technology leadership board

Well Construction Cost Reduction Hackathon Output Report

13 December 2016

Contents

Executive Summary 3
Introduction 3
How Does a Hackathon Event Work? 4
Actions 5
Ideas Generated 6
Challenge 1: Rock Cutting and Transportation 6
Challenge 2: Borehole Stability and Formation Pressure 24
Challenge 3: Wellbore Isolation 34
Challenge 4: Materials for downhole equipment 42
Challenge 5: Maximising productivity from a well 48
Hackathon in Numbers 57
Appendix A: Explanation of Well Construction Process 58
Appendix B: List of Attendees 61
Appendix C: Additional Ideas Generated 63

Executive Summary

Reducing the cost of well construction for the UK Continental Shelf (UKCS) is a key theme for Technology Leadership Board (TLB) and in line with the MER UK strategy. A hackathon event was held to identify new adapt and develop technologies that can contribute to lowering well construction costs. A large number of novel ideas were generated for five key challenge areas during the event and will now be picked up by technology delivery organisations that will, in collaboration with industry, develop the ideas into technology programmes.

Introduction

The cost of well construction in the United Kingdom Continental Shelf (UKCS) has increased at a growing rate over the last 10 years, with some operators indicating a 399% increase in P50 dry hole costs from 2001 to 2014[1]. To ensure the UKCS remains a commercially viable region to operate in, the MER UK strategy recognises a need to reduce the cost of well operations. The TLB adopted well construction cost reduction as one of its key themes, and set up a workgroup, tasked to identify new technological solutions and practices which will reduce the cost of well construction on the UKCS. It has been identified that a combination of actions related to process improvement and new technology introduction are required to meet and exceed the work group target of a 50% reduction in the cost of well construction. The relationship between MER UK forums and work groups can be found on the Oil and Gas Authority (OGA) website here.

To target the Adapt and Develop technology areas, a wells hackathon event was held to identify technologies that could significantly impact low cost well construction. An event of this nature was utilised as it is a proven tool; with TLB Small Pools and the OGA Southern North Sea Well Abandonment events being previously held. A hackathon event is seen as an effective engagement mechanism and can lead to faster delivery of ideas.

Jointly driven by the Technology Leadership Board Workgroup, Industry Technology Facilitator (ITF), Oil and Gas Technology Centre (OGTC) and the OGA, the focus of the Hackathon event was to highlight challenges associated with well construction and to use the day as a platform for cross-industry supply companies (including small developers) to work with industry to identify innovative solutions. Of particular value are potentially shorter time-to-market solutions that can be adapted from other industries as well as new, blue-sky innovative ideas that could transform how wells are constructed.

Ideas generated will be published in a report on the OGA website for technology delivery organisations such as the OGTC and ITF to turn into projects.

[1] ITF Technology Showcase presentation from Olav Skår (Shell E&P) March 2016

How Does a Hackathon Event Work?

A hackathon event is undertaken to draw together the industry and supply chain, to find creative solutions to reduce, in this case the oil and gas industry cost of well construction. Hackathons started in Silicon Valley as a way to inspire new ideas, and were held internally by large software companies to promote new product innovation from its staff. It's reported the Facebook like button was the output of a Facebook hackathon event. Centrica has utilised the idea and used it internally for many of its business units. To run these internal events Centrica trained a small team, currently around 25 people, to facilitate the days. These facilitators are called "Pioneering Facilitators".

The underlying idea behind generating new ideas at Hackathons is based on:

Identify × **Insight** × **Ideas** × **Impact** = **Innovation**

One of the key aspects of a hackathon is for participants to stay expansive, offering new possibilities and opinions and to try to restrict reductive thinking by judging ideas or instantly thinking and saying "no". Any idea generated is developed and discussed in a figurative Greenhouse of ideas where all ideas are understood and nurtured. While it is accepted that some of these seedling ideas may turn out to be weeds, equally there will be some seedling ideas that can flower. The ideas are recorded on a T bar sheet with a title, short explanation and graphic representation.

The agenda for the day was based on five themed stations on the following pre-selected challenge areas generated by the TLB workgroup:

1) Rock cutting and transportation
2) Borehole stability and formation pressure
3) Wellbore isolation
4) Materials for downhole equipment
5) Maximising productivity from a well

Ideas generated during the event are presented, along with a more in-depth explanation of each challenge area. In each of the five challenge areas T-Bar sheets were drawn up for each idea generated. The ideas generated between sessions are represented in Appendix B. For those unfamiliar with oil and gas well construction, a top level explanation is presented in Appendix A. In the final breakout sessions all the generated ideas were explained by the relevant subject matter experts and some of the top ideas described. All participants then reviewed each idea in their respective challenge areas and voted for those they thought were best. The number of votes received for each idea is represented on each the T-bar sheets, on a yellow post-it note.

A small number of attendees were unable to share their ideas at the hackathon due to confidentiality constraints such as Intellectual Property (IP). The OGA will work with these organisations until the confidentiality issues are resolved and the ideas can be shared with the delivery organisation.

Actions

The key follow on action arising from the event are:

- TLB ‘Well Construction Cost Reduction’ workgroup to publish free report detailing results from the day.
- Technology delivery organisations, in collaboration with industry, to develop the ideas into technology programmes.
- Progress of ideas to be reviewed by the TLB.

Ideas Generated

Challenge 1: Rock Cutting and Transportation

Rock Cutting

Problem Statement

Hydrocarbon bearing rock formations are typically located thousands of feet under the ground (either onshore or from the seabed). To reach these formations we are required to drill down through the earth's crust to reach the reserves and provide an open conduit to surface to allow extraction. The current rates of penetration of the rock are dependent on many factors. The main three being the drill bit compatibility to the rock it is cutting; some drill bits (roller cone) work by disintegrating the rock by compressive failure, some bits (PDC) remove rock by shear failure. The bottom hole assembly above the bit contains heavy walled pipe that provides weight to the bit. The third factor is the pressure differential between the formation pressure and the circulating fluid pressure at the bit.

Functional Requirement

The requirement is for a new method or technology that can increase the rate at which we can cut and remove rock.

Cutting Transportation

Problem Statement

By itself, rotating a bit doesn't fully get the job done. The rock cuttings created by the drill bit must be removed from the hole; otherwise they collect at the drill bit and impede drilling. A pipe from surface to the drilling bit provides a conduit for a powerful pump at surface to move drilling fluid down the pipe, out of a series of nozzles in the drilling bit and lift the cut material away from the bit to surface. The drilling fluid has many purposes, in this case we are concerned with:-

- Ability to clean cutting from the hole – influenced by fluid viscosity and velocity
- Suspend cuttings when circulation stops – settling can result in avalanching, hole fill and bridging
- Release the cuttings at surface- to maintain required fluid density

Functional Requirement

The functional requirement is for a revised and improved method to clean the hole of drilled material.

Summary of Top Ideas Generated

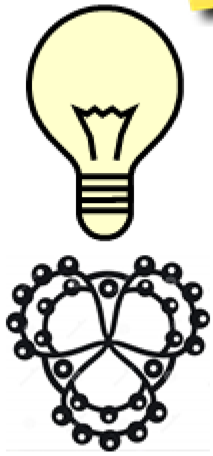
Idea	Votes Received
Smart Bit – Sensors in bit with machine learning	14
Fuse Rocks – melting rock to use as casing	12
Underbalanced MPD – Increase ROP and reduce loss circulation by combining techniques	8
Implementation Hackathon – how to get existing technology implemented by industry	7
Mole Drilling – exploration drilling without creating a conduit	7

T-Bar Ideas

Smart Bit

14 Votes

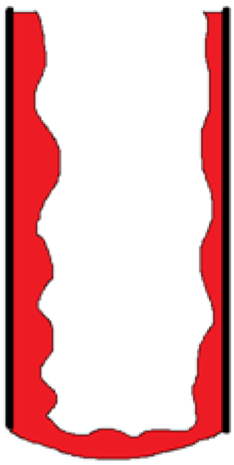
- Machine Learning
- Enables running a bit until failure
- Remove Humans – data driven decisions
- Include sensors in bit
- Basin wide database
- Reduces loss of experience
- NASA can remotely assess dust on mars



Fuse Rocks

12 Votes

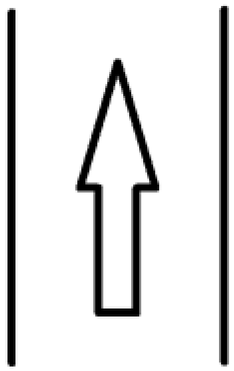
- Melt rocks
- Use molten rocks as casing



Underbalanced Managed Pressure Drilling

8
Votes

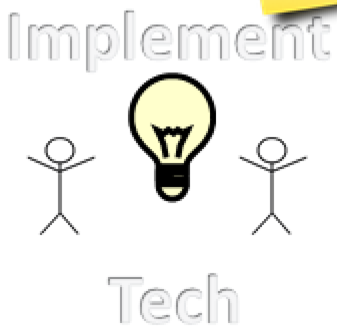
- Weakens rock
- Increase ROP
- Better cutting transport
- Less stuck pipe
- Less loss circulation



Implementation Hackathon

7
Votes

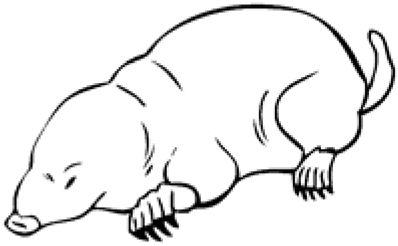
- Lots of established techniques not applied by industry
- How can we make it happen
- Change working culture in UK to promote innovation



Mole Drilling

7 Votes

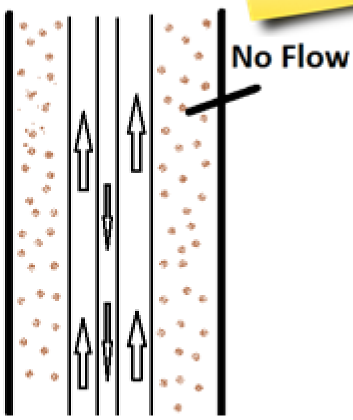
- Exploration wells do not need a conduit
- Use mole, lets hole collapse behind it
- Only transport information up to surface
- Pilot in Norway for civil eng.....called Badger

