tests of Well Barriers
g. Cementing and Zonal Isolation
h. Drilling Margin Events
i. Station Keeping and Dynamic Positioning
EXAMPLES FROM OTHERS

Building on the foundations of people who have done this before
WHO USES RTM AND WHY?

• RTM is used by industries that can benefit from central observation and coordination and where spatial, safety, economic, or other limitations make remote monitoring ideal.

• RTM is generally required when:
  • Systems are sufficiently complex that local personnel cannot consume all information effectively
  • Information must be simultaneously and instantaneously available to numerous users
  • Systems/operations present sufficient risk to life, health, property, or the environment that adding personnel is unwise.
  • It is not reasonable or possible to increase staffing levels (i.e. space constraints)

• Examples Include:
  • Military
  • Aviation and Aerospace
  • Power Generation (particularly nuclear)
  • Public Safety
  • Infrastructure
  • Petrochemical
  • Offshore Drilling generally meets criteria that has driven RTM in other industries
REGULATOR RTM EXAMPLES

• Nuclear Regulator Commission
  • Does not provide operating instructions, only ensures safety and security

• Air Traffic Control
  • Planes are not told how to fly, they are coordinated with respect to each other and FAA rules

• Coast Guard
  • Vessels are not told how to load/unload, they are coordinated with respect to each other and maritime laws
  • Data sharing and coordination is available in case of emergency

RTM requirements do not remove responsibility at ANY level
WHAT PARADIGM IS MOST APPROPRIATE?
ADMIRAL RICKOVER’S WORDS APPLY
WHY THE OILFIELD IS LIKE THE NUCLEAR NAVY

1. Neither organization (typically) is directly involved in the manufacture of their primary good (wells or ships).
   1. Both design, and operate a finished product that they have largely no part in building.
   2. Both rely on the honesty, integrity, and capability of contractors

2. Both rely on well-trained personnel to act independently in harsh, remote locations

3. Release of stored energy (pressure and/or radiation) can have significant, negative impacts on workers and the public.
“As a guide to engineering ethics, I should like to commend to you a liberal adaptation of the injunction contained in the oath of Hippocrates that the professional man do nothing that will harm his client.

“Since engineering is a profession which affects the material basis of everyone’s life, there is almost always an unconsulted third party involved in any contact between the engineer and those who employ him — and that is the country, the people as a whole. These, too, are the engineer’s clients, albeit involuntarily.”

“Engineering ethics ought therefore to safeguard their interests most carefully. Knowing more about the public effects his work will have, the engineer ought to consider himself an “officer of the court” and keep the general interest always in mind.”

-Hyman Rickover
**THE CENTRAL PURPOSE OF RTM**

1. Ensure that, using data commonly available from RTM systems, anyone skilled in the art can reasonably recreate the observations, interpretations, and conclusions used for operational decision making.
   - Data Must be Necessary and Sufficient
   - Data Must be Reliable, True, and Transparent

2. Demonstrate the ability to plan for, detect, communicate, and act on critical events to protect life, health, property, and the environment.
   - Priority placed on action makes planning, detection, and communication vital precursors

In Other Words.....TRUST BUT VERIFY
WHAT RTM IS (AND IS NOT)

What RTM Is…
1. Structured Collection and Dissemination of Sensor Data
2. Ability to Receive and React to data, Route information and work to the right people at the right time, and Report results as necessary

What RTM Is NOT…
1. Fancy Visualizations
2. High-Cost NASA Style Command Centers
3. High-end hardware and software specific to oil and gas
4. A collection of SMEs occupying the same physical space
5. A replacement for on-site expertise—remember the gemba
MAJOR RTM COMPONENTS

1. Supply Chain Management
   - Nothing can happen effectively without rigorously defined and enforced specifications
   - Not explicitly described in the recommendations but is implicit at every step

2. Data Management
   - Sampling, Aggregation, Manipulation, Transmission, Storage

3. Analysis
   - Pressure Testing, Well Control, Cement, Wellbore Positioning, Station Keeping, Critical Systems (BOP, etc.)

