* 20 April 2010 – introduction
  + Series of unfortunate events + bad decisions + dangerous actions + equipment/safety failures 🡪 gas + oil pouring over rig platform 🡪 ignition + explosion (fire inextinguishable) 🡪 rig lose control + begin to drift 🡪 drill pipe ripped out 🡪 safety shutoffs failed in numerous ways 🡪 oil from undersea field began to spew unchecked into ocean (continued for months)
  + Consequences – largest oil spill in US waters
    - 11 crewmen killed from explosion on rig
* Engineering aspects of accident
  + Understanding the catastrophe is first step in preventing another
  + Decisions need to be based on knowledge and actual facts
* The process + equipment of deep-water drilling
  + BOP – blowout preventer – main control of well
    - BOP – only direct control mechanism on well (5000 ft below rig)
    - Riser – 5000 ft long pipe between rig and BOP, allows mud circulation down to BOP, allows for casing to go through
      * Provides no mechanism of control at surface, where it is attached to vessel, all of control of well is at BOP
    - Deepwater Horizon – 5000 ft of open pipe 🡪 if crew or BOP allows hydrocarbons to enter the riser, it will come to the rig 🡪 NO PREVENTION AFTER HYDROCARBONS ENTER RISER
  + Dynamic positioning/anchoring of vessel
    - Deepwater Horizon – dynamically positioned vessel (motors + propellers continuously operating to keep in same location)
      * Vessel requires power at all time (was not an anchored vessel)
      * Lose power 🡪 thrusters shut down/insufficient capacity to go against current 🡪 NOT STATIONARY 🡪 NEED TO LET GO QUICKLY OF WELLHEAD
      * If need to drift away – let go of wellhead
        + Mechanism of MLRP separating from BOP
        + Mechanism of separating drill pipe – BLIND SHEAR RAM

Need to cut through pipe + blocks over the wellbore

* + Crew rotation (21/21, 12/12)
    - 126 people on board in 2 shifts
    - Every 12 hours they changed
    - Every 21 days new crew sent offshore (4 separate crew)
    - Deepwater Horizon – required around 60 ppl to operate vessel for complex task
  + Isolation from shore/office – anything required needs to sent out
    - Everything done on seafloor done through remotely operated vehicles (ROV)
      * Controlled from the surface (not in person)
  + Multiple contractors – many companies involved in drilling process, all need to coordinate at the same time
  + Expense – costing $600k per day, any delay costed money 🡪 affected work quality
* Issues causing accident
  + Cement job failed to seal off producing reservoirs + casing seal failed 🡪 hydrocarbons entered the wellbore
    - Cement job – no agreement between BP + Halliburton and unclear how it occurred (definitely failed to isolate the producing formation – hydrocarbons can’t go to wellbore except through cement)
      * Converting float collar requires excessive pressure – supposed to just require 400-700 psi, but required 9 attempts (one as high as 3000)
        + Pressurize against formations can cause fractures to form 🡪 ability to lose fluids 🡪 lose cement 🡪 lose ability to seal
      * Small pressure window required lightened cement
        + Well pressure must exceed pore pressure + must not exceed fracture pressure
        + Window is extremely small in Gulf of Mexico – high geo pressure 🡪 small margin of error
      * Lost circulation zones – losing fluids earlier in the process
      * Few centralizers
        + Require 21 centralizers to prevent channelling
        + Only 6 centralizers on board
        + 15 centralizers were requested, where on board, NOT USED
      * Logging crew to run cement bond log – common procedure
        + Determines if completed successfully – had the choice for it
        + Log was not done in the end
    - Casing seal – even with failure of cement, casing supposed to be closed
      * Even if hydrocarbons in the annular spacing around casing, seal should still prevent it from coming into wellbore
      * Sealed in 2 places – either one needs to fail before fluids going up casing (reports seem to go towards casing shoe – not recovered)
        + Cashing shoe – filled with cement + 190 ft long
        + Casing seal – sit below BOP + stops flow of fluid up the back, into the riser
  + Hydrocarbon inflow not recognized (even if they had the mechanisms to do so) 🡪 crew did not active the BOP early 🡪 hydrocarbon from wellbore entered riser
    - Once in the riser, they are definitely coming onboard
    - Two negative tests conducted, and accepted by crew as successful
    - Negative test interpretation made more difficult by pressure of unusual spacer
      * Spacer – separate mud from the water
      * Used lost circulation material LCM as spacer – they had 400 barrels
        + Dischargeable material – only if used in well 🡪 forced to use

Did not approve use of material

* + - * + About four times more material than usual
      * Spacer may have entered kill-line (used to monitor pressure levels in negative test) + caused anomalous U-tube pressures
    - No standard procedure for negative test
    - Pit levels confusing because of fluids being offloaded to service vessel
  + Gas found an ignition source and caused explosion on rig 🡪 caused fire + loss of power 🡪 loss of ability of dynamic positioning 🡪 drifted off station
    - Gas was diverted to MGS, instead of overboard diverter [BP]
      * Could have diverted hydrocarbons off to the side or divert them through separators 🡪 choose separators 🡪 meant hydrocarbons will come to rig
    - Engine room intake closure was not activated automatically on gas alarm
      * Safety devices to prevent hydrocarbon gas intake causing an explosion were manual
    - Engine overspeed 🡪 loss of power (+ source of ignition?)
      * Automatic governors on motors to prevent overspeeding
      * Governors shut off the fuel – fuel was provided through air intakes of engine + governors were not functional
  + BOP failed to seal well
    - If it managed to close, the rig would be in disaster but the wellbore would have been closed off
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* + - 3 modes of closure – if blowout
      * Manual function failed
        + Close on rig floor with hydraulic pressure (HP line)
        + Emergency disconnect system to automatically cut off everything (EDS)
      * Automatic function failed – supposed to activate with loss of communication to rig
        + Automatic Mode Function (AMF or Dead-man switch) automatically shuts it off with loss of power

Mechanism of MLRP separating from BOP

Mechanism of separating drill pipe – BLIND SHEAR RAM (BSR) – cut through pipe + block over wellbore

The one thing that had to work to prevent

* + - * + AMF was unsuccessful – had a battery duplex

Blue pod – had flat battery

Yellow pod – good battery but one of the solenoid valves used to close the BSR was not functioning

Neither of the 2 pods were capable of activating the BSR

* + - * ROV attempt failed
        + Can attach to the BOP, provide hydraulic pressure + activate rams using pressure from external

Hydraulic leaks on BOP – can’t activate Rams

* + - * + Once cut the auto shear pin, BSR did not cut pipe

BSR can only cut