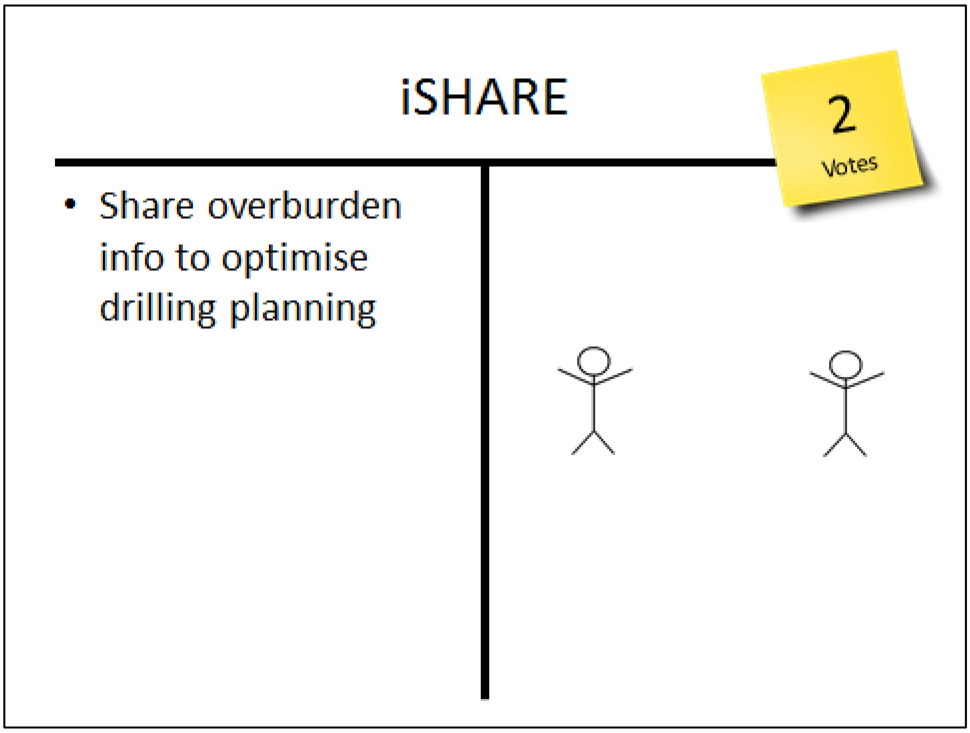


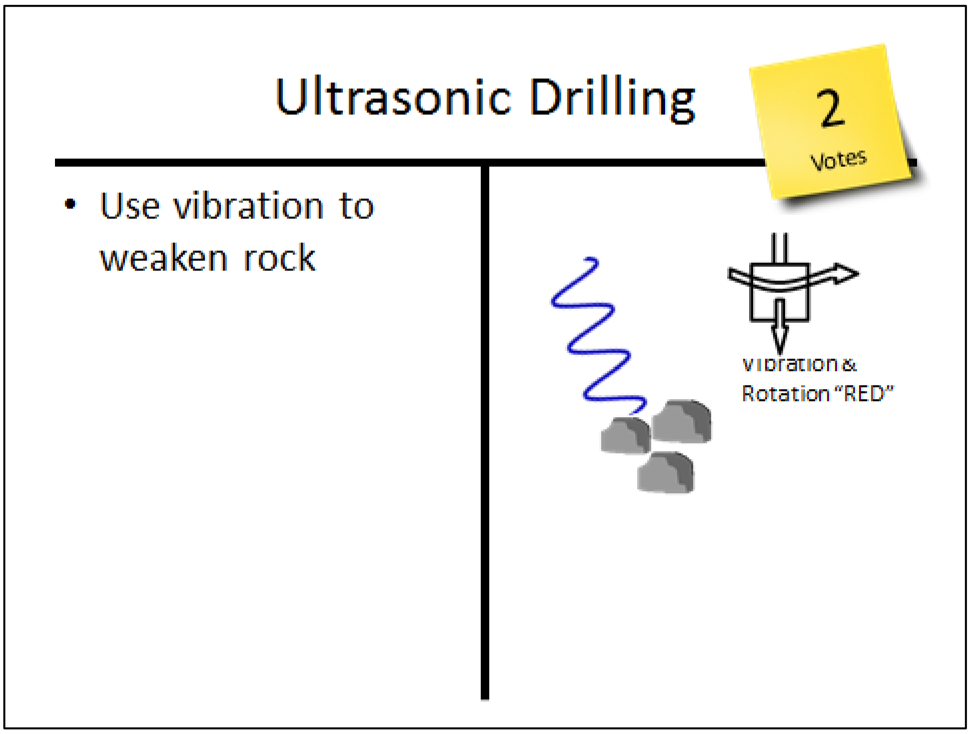
Internal Circulation

6 Votes

- Cutting going inside drill pipe
- Dual Walled drill pipe
- Reel well commercial offering already??



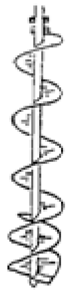

iSHARE
2
Votes
Share overburden info to optimise drilling planning


Ultrasonic Drilling
2
Votes
Use vibration to weaken rock
vibration &
Rotation "RED"

Mechanical Cutting Transport

2 Votes

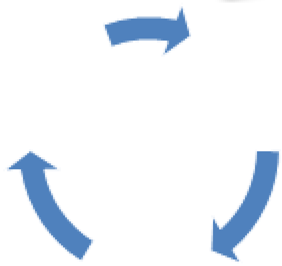
- Move cuttings using mechanical process
- i.e. auger or belt



Recycle Cuttings

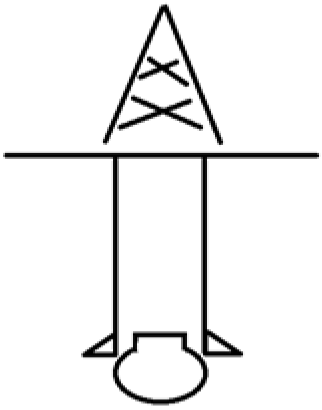
1 Vote

- Use Cuttings In Cement
- Less Transport



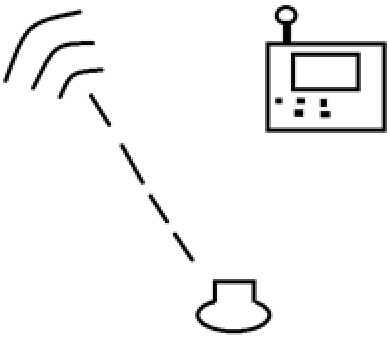
Casing Drilling

- Run Casing While Drilling
- Torque issues?
- More development needed



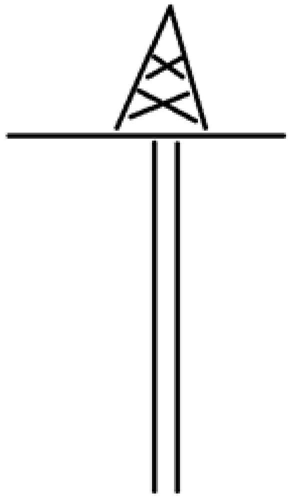
iDRILL

- Improve data recording, processing and transport
- To optimise drilling process



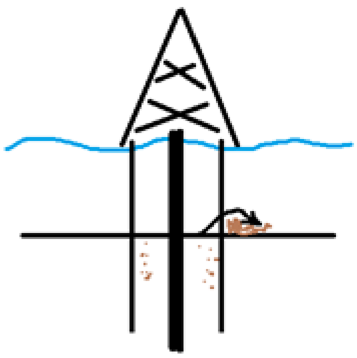
Monobore

- Reduce volume of rock that needs to be removed



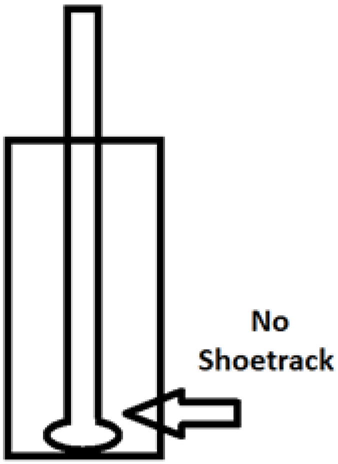
Subsea Cutting Processing

- Process cutting on sea floor



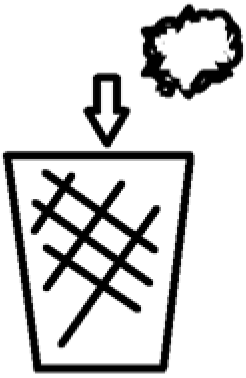
Drill-less Cement

- Eliminate shoetrack
- Cut down the material to be cut



Reduce Bureaucracy To Improve Innovation

- Take U.S. unconventional well cost reduction as example
- Too many sign offs / people involved to try out new technology

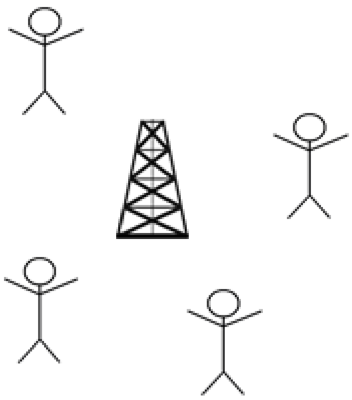


Incentivise Innovative Trials

- No incentive to try out new technology (that has been used elsewhere)
- Incentivise it??
- BY: Award?