4. Competency Management
   - Training, Certification, Auditing

5. Workflow Management
   - Case (Ticket) Management, Communications, Audit and Traceability

6. Cyber Security
   - There is significant cause for concern here due to DHS rules and automation
DATA MANAGEMENT

- SAMPLING
- COLLECTION
- AGGREGATION
- MANIPULATION
- TRANSMISSION
- STORAGE
“The man in charge must concern himself with details. If he does not consider them important, neither will his subordinates. Yet “the devil is in the details.” It is hard and monotonous to pay attention to seemingly minor matters. …when the details are ignored, the project fails.”

“Any one detail, followed through to its source, will usually reveal the general state of readiness of the whole organization.”

-Hyman Rickover
CHK Built a software system to detect potential kicks by monitoring flow out and pit volumes and to automatically fill in well control sheet.

Compared results of software to reported kicks, slow pump pressures, pit gains, and other human inputs into WellView.

- Wellview records were within 10% of the RTM data less than 25% of the time
- Many RTM pressure measurements seemed invalid based on intuition and integration of other data sets
- What caused these differences?
- Would a driller reasonably trust our system if it disagreed with his observations all the time

**Trustworthy Data**

**is THE Necessary First Step Toward**

Monitoring, Analysis, Decisions, Optimization, and Automation
TO MEASURE

IS TO KNOW

Without good measurements, you don’t know what you don’t know.
WHY FOCUS ON DATA AND DATA QUALITY?

1. Transparency is the primary focus of RTM and true data is the foremost prerequisite

2. Regulators, legislators, the public, and any interested party has a reasonable expectation to the truth
   - Realtime data should have the same expectation of accuracy and completeness as any other data provided an APD or other regulator filing.

3. Bad data can lead to bad decisions
   - There were questions about sensor accuracy when evaluating Macondo
   - Bad surveys can lead to well intersection
   - Bad pressure data can lead to extended well control scenarios or loss of well control
   - Bad data is a root cause of waste and poor performance

4. You cannot improve what you cannot measure is an axiom in EVERY other major industry—manufacturing, aerospace, semiconductor.....
HOW I LEARNED ABOUT MEASUREMENTS

- Interviewed tool pushers, rig managers, and drilling contractor management (NOMAC, Cactus, Nabors, H&P, etc.) to discuss how they manage instruments on the rig.

- Audited PVT/EDR (NOV, Pason, Canrig) and BOP Testing service providers in Texas, Oklahoma, Ohio, Pennsylvania, Wyoming, Calgary, and evaluated the following:
  - Inventory Management (for new, inbound, in-service, and outbound items)
  - Traceability—can items be traced to OEM and material origin
  - Calibration and Validation Practices (laboratory and field)
  - Shipping and Handling Practices
  - Installation, Commissioning, Validation, and Testing Practices
  - Follow-Up and Auditing Practices
  - Management, Quality Systems (i.e. ISO), and Training Practices

- Developed New Tools and Procedures When Existing Methods Were Insufficient
  - Drilling Pit/Tank Strapping Methods
  - Iron Roughneck Testing Tool
  - High-Spec BOP Tester

- Founded Operators Group for Data Quality (OGDQ)
  - Gave away all technical and contract specifications to improve industry at large
AN OVERVIEW OF LESSONS LEARNED

- Errors were present across all rigs and all measurements.
- Problems appear to be systemic and reflect a lack of attention to surface sensor metrology.
- Downhole MWD and log metrology has generally been well addressed by a variety of industry consortia.
- Downhole dynamics measurements suffer from the same problems.

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EXAMPLE: PIT VOLUME DEVIATION

- Errors caused by:
  - Deadwood in Tanks
  - Non-Level Tanks
  - Lack of Resolution in Tanks
  - Assumptions about prismatic or other tank volumetric properties
  - Differences between engineering drawings and as-build volumes.
EVALUATING BOP TESTERS

- Most testing companies do not have internal calibration/verification capabilities
  - All calibration is done by third parties but as found/as left records are not typically provided

- Storage, Shipping and Handling practices contribute to significant errors and damage to testing equipment

- Gages, recorders, and pumps were frequently found to be out of order across all vendors. Leaks were common and repairs were required nearly 100% of the time before a closed system test could be performed.