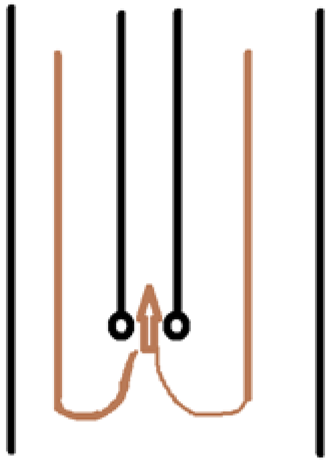
Collaborative Trials

- Removes threshold to new technology
- Can mean a step change for well cost reduction



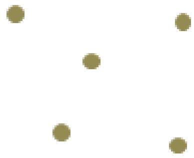
Reverse Circulate Drilling

- Reverse Circulation
- Better lift of cuttings
- Transporting cutting faster



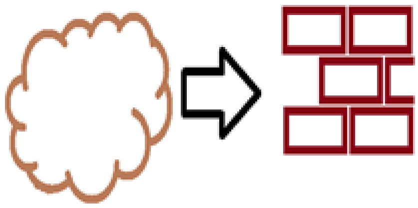
Nano-mud

- Improved rheology
- Improved mud properties (purebore)



Mud to cement

- Use a drilling fluid that converts to cement
- Faster cementing

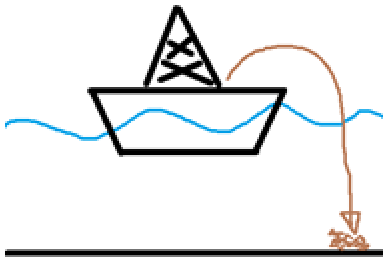


Self Sharpening Bit

- Cutting Edge Based on rodent teeth (hardside & softside)
- Self - sharpens

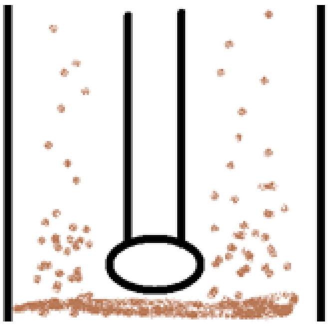
Offshore Cutting Cleaning

- On Site cleaning of cuttings to allow cuttings to go overboard



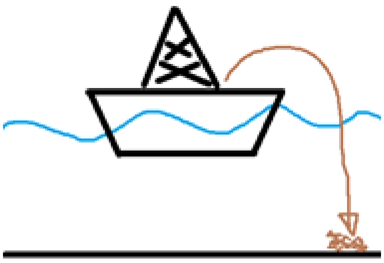
Downhole Cuttings Dissolve…

- Dissolve cuttings downhole
- = no need for transport



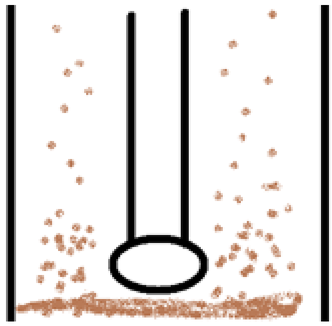
Happy Mud

- Less Harmful Mud to allow dumping of cuttings
- Local cutting dumping



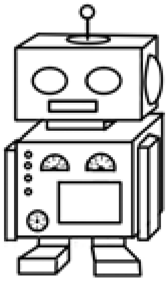
Slurrification

- Chemicals to weaken / dissolve rock in drilling fluid.



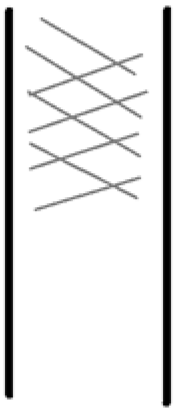
Automated Rock Cutting NOT the rig

- Current automation focussed on existing manual rig
- Fully automatic process rig to bottom



Composite Casing

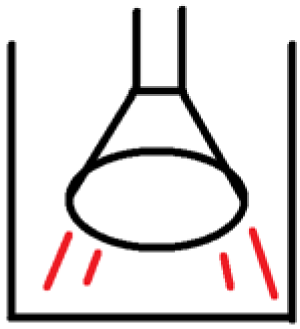
- Low weight
- Not corrosive



Rock Face Soften

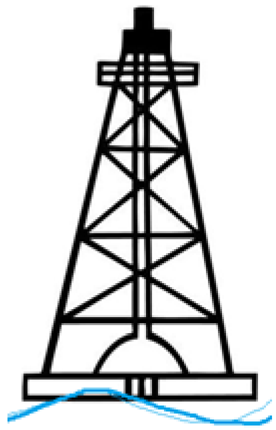
- Tool wear ↓
- Changeout time ↓
- Vessel time ↓

- Ultrasonic
- Chemical heat
- Jetting



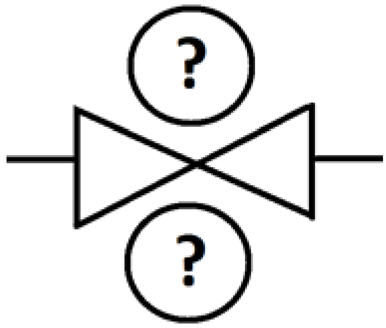
Standardise Rig Equipment

- Equip all rigs with
  - MPD
  - Wired Drill Pipe



Choke Model

- Cutting and Transport is probably no the choke, other things can slow down drilling
- Establish what is slowing drilling



Challenge 2: Borehole Stability and Formation Pressure

Wellbore Stability

Problem Statement:

Due to the depositional and buried environment, all formations have an existing stress regime in place. During the process of drilling rock is removed. This disrupts the in-situ stress regime and leads to stress changes within the rocks adjacent to the wellbore. This can result in deterioration of the stability of the wellbore as portions of the formation adjacent to the wellbore may break-off and fall into the wellbore. This is known as wellbore instability. It results in a number of drilling problems/challenges as this extra material needs to be removed from the wellbore. If the volume is too large and not removed it may be severe enough to close around the drill string trapping it in the well and resulting in the loss of the wellbore. Additionally, rock debris remaining in the wellbore can cause issues in running the drill string and subsequent casing strings in and out of the hole.

Functional Requirements:

The requirement is for methods or mechanisms to reduce or prevent this deterioration in the wellbore. Whichever mechanism is chosen must ensure that the wellbore pass through diameter is kept the same, or very close, to that which is initially drilled. The deployment mechanism for positioning the solution at the appropriate position in the wellbore also needs to be considered.

Formation Pressure

Problem Statement:

During the construction phase whilst exploring down through the rock layers, porous formation are penetrated which may contain fluid (water, oil or gas) in its pore spaces, at pressure, that for permeable formations wants to flow into the well bore and up to surface. This fluid needs to be held back in the formation by maintaining a higher pressure in the well bore or by allowing it to flow using a pressurised containment system to prevent releasing the hydrocarbons. If left to flow without control, the pressurised water or hydrocarbons, would expose personnel and the environment to significant damage or risk at surface.

Formation Pressure > Wellbore Pressure = Reservoir Fluid enters the well bore

Formation Pressure < Wellbore Pressure = Reservoir Fluid remains in the formation

Note: Too much pressure in the well bore and the formation breaks down

Functional Requirement:

We are seeking to develop innovative technologies and solutions to enable to penetration of the rock to reach the reservoir in a safe and controlled manner, managing the formation pressure or formation fluid, whilst not suffering an uncontrolled release to the environment.

Summary of top Ideas Generated

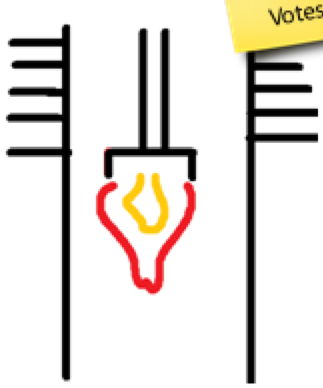
Idea	Votes Received
Plasma Drilling and Casing – using plasma to drill and “melt” rock	14
Big Data Real Time Algorithms – incorporate all rig data	13
Chemical Casing – reaction with formation to secure borehole	11
Liquid Casing – 3D print casing downhole	6
3D printed casing – printer behind bit	4

T-Bar Ideas

Plasma Drilling & Casing

14 Votes

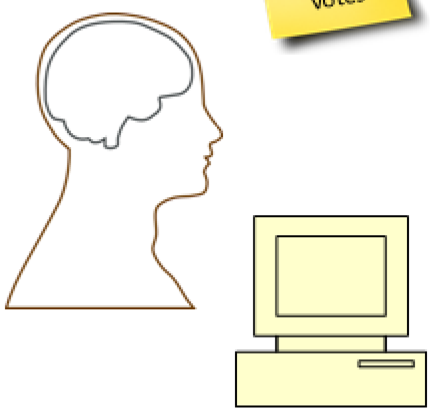
- Plasma drilling & Melt rock to make glass casing
- NOT to be used in reservoir



"Big Data" Real Time Algorithms

13 Votes

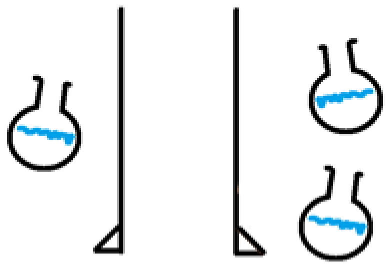
- Incorporate all data
  - LWD, LOT, W/L
  - MW etc
- All look ahead data
- "AI" algorithm
- Dynamic Adapting



Chemical Casing

11 Votes

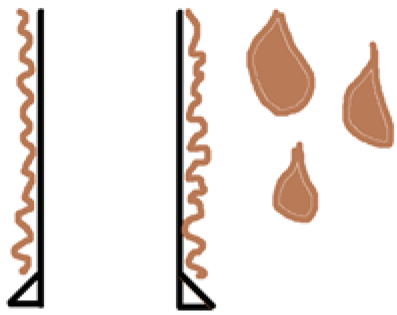
- Reaction with formation to secure rock
- "Casing" as you drill
- Ideally casing string or just one joint



Liquid Casing

6 Votes

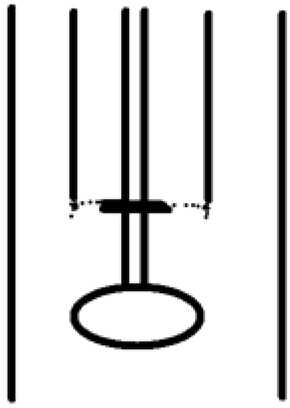
- 3D print casing downhole in real-time
- Or intelligent drilling fluids auto sealing formation
- Activated chemicals to make casing



3D Printed Casing

4
Votes

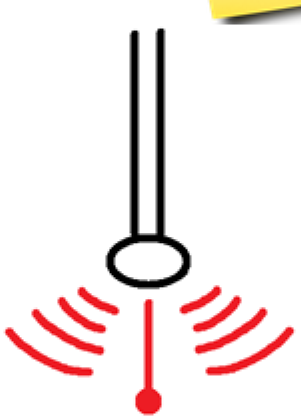
- "3D Printer" behind bit
- Print Casing "as you go"



"Look Ahead" Data

4
Votes

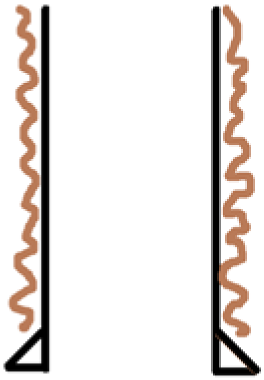
- Probe ahead of bit
- Acoustic sensors
- Compare with traditional behind bit data



Casing & Cementing While Drilling

4 Votes

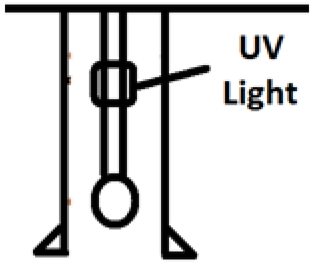
- Polymer coating on outside of casing
- Seals off formation "Cements" as we drill



UV Casing

3 Votes

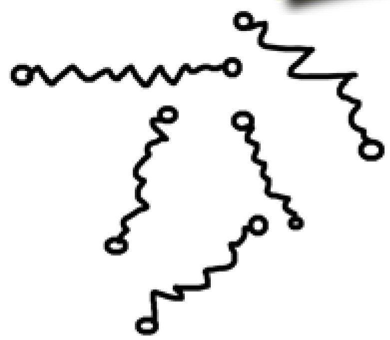
- Like dentist glue
- Create casing from filter cake using UV-activated chemicals



Polymer Drilling Mud

2 Votes

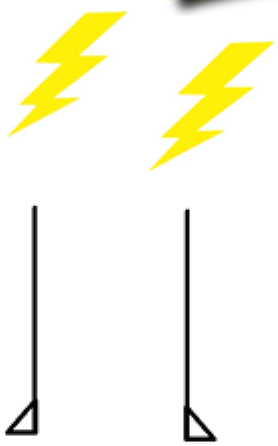
- Replace filter cake with long chain molecules
- Seal off formation



Eleco-Rheological Fluid

1 Vote

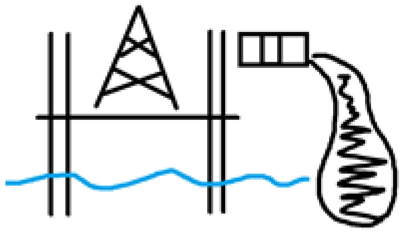
- Electric signal can turn fluid to solid in split seconds (1/18")
- Instantly fix a well control situation



Allow OBM Discharged Overboard

- Treated to reduce environmental impact?
- How damaging is modern mud
- Research with universities
- Big cost drilling in winter, WOW for cutting boats

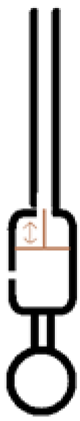
1 Vote



Downhole Pressure Accumulator

- Accumulator downhole to absorb "spikes" in pressure
- Smooth out the pressure spikes

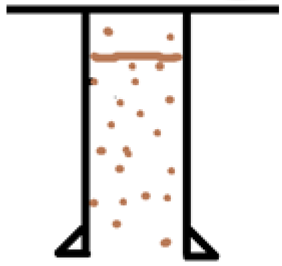
1 Vote



Thixotropic Drilling

1 Vote

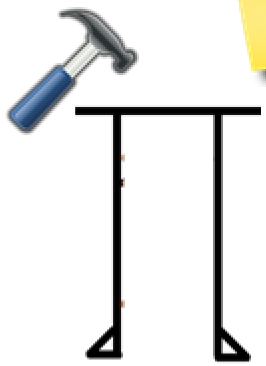
- Use a foam instead of mud
- Reduced equivalent circulating density
- Drill through narrower drilling windows
- Remove Casing strings from designs



Pile drive to TD

1 Vote

- Eliminate drilling
  - No bit
- Hammer casing to TD
- Use vibration to help
- Use drilling just for reservoir section
- Can be closed end
- Telescopic?



Common Database with GIS

- All pore pressure /LOT in database
- Standardised / generated by neutral body

Challenge 3: Wellbore Isolation

Wellbore Isolation

Problem statement:

Buried porous rock formations will contain fluids (water, oil, gas) under pressure. The actual pressure will be dependent upon a number of factors linked to the depositional environment and subsequent geological movements. The pressure may be equal to a normal hydrostatic pressure from surface or be substantially higher or lower than hydrostatic. Before the well is drilled, this pressure is kept in place by overlying seals provided by impermeable non-porous formations. During the drilling process, as formation is cut, these seals are broken and the wellbore itself will provide a conduit for these pressured fluids to flow. It is a safety imperative that these fluids are contained in-situ and not allowed to flow into the wellbore. This needs to be done whilst the formation is open as the well is being drilled but more importantly on a permanent basis once the section of the wellbore is complete or the well is being permanently abandoned. Otherwise these fluids could migrate to other formations exposed by the wellbore or be released to the environment.

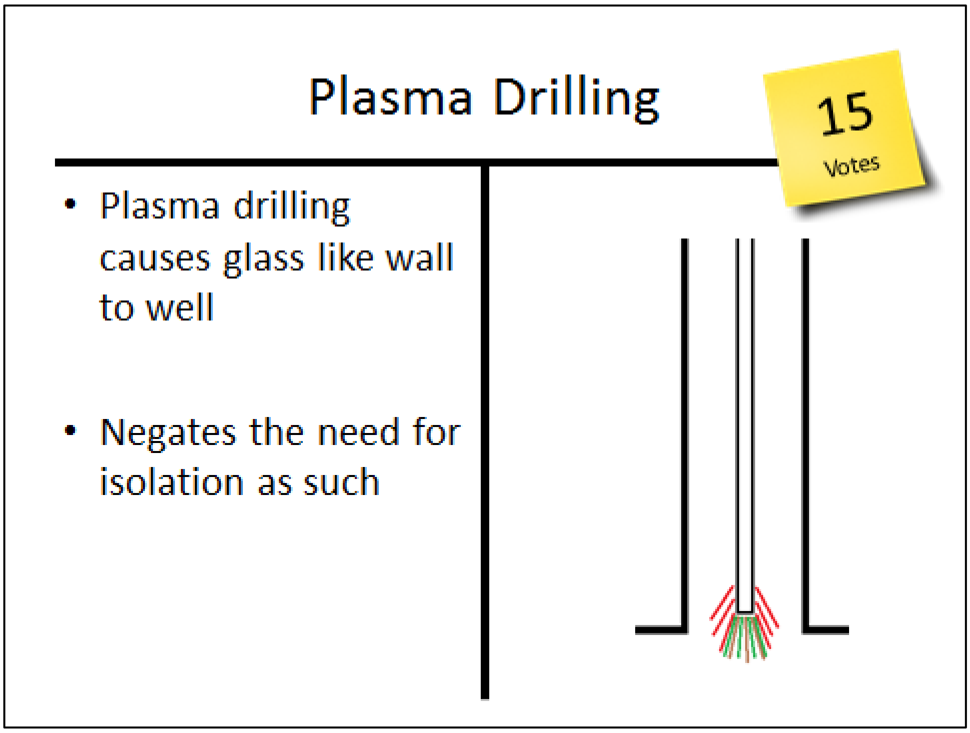
Functional Requirements:

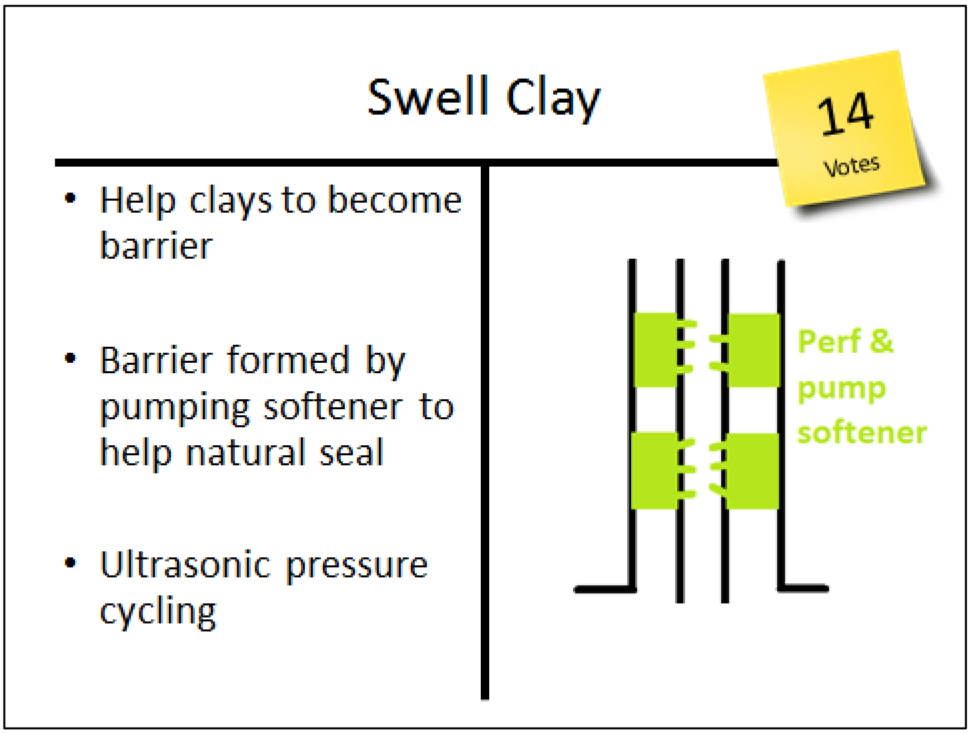
The isolation requirement is for when the section of the well has been drilled. The isolation must re-establish the seal and ensure formation fluids cannot escape from the formation and migrate to other sections of the well, or be released from the well to the surface environment. The isolation barrier must be able to be tested to prove its presence and functionality. The seal must be able to be classified as a permanent barrier over extremely long durations. For example steel could not be called a permanent barrier as it will corrode over time.