- Testing companies do not regularly field-verify equipment before BOP testing begins
  - Closed systems tests at all companies revealed significant differences between on-board pressure gages and pressure recorders. Average error is >500 psi and observed up to 1200 psi.

- Commonly accepted instruments used to test BOPs are not sufficient to ensure a properly operating BOP.

- No BOP Testing Company had the ability to verify torque for BOP assembly
  - This significantly affects the ability of the BOP to resist pressure over time and to resist wear and damage

- 1/6 Testing Companies had a formal training program with testing and skills demonstration requirements
SO... WE MADE OUR OWN TESTER

- 0.01% Accuracy from 0-10,000 psi
  - 1 psi resolution
- Encrypted Binary Files
  - Cannot be read or modified by user
- Bluetooth and WIFI Remotely Controlled
- .CSV and WITSML
  - Can be exported for analysis
- 2GB onboard FIFO
- Hardened Case with Poka-Yoke Connections
  - User prevented from incorrectly connecting
  - Hard to damage
- ~$10,000 to develop
GUIDING PRINCIPLES FOR DATA MANAGEMENT

1. Anyone skilled in the art can reasonably recreate the observations, interpretations, and conclusions used for operational decision making.

2. Data Should be Explicitly Trustworthy
   ▪ Third parties have a reasonable expectation that data provided thereto is trustworthy

3. Information Should be Preserved at Every Step
   ▪ Smoothing, filtering, decimation, database ETL, and other lossy manipulations should be avoided

4. Sampling Should Ensure that Phenomena of Interest Can be Effectively Observed
   ▪ The Nyquist Limit should be calculated for each event of interest
CONSIDERATIONS FOR GOOD DATA MANAGEMENT

**Sensor Attributes**
- Range
- Accuracy
- Precision and Sigma Level
- Sensitivity
- Resolution
- Linearity
- Hysteresis
- Reliability

**System Attributes**
- Sampling/Conversion
- Smoothing/Filtering
- Transparency (Manipulation)
- Timeliness
- Traceability
- Fidelity
CRITICAL, AND OFTEN OVERLOOKED, ASPECTS

1. Error Potential—Even Calibrated Sensors can Report Errors
   1. Sensor specifications must account for potential for error, tolerance for error, and expected shifts and drifts
   2. Sensors should be calibrated in expected in-situ conditions with enough samples to demonstrate a process sigma that is acceptable. $6\sigma$ process (with $1.5\sigma$ shift and drift) should yield 3-4 errors per million observations.

2. Sample Rate
   1. Nyquist limit states that data should be sample 2x faster than phenomena of interest

3. Data Manipulation
   1. Most data delivered by service companies is highly manipulated. Most surface sensor data has band-pass cutoffs, time-averaged smoothing, or other lossy manipulations applied before or during aggregation.
   2. Smoothing often leads to inability to see critical events.
WHAT WE LEARNED FROM ‘BIG’ RTM

1. The physics of most problems is understood well enough to code a solution that is good enough for most cases or to serve as high level alarming.

2. Technology is ahead of us, no the other way around.

3. Data quality was the single biggest root cause of failure of every analytical method we deployed.

4. Culture and Human Factors were a root cause of nearly every failure.
COMPETENCY MANAGEMENT
WHAT IS AND IS NOT DEMONSTRATIONS OF COMPETENCE

• Subject Matter Experts
  • Continuous human monitoring 24/7 is not necessary. It is often expensive and impractical (people have to take breaks)

• Management by Exception
  • Expert software systems can act as a first-line of defense and mitigate the need for human SMEs
  • It is more efficient to call SMEs when needed, use data to drive alarms and analysis

• Controls to Prevent/Mitigate Negative Events
  • Competence can be demonstrated by methods which prevent or preclude certain events from happening. This is a fundamental part of automation
  • Not all events or scenarios can be controlled