Summary of Top Ideas Generated

Idea	Votes Received
Plasma Drilling – create a glass like wall to well	15
Swell Clay – allow drilled clay to become barrier	14
Slurry case – pump casing while drilling	6
Swell – casing – isolation + smart materials	4
Self-healing well – pump material during construction to repair	2

T-Bar Ideas

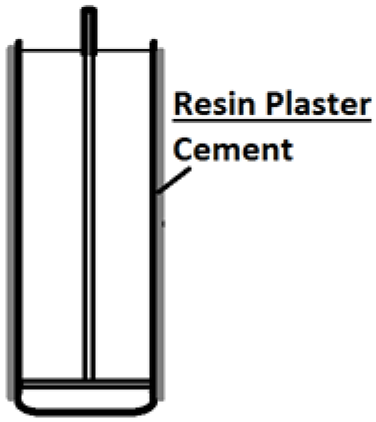

Plasma Drilling
15
Votes
• Plasma drilling causes glass like wall to well
• Negates the need for isolation as such


Swell Clay
14
Votes
• Help clays to become barrier
• Barrier formed by pumping softener to help natural seal
• Ultrasonic pressure cycling
Perf & pump softener

Slurry Case

6 Votes

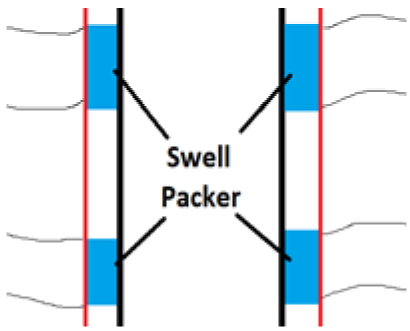
- Pump the casing during drilling
- Material sets with pressure/temp



Swell – Casing – Isolation + smart materials

4 Votes

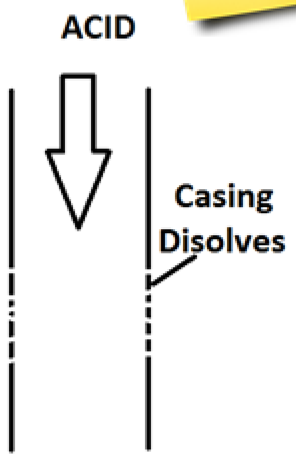
- Monobore completion / casing hybrid
- Swellable packers for isolation
- Composite swellable



Mirage Casing

2 Votes

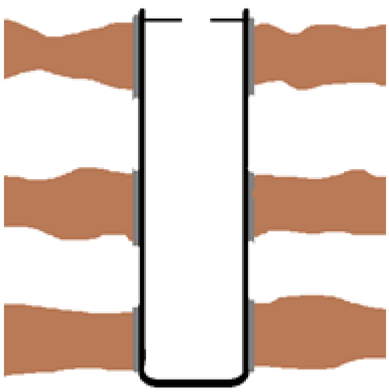
- Dissolvable Casing
- Or has a set lifetime then self destructs
- Clears the way for abandonment



Target Casing

2 Votes

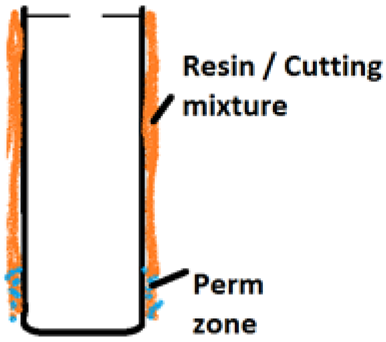
- Only target pressure areas for isolation
- Uncased well



Chem Pilot Casing

2 Votes

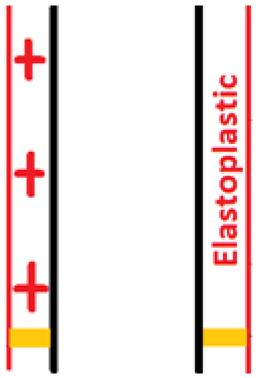
- Drill & pump chemical into the wellbore
- Drill through
- Leave areas of interest



"Self Healing" Well

2 Votes

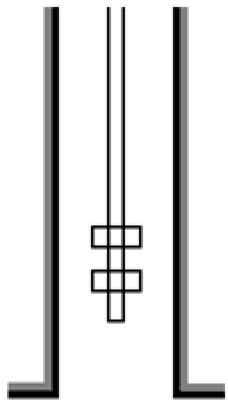
- During Construction pump fluid into the annulus
- Self heals if there is a minor breach



Exp-Solid Screen

2 Votes

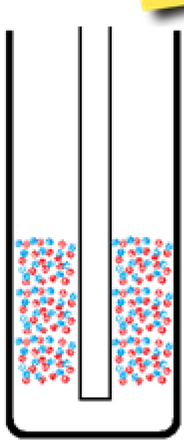
- Expandable metal skin on walls of well
- Deployed using current sand screen expander
- Bismuth alloy or similar



Swellable Platelet

2 Votes

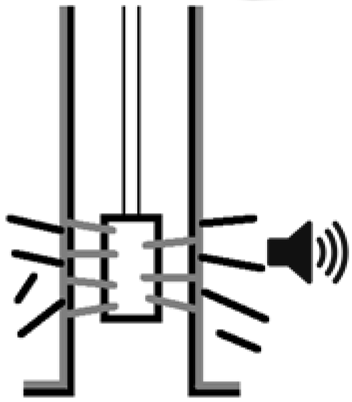
- Swellable mix pumped into area to be isolated
- Swells to provide barrier



Ultrasonic Destabilisation

2 Votes

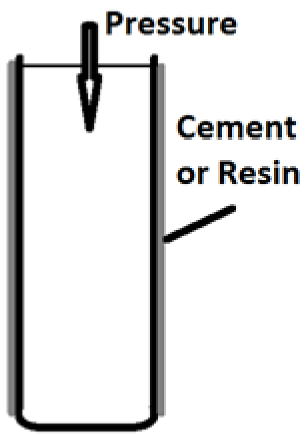
- Clays destabilised with ultrasound providing bond.



Chim Case Well

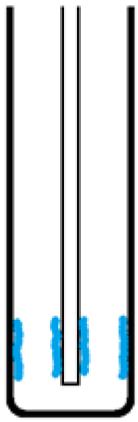
1 Vote

- Chimney type liner
- Balloon to hold back



Compaction Barrier

- Mechanical compaction of near wellbore to provide skin / new sealed wall



Challenge 4: Materials for downhole equipment

Problem Statement:

The loads, pressures, temperatures, and potentially corrosive conditions that may be found in a wellbore create the need for metals and materials that can resist such conditions. The high specification materials are expensive and require significant QA/QC to ensure the material meets the specification.

Some commonly used materials for manufacture of downhole equipment are as follows:-

Metals & Metal alloys

Low-alloy steels with minimum yield strengths of 110 ksi are used for standard service in noncorrosive environments.

Low-alloy steels with a maximum hardness of Rockwell 22C, and which meet NACE MR-01-75 requirements, are intended for use in both standard service and service in sour H_2S environments.

Martensitic steels such as 9% chromium, 1% molybdenum, and 13% chromium alloy steels are used in some wet CO_2 environments.

22% chromium and 25% chromium duplex stainless steel are commonly used in some wet CO_2 and mild H_2S environments.

Austenitic stainless steels, cold worked 3% Mo high-nickel alloy steels, and precipitation-hardening nickel-based alloys are suitable for some environments containing high levels of H_2S, CO_2, and chlorides at moderately high temperatures.

The successful application of any of these materials depends strongly on the specific downhole well environment. Many factors such as temperature, pH, chlorides, water, H_2S, and CO_2 concentrations can have adverse effects on the material performance and can lead to failures associated with:

- Pitting
- Corrosion
- Chloride stress cracking
- Hydrogen embrittlement

Elastomers

Nitrile is used in low- to medium-temperature applications for packers and packer-to-tubing seal assemblies in one form or another. It shows good chemical resistance to oils, brines, and CO_2 exposure. However, its use is limited in wells that contain even small amounts of H_2S, amine inhibitors, or high-pH completion fluids. Exposure to high concentrations of H_2S and bromides generally is not recommended

Hydrogenated nitrile or HNBR (chemical name: hydrogenated acrylonitrile butadiene) has a somewhat higher temperature rating and shows slightly better chemical resistance to H_2S and corrosion inhibitors than standard nitrile. HNBR is more prone to extrusion than standard nitrile and, as a result, requires a more sophisticated mechanical backup system similar to that found on most permanent and higher-end retrievable packers.

Two fluoroelastomers that are commonly used in the oil and gas industry are hexafluoropropylene (vinylidene fluoride, commonly known by the trade name Viton* and tetrafluoroethylene (propylene, trade name Aflas**). These compounds are used in medium- to high-temperature applications. Both compounds show excellent resistance to H_2S exposure in varying limits, CO_2, brines, and bromides. However, the use of Viton should be questioned when amine inhibitors are present in packer fluids and in the case of high-pH completion fluids.

Ethylene propylene (EPDM) is an elastomer commonly used in steam-injection operations. EPDM exhibits poor resistance to swelling when exposed to oil and solvents; however, EPDM can operate in pure steam environments to temperatures of 550°F.

Challenge for hackathon

To propose alternative, more cost effective materials.

Summary of Top Ideas Generated

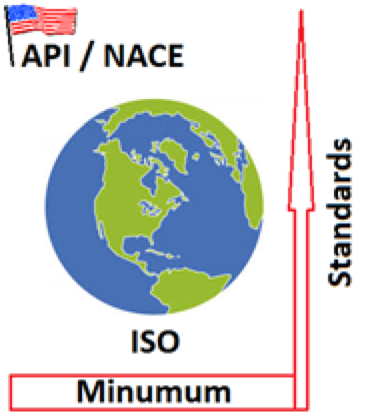
Idea	Votes Received
Raise the Standards roof – creating minimum standard to meet global operators requirements	14
The other guys – use of alternative materials for downhole equipment	12
Less is more – use smaller and lighter materials	11
Controlled Testing – testing and design in a controlled environment	5
Superstore membership – bulk buying from standardised stock across operators	4

T-Bar Ideas

Raise the Standards Roof

14 Votes

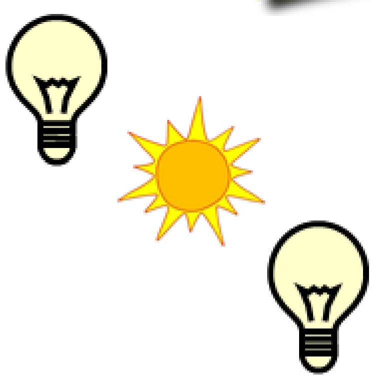
- Create a minimum standard (increased) that satisfies the global operator
- Remove the abundance of operator-specific requirements and reduce costs by standardising the manufacturing practices
- Simplify QA/QC inspection



The Other Guys

12 Votes

- Use alternative materials for downhole equipment
  - Composites (aero)
  - Honeycomb
  - Living Materials
- Design again
  - What is actually needed
- 3D valve printing
- Dissolving polymer clamps



Less Is More

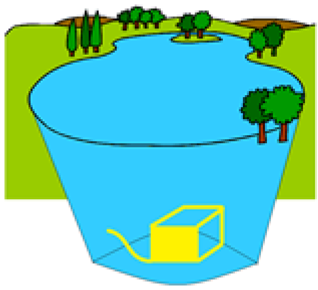
11 Votes

- Go Small or Go Home
- Make Materials
  - Lighter
  - Smaller
  - Less Specific when it doesn't need to be
- Will reduce need for bigger rigs

Controlled Testing

5 Votes

- Testing and design experimentation in a controlled environment
- Identifying maintenance issues quicker and reduce fix time
- Quicker to market as design refined
- Experimentation



Superstore membership

4 Votes

- Find biggest bang for buck and bulk buy
- Wells club / casing club
- Design discounts
- Promote
- Bring in Gov support
- Global operator champions (Sponsors)
- Convenience for smaller operators/procurement
- Promotes “shared equipment”

Superstore OIL&GAS

Wellheads

Valves

Trees

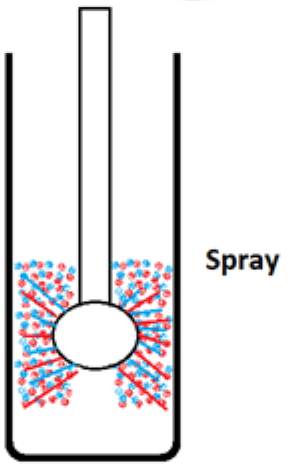
Elastomers

Tubing

Coat in Hole

4 Votes

- Use cheaper material
- Reduce defects because coating will be sprayed on after installation
- Coating will be varied depending on conditions (multi-purpose coatings also)
  - Self healing
  - Flaking / functional coating
  - Hydrophobic coating



Share & Share alike

2
Votes

- Learn from what has worked or not
- Limit variations on spec / designs
- Pool locations to share

Challenge 5: Maximising productivity from a well

Problem Statement:

Maximising the volume of hydrocarbons we can ultimately recover from a well not only maximises value for the operator and their partners, but also for the UK oil and gas industry, and the UK economy as a whole.