• Remember the GEMBA. All SMEs should have regular visits to the rig
ANALYSIS
RECOMMENDATIONS FOR RTM ANALYSES

1. Should offer clear and convincing evidence that work has been performed according to plan and/or according to statutory requirements

2. Should be reasonably reproducible using data and metadata which is available to third parties

3. Should be physics based and/or recognized as best practices

4. Should be standardized when possible to enable sharing with, and evaluation by, third parties.

5. Should not be prescribed by regulators without compelling justification
WORKFLOW

PROCESS AND COMMS MANAGEMENT
WORKFLOW MANAGEMENT RECOMMENDATIONS

• What is workflow and why do I need it?
  • Workflow is the ability to manage a case or scenario using pre-defined rules documented in your RTM Plan
  • Workflow is strongly recommended because the ability to act on information is infinitely more valuable than the information itself.

• Without disciplined methods to translate monitoring into action, RTM is just for show or to comply with statutory minimums
  • Workflow systems often drive considerable value and allow organizations to focus on learning and improvement rather than ‘fire fighting’
WORKFLOW MANAGEMENT RECOMMENDATIONS

**Recognize**—detect when certain situations have occurred or will likely occur. These may include planned events such as BOP testing or cementing, or unplanned events such as a kick or lost circulation.

**Route**—get data to the right people/systems at the right time. In most analyses, data identification and collection takes between 40% and 60% of the time it takes to reach a conclusion. RTM solutions must be able to do this very quickly.

**React**—deliver results of analysis to persons or systems to enable a change in the operation based on data available in real-time. This may be permission to proceed, stop-work authority, or suggestions for changes in procedure.

**Report**—tell all relevant stakeholders involved in RTM what happened. This should be structured, timely, and easy for a novice (or the public) to understand. Auditability is critical for regulators.

**Review**—follow up after events with after-action reviews (AARs), Job Safety Analysis (JSA) reviews, informal tool-box talks, meetings, questionnaires, or other post-process information sharing/gathering. Have regular conversations about lessons learned. Create a knowledge sharing database if possible/practical.
SOLUTIONS ABOUND
10 MINUTES OF WEB SEARCH YIELDS THE FOLLOWING:

Open-Source Solutions
• Intalio
• Process Maker
• Bonita Soft
• Activiti
• Cuteflow
• nexFlow
• Orchestra
• jBPM
• Talend
• Camunda

Commercial Solutions
• Salesforce.com
• JIRA
• SigmaFlow
• K2
• Agiloft
• Zendesk
• Cherwell
• IssueTrak
CYBERSECURITY
THOUGHTS ABOUT CYBERSECURITY

• Required by DHS (Department of Homeland Security) because most MODUs and Production facilities are defined as ‘critical infrastructure’
  • Likely the most arduous requirements will stem from this
  • It is not practical for operators to approach this alone

• Remember STUXXNET (and that it was not unique)
  • MANY similar viruses have been found that do very simple, but highly damaging things like repeatedly cycling a pump until failure. Municipalities are common targets but hesitate to announce it.
  • Many critical systems are logical targets including BOPs, fluid control systems, dynamic positioning, etc.

• Intrinsically safe technology is likely not possible
  • Human factors (cultural exploits) are the most common and hardest to detect and defend
  • No network is safe

• RTM will likely have small (although non-zero) cybersecurity implications
  • Because it is typically read-only.
REAL TIME MONITORING

Recommendations for Regulators
BOP TEST EXAMPLE WORKFLOW

Start

1. Operator Fill Out Web Form for BOP Test
2. Tester Make, Model, Serial
3. Technician Info
4. Calibration and Validation Results

Case Assigned to Auditor

Test Performed per Plan

Results Evaluated by Auditor

Results Evaluated by Operator

Test Pass

Retest Required?

YES

YES

YES

End

NO

NO

NO

Contact Operator and Follow Escalation Plan

Proceed According to Plan

Correct Deficiency and Re-Test
“I believe it is the duty of each of us to act as if the fate of the world depended on him. Admittedly, one man by himself cannot do the job. However, one man can make a difference”

-Hyman Rickover