Although we do not have the ability to control reservoir rock properties and fluid properties, the flow of fluids into or out of a wellbore can be impeded for a variety of reasons;

- The drilling practices, and fluids used, during the construction of a well can damage the reservoir's ability to flow
- The geometry, and design, of the tubing and completion equipment can impede the flow of hydrocarbons
- The reliability, maintenance requirements and service life of the tubing and completion equipment can impact the total hydrocarbons recovered

The rate at which we draw down hydrocarbons from a well can accelerate sand and fines production and/or coning (the production of bottom water or gas cap gas). Sand and fines production can impede the flow of fluids into and out of the wellbore. Coning is a problem because not only must the second phase also be handled at the surface, but also the well's production rate is usually dramatically reduced. Furthermore, gas coning can rapidly deplete reservoir pressure and, ultimately, force shut in of the oil well.

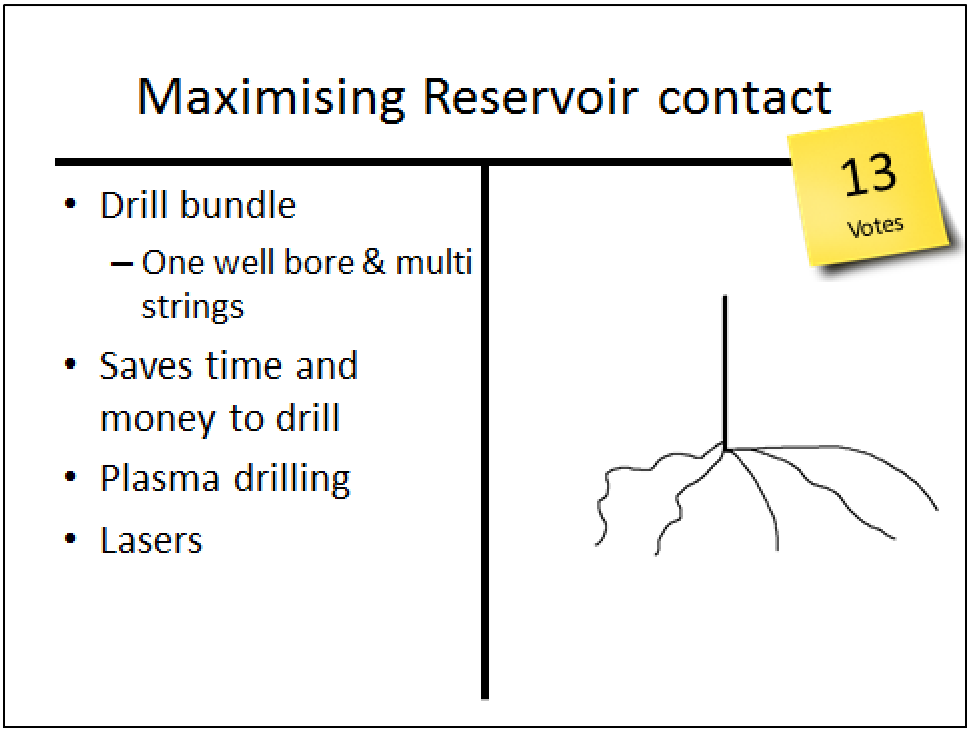
Challenge for hackathon

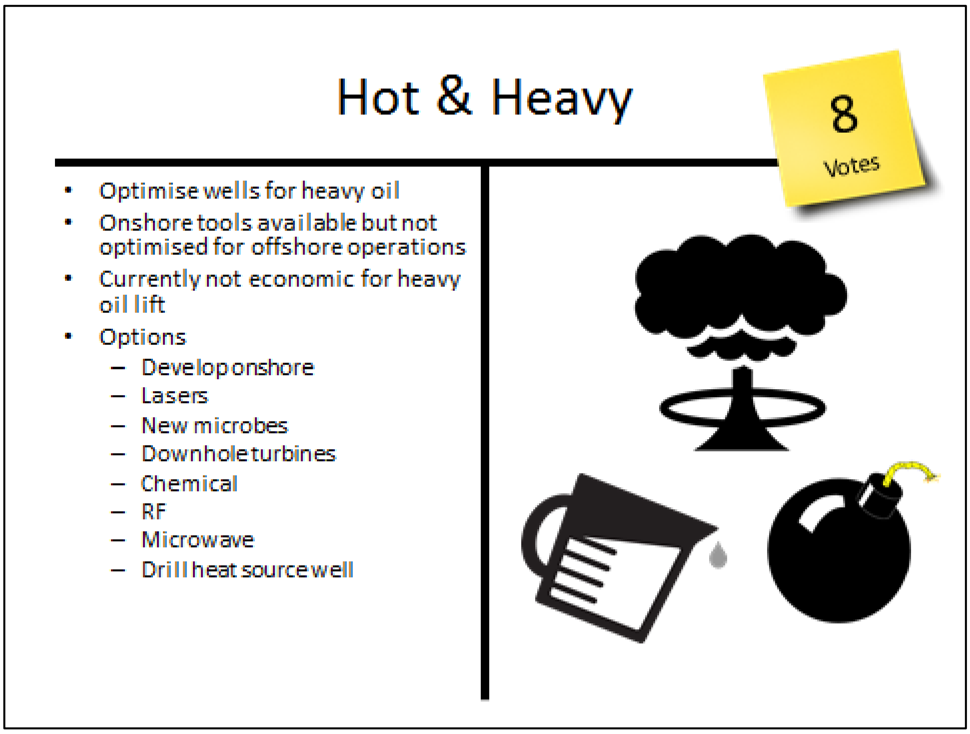
We are seeking innovative technologies that can be deployed to maximise the volume of hydrocarbons we can ultimately recover from a well.

Summary of Top Ideas Generated

Idea	Votes Received
Maximising reservoir contact – main well bore and multi string off it	13
Hot & heavy – optimise wells for heavy oil	8
Downhole gas generation – to help gas lift	7
Tree roots – multiple small diameter capillaries	6
Keep it local – downhole oil / water separation, and reuse water downhole	4

T-Bar Ideas

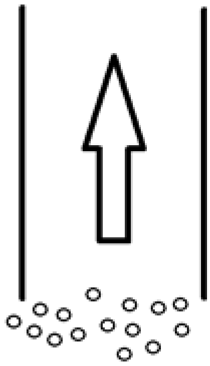

Maximising Reservoir contact
13
Votes
• Drill bundle
– One well bore & multi strings
• Saves time and money to drill
• Plasma drilling
• Lasers


Hot & Heavy
8
Votes
• Optimise wells for heavy oil
• Onshore tools available but not optimised for offshore operations
• Currently not economic for heavy oil lift
• Options
– Develop onshore
– Lasers
– New microbes
– Downhole turbines
– Chemical
– RF
– Microwave
– Drill heat source well

Downhole Gas Generation

7 Votes

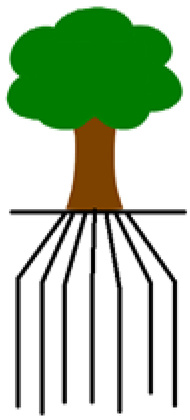
- Fuel cell
- Max flow
- Electricity
  - Power source downhole
- Micro organisms
- Cracking
- Self lifting
- Old & new installations
- The Effervescent well



Tree Roots

6 Votes

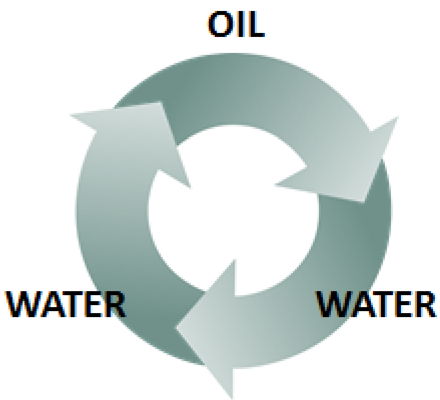
- Multiple capillaries to draw grand scale rather then local
- Small diameter
- Limits coning
- Maximising reservoir contact
- Extreme contact



Keep It Local

4 Votes

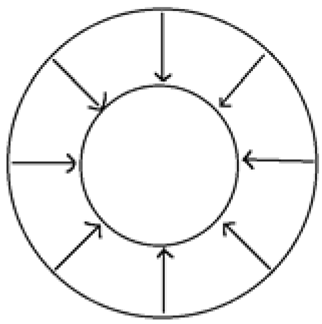
- Cutting water underground
- Downhole oil & water separation
  - Re-cycle into well
- Reduce topside maint. And OPEX
  - Use additives
  - Limit water /monitor
- Use vibration / shock to separate



The Morphing Tube

4 Votes

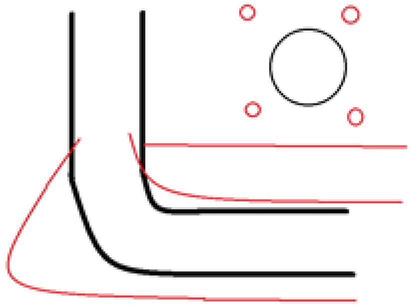
- Maximising Production Over Time
- Reducing diameter
- Original diameter not fit for purpose over life of well
- Auto reduces in size to meet spec
  - Mechanical
  - Fluid / Acid
  - Use water if swellable



Radial Injection System

2 Votes

- Creating system to charge up the formation
- Built from day 1
- Small injectors
- A plumbers guide



Keep it Flowing

2 Votes

- Optimise and invest in reservoir modelling
- Continuous monitoring
- Flow assurance

Water into Wine

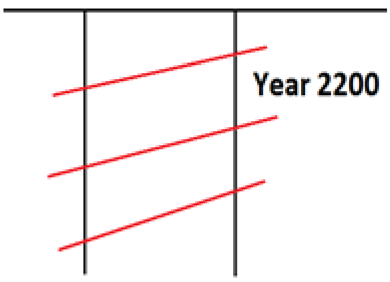
2
Votes

- Turn water into commodity and generate revenue
- Re-cycle water downhole
- Use to power downhole equipment with salt diff
- Water flooding

The self disposing well

1
Vote

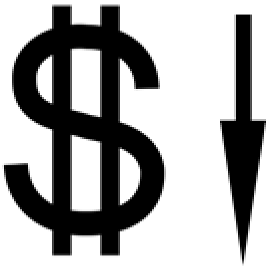
- Fit & Forget
- Self Abandons
- Do not need to spend to remove anything
- Can pump fluid to abandon
- Or materials all ok to leave



Show me the money

1 Vote

- More interventions
- Funding structure encourages higher life cost to lower upfront cost
  - Crowd funding
- Drone autonomous intervention
- Do it right first time
- Willingness to try new things
- Do field interventions for appraisal rather then 1 off



Thor's Hammer

1 Vote

- Change rock properties to increase permeability
- Freezing / cryogenics
- Vibration – Ultrasonic
- Smart Fluid
- Resin
- Acid / chemicals
- Liquid air expansion
- Expanding foam permeable

The Future Proofed Well

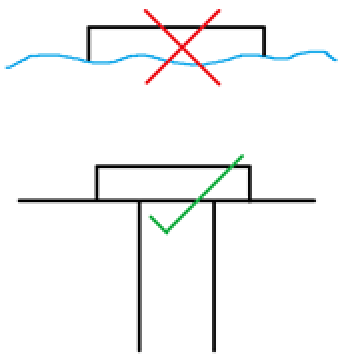
1 Vote

- Make the well "ready" for future drill activity
- Build with sufficient integrity so does not require full abandonment
- Option to look back in at future date
- Can last long time
- Ready for future tech

IT Sucks

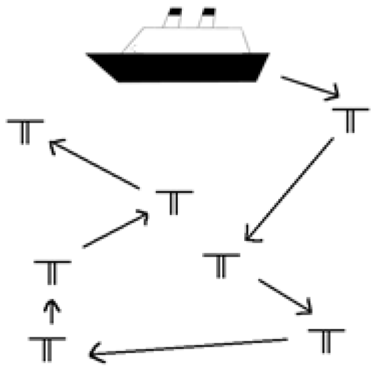
1 Vote

- Create suction on seabed
- Pumps to "suck"
- No requirement to "manage" topsides
- Based on seabed so no intervention
- Increased production



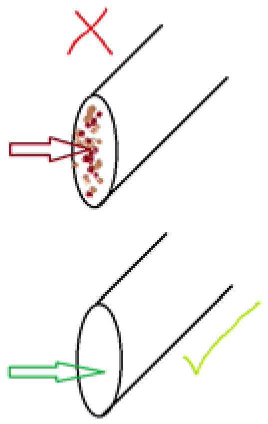
The Milk Run

- FPSO to go round submarine small wells & quickly extract volumes
- Not economic to do in isolation – needs economies of scale



The Slicker the Better

- Remove Obstacles
- Chose the right size completion
- Coatings to "encourage" flow up the well
- Slick production tubing



Hackathon in Numbers

1455 Email invites	**491** Email opens **34%** Email opens	**89** Attendees **660** Man hours	**82** T-Bar sheet ideas across **5** Challenge areas
6 Academic institutes in attendance	**50** supply chain and developer companies in attendance	**8** Operators in attendance	**4** countries attending

Appendix A: Explanation of Well Construction Process

This explanation will go from the point where an oil company has identified a geological formation that it believes contains hydrocarbons; to the oil company extracting the hydrocarbons through a conduit to surface (either the sea bed or land).

An oil or gas well is created by drilling a series of decreasing diameter (36" to 3") hole sections into the earth using an oil rig. After the hole is drilled the drilling assembly is pulled out of the hole (tripped out), and the wellbore is secured with a steel liner pipe, called casing. This pipe is supplied in short lengths 30-50ft and is threaded at both ends. This is screwed together and lowered, not drilled into the finished position and is marginally smaller than the diameter of the well bore. Liquid cement slurry is pumped down the casing pipe using a bottom plug, cement slurry, a top plug and drill mud. The pressure from the drill mud causes the cement slurry to move through the inside of the casing out through the bottom of the well. The slurry then reverses up around the outside of the casing (annulus) to fill the space between the outside of the casing and the drilled hole. Finally, the cement is allowed to harden and then tested for hardness, alignment, and a hydraulic seal.

Well construction continues in stages: drilling, running and cementing new casings, then drilling again. This cemented casing provides structural integrity for the newly drilled well bore in addition to isolating potentially hazardous and unstable zones from each other and from the surface. With trouble zones safely isolated and the formation protected by the casing, drilling of the well can proceed deeper (into potentially more unstable or abnormally pressured formations) with a smaller diameter bit. This drill bit is conveyed to the bottom of the hole through the casing in place and is smaller in diameter than the inside diameter of the casing. This section is also subsequently cased off with a smaller sized casing. This process can be repeated two to five times, with increasing hole depth and decreasing casing size (decreasing depending on the internal diameter of the previous conduit) each with a cemented casing.

Generally casing is run from well bottom to the surface; but the cement may not be pumped all the way to surface, just pumping the amount needed to cover the bottom part of the well which is open to the formation. Eventually the depth is reached where it is known or surmised there are hydrocarbons present. In a success case the well can then be completed to provide a controlled conduit to surface for hydrocarbons.

A drilling rig contains all necessary equipment to circulate the drilling fluid, hoist and turn the pipe, control down-hole pressures and remove cuttings from the drilling fluid. It also generates power for these operations. The basic steps to actually drilling a hole involve screwing together the drill bit, drilling collars and drill pipe and lowering into the hole; attaching the top-drive (a power swivel) commencing circulation of drilling fluid down the pipe and out of the bit to transport cut material (cuttings) out of the hole; and then commencing drilling. As drilling progresses, new 95ft sections (joints) of drill pipe are added as the hole gets deeper. Trip out the drill pipe, drill collar and bit when the required depth is reached or a change in the drilling assembly is required.

The success of drilling a hole depends greatly on the performance of the drilling fluid being circulated around the well bore. As the industry moves into deeper offshore areas and also drilling deeper more complex wells the performance of the drilling fluid becomes much more critical. The correct formulations, maintenance and performance of the fluid can strongly influence the total cost of a well. Depending on operations there are various functions, which a mud must perform. This is true regardless of which hole section we are drilling, although the emphasis changes in different hole sections.

Controlling formation pressure is the drilling fluids primary function and must be engineered at a density so that it holds back the pore pressure throughout the open borehole without fracturing the formation. It must also prevent caving of the formation as it is desirable to have the hole we have drilled to be as close to the gauge as possible. This makes the hole easier to log, helps to ensure that the casing is properly cemented in place, and minimises mud costs. If the hole collapses during drilling, there is a danger of the pipe becoming stuck. Too low a mud weight may allow the walls of the hole to fall in. The hydrostatic pressure exerted by the mud must match or exceed the formation pressure. Mud chemistry is also important; reactions between the mud and the formation may cause the formation to swell. The extra pressure from the formation swelling may cause caving. In order to minimise loss of fluid to the formation the mud must contain suitable solids that form a protective mud cake which builds up on the borehole wall and prevents mud seeping into the formation. How easily cuttings are removed from the hole depends on the size and weight of the cuttings. It also depends on the flowrate, or more correctly, the annular velocity. In term of properties, cuttings removal depends on the viscosity of the mud. Muds with higher viscosities clean the hole better. The mud weight also plays a part. With higher mud weights, the buoyancy factor is greater. The cuttings have fewer tendencies to drop back down the hole, and are more easily carried to surface. A mud must also suspend cuttings when circulation stops. To suspend cuttings when circulation stops, the mud must have a gel structure. Gels are not the same viscosity. They are a property of the static mud. Viscosity is a mud property when it is moving. Too strong a gel structure can cause problems with breaking circulation and with swabbing (drawing in fluid) when tripping. Mud weight is also a factor: at higher mud weights, there is more buoyancy and the cuttings are closer to floating. The mud must also suspend the other solids that it contains for example Barite, a weighting material.

When sensors in the drilling assembly and rock cuttings reveal oil, the reservoir rock may have been reached, the drilling apparatus is then removed from the hole and several tests performed to confirm the finding. Well logging involves lowering an electrical cable with a string of various sensors on the end to the bottom of the well. Taking core samples of rock to directly determine the characteristics of the reservoir rock, or a well test where fluids are produced to surface and tested.

In a success case, with a discovery of hydrocarbons, the well can be ‘completed’. Completion is the process by which the well is prepared for optimal production of hydrocarbons. The area above the reservoir section of the well is isolated inside the casing, and connected to the surface via the pipe of smaller diameter, named the production tubing. In many wells, the natural pressure of the subsurface reservoir is high enough for the oil or gas to flow to the surface. However, this is not always the case, as in depleted fields where the pressure has been lowered by other producing wells, or in low permeability oil reservoirs. Installing tubing with a smaller diameter may be enough to facilitate production, but artificial lift methods may also be needed. Common solutions include down hole pumps and gas lift. The way a well is completed depends heavily on the rock type the hydrocarbons are found in. For limestone reservoir rock, acid is sometimes pumped down the well and out the perforations. The acid dissolves the limestone creating channels through which oil can flow into the well. For sandstone reservoir rock, a fluid containing proppants is pumped down the well and out through the perforations. Once the oil is flowing, the oil rig is removed from the site, and production equipment is set up to extract oil from the well.

Appendix B: List of Attendees

Thanks to the following persons, who form the ‘Low Cost Well Construction’ workgroup, for organisation of the event:

Margaret Copland – Oil and Gas Authority
Malcolm Banks – Oil and Gas Technology Centre
Katy Heidenreich – Oil and Gas UK
Fraser Evans – Engie
Neil Jack – Shell
Ben Foreman – ITF
Pauline Hailstones - ITF

Thanks to Centrica and the following Centrica ‘Pioneering Practitioners’ for facilitating the five stations

Alan Littlejohn
Alistair Currie
Jessica Thompson
Phil McCaffrey
Vincent Verlinden

Thanks also to the five subject matter experts who ran the five challenge stations and provided expert feedback to participants in each working session.

Phil Davies – LR
Paul Davidson – Shell
Mike Hartley – Engie
Boris Thomas –Shell
Ian Crossland – Resman AS

Attendees

Abraham Salazar	ANA Engineering Ltd
Alasdair Campbell	Well Wizards Ltd
Alex Kemp	University of Aberdeen
Alex Neame	Centrica
Alistair Montgomery	Centrica
Anders Bak-Jensen	Danish Hydrocarbon Research and Technology Centre
Andrew Mackay	NRG Well Management Ltd
Andrew McHardy	Blue Skies Energy Resources Limited
Angela Mathis	Thinktank Matters
BABS OYENEYIN	ROBERT GORDON UNIERSITY
Bill Cattanach	Oil and Gas Authority
Carlo Procaccini	Oil and Gas Authority
Charles Leslie	Blade Energy Partners Ltd (UK)
Claudia PIEMONTE	TOTAL E&P UK
Colette Cohen	The OGTC
CRAIG FORREST	Emerson Process Management
Craig Usher	Centraflow
Darran Falconer	Centraflow
David Hartney	Oil and Gas Authority
David Roberts	2H Offshore Engineering Ltd
Donald MacArthur	Fraser Well Management
Drummond Lawson	Subsea Technologies Limited
Duncan Hart	The Datalab
Frank Allison	FIS360 Ltd.
Gary Couples	Heriot-Watt Univ
Graham Stott	Emerson Process Management
Hassan Mansir	COREteQ Systems Ltd
Helen Lewis	Herriot Watt University
Helen Tulloch	HVM Catapult
Iain Lees	Resolute Energy Solutions
Iain Maclean	Zi-Lift Ltd
Iain Sutherland	Nexen-CNOOC Ltd
Ian Phillips	OGIC
JAMIE AIRNES	Ithaca Energy (UK) Ltd
John Hunter	Tendeka
John Youles	Oil and Gas Authority
Joseph Hawkins	COREX
kabiru Jega Hassan	University of Salford
Katie Macdonald	Oil and Gas Authority
Ken Canning	Rochling Engineering Plastics (UK) Ltd
Ken Horne	Multilateral Solutions
Ken Stewart	Rotech Holdings Ltd
Louisa Dahmani	Baker Hughes
Mark Maylin	3-Sci Ltd
Matt Manning	Well-Centric
Mohammad Yasir	Halliburton/Landmark
Neil Robertson	Crondall Energy
Ola Michael Vestavik	Reelwell, Stavanger, Norway
Pamela Forgie	Subsea Deployment Systems Ltd.
Patrick O'Brien	ITF
Paul Cantwell	University of Strathclyde
Paul Goodfellow	Shell UK
Paul Howlett	SUDELAC
Paul Knight	National Nuclear Lab
Paul Lynch	Delphian Ballistics
Paolo Nunzi	ENI UK
Ralph Clark	i-spot
Reginald Minton	Mosarric Services Ltd
Reza Sanaee	Robert Gordon University
Richard Harris	Technip UK Ltd
Richard Neilson	University of Aberdeen
Ross Lindsay	Halliburton
Sarah Roberts	Xcite Energy Resources
Scott Petrie	Analysis Logic Limited
Sidney Johnston	SPEX Group
Steve Ham	The Underwater Centre
Stuart Berry	Paradigm Geokey
Stuart Brown	Independent
Stuart Ellison	Exnics
Sylvia Buchan	Oil and Gas Authority
Thomas Devaraj	IHS Markit
Tristam Horn	Deepwater Oil Tools
William Kilpatrick	Frazer-Nash Consultancy

Appendix C: Additional Ideas Generated

Challenge	Idea
Rock Cutting And Transportation	Reduce the amount of cuttings by drilling / adding laterals and not having to drill top hole sections
Rock Cutting And Transportation	Bit that selectivly chooses PDC or rock bit charactertics. Based on rock strength / type
Rock Cutting And Transportation	Maximise ROP by reducing overbalance e.g. Managed Pressure drilling
Rock Cutting And Transportation	Produce drill bits that create smaller chips for removal
Rock Cutting And Transportation	Core to total depth
Rock Cutting And Transportation	Bigger cuttings are harder to remove, bit design to create "rock flour" (v.small cuttings / powder) which remain in mud system. Less risk of cutting bed, no requirement to clean holes at connection.
Rock Cutting And Transportation	Reverse circulate to improve cutting removal
Rock Cutting And Transportation	Use cutting as aggregate +? To case hole as you go
Rock Cutting And Transportation	Follow jetting technology as the similar for perforation. More intrusive drilling fluids (environmentally hazzards).
Rock Cutting And Transportation	Case as drill - smaller holes - HP similar to jetting
Rock Cutting And Transportation	Cuttings transportation internally. Use coring system to take cuttings up bore - reverse circualtion. Not effected by washout sections
Rock Cutting And Transportation	Make cutting smaller and inject them into the formatiuon as you drill.
Rock Cutting And Transportation	Drilling tool in BHA for live rock analysis, combined with data matrix. This would allow drilling optimisation automatically.
Rock Cutting And Transportation	Cutting transport, minimise the amount, hole hze drilled, therefore minimise cuttings. Exploration wells in very small hole size.
Rock Cutting And Transportation	Drill bit changed and drillstring capable of transporting cuttings, change the concept of transportiation using the drill string
Rock Cutting And Transportation	Offshore remanufacture for worn parts, impact spares carried.
Rock Cutting And Transportation	Maximise bit on bottom time. Minimise tool failure
Rock Cutting And Transportation	Smart control for stick slip and bit bounce
Rock Cutting And Transportation	Tools in string that measure ECD at intervals along drill sting. Flow can then be diverted to clear cuttings bed as soon ans they are formed, no human interventin required
Rock Cutting And Transportation	Feedback sensor for drill bit, to control weight, hydraulics and speed
Rock Cutting And Transportation	Highest ROP with PDC bit, so need to protect them. Cutters with sensors controlling WOB, RPM and flowrate. Cutters that can estimate rock strength and adjust paramenters
Rock Cutting And Transportation	Water jetting / ice setting. Local source or imported treated water.
Rock Cutting And Transportation	Chemical reactions. Injecting high temperature to soften rock face prior to contact of drill face
Rock Cutting And Transportation	Compacting rock while drilling, while drilling compact part in to channel generated
Rock Cutting And Transportation	High frequency small displacement hydraulic hammer - no cuttings push rock out of way
Rock Cutting And Transportation	Reduce strength of rock by vibration "resonance enhanced drilling"
Rock Cutting And Transportation	Drill many small diameter holes to same reservoir
Rock Cutting And Transportation	Use hopper fed explosives (gatlin-gun) to break through harder rocks
Rock Cutting And Transportation	Use lasers to cut rocks-may allow larger chunks to be pulled out.
Rock Cutting And Transportation	Use microwaves (hi energy) to boil the water in rocks to help crack rocks
Rock Cutting And Transportation	Use high voltage electric discharge to help fracture rocks
Rock Cutting And Transportation	Sonification: High power ultrasonics at cutting face; or use high power ultrasonics to change viscosity along annulus - drillstring with seneors required; or to create smaller cuttings
Rock Cutting And Transportation	Use casing to drill and transport cuttings up centre and leave in hole when target reached
Rock Cutting And Transportation	High side restriction. Change flow regime and increase flow velocity on low side.

Challenge	Idea
Wellbore isolation	Swelling elastomers and shales
Wellbore isolation	Single string with structural cement
Wellbore isolation	Question if isolation required for all, production life relative isolation technique
Wellbore isolation	Tunnel construction spray cement as you drill
Wellbore isolation	Reactive mud that penetrates the formation for isolation (permanent) through chemical means. Other tools to systematically test these zones.
Wellbore isolation	Plastic pipe and downhole 3D printing
Wellbore isolation	Examine whole process concern with creating fractures in drilling process. Cement may not case this as wellbore is now unstable.
Wellbore isolation	Examine formations to be drilled and create a roadmap process, can then examine use of drilling motors etc.
Wellbore isolation	Look to other industries if something better then cement material and process wise is being used.
Wellbore isolation	Logging concerns - do we need to log? Review the fluid flow paths during drilling - use of circulation subs to allow different fluids in different sections. Treat different sections with flow modifiers.
Wellbore isolation	Use coated casing that is triggered to seal by use of a signa. Wireless valve technology to open / close casing valves, (like stage cementing) to allow fluids to go to certain areas.
Wellbore isolation	Look at formation damage. Purposely undertake formation damag. Fix the wellbore walls. Pump certain fluids proir to cementing. Use a packer system to inject into certain areas.
Materials for downhole equipment	Flow assurance material - scale and wax cannot adhere to. Chemical reactive coating
Materials for downhole equipment	Use titanium and 3D print
Materials for downhole equipment	Use various tubing thickness to suit - a tapered string
Materials for downhole equipment	Coat to suit application: gas injection wells , water wells, CO2 injection
Materials for downhole equipment	Ensure the material is suitable for application. Cas by case e.g. no sand / particles no need for erosion capacity
Materials for downhole equipment	Spoolable flexible tubulars. Use carbon steel and coat it.
Materials for downhole equipment	Coatings - continues glass coating galvanising.
Materials for downhole equipment	Coat the tubulars: with carbon fibre; epoxy; resin ; fibreglass
Materials for downhole equipment	Alter existing materials, beat corrosion, erosion use of flexible tubulars
Materials for downhole equipment	Implant to release over period of time. Hydrophobic coating like on car windscreen
Materials for downhole equipment	Corrosion cracking step away from metals: "living materials"; carbon nanotubes; graphite,regenerating aerospace
Materials for downhole equipment	Self healing elastomers, swelling. Robust enough to take load and deal with different temeratures / fluids
Materials for downhole equipment	A catalyst that reacts to scale / wax. Decomposing layers that fall off, taking the scale / wax with it. At micron level
Materials for downhole equipment	Most expensive failures. Anything that requires a rig / vessel. Removal of tree/tubing /casing
Materials for downhole equipment	Sacrifical anode. Smooth surface to make it difficult for scale/wax etc to deposit on pipe. Electrical current to change chemical properties

Oil & Gas Authority

www.ogauthority.co.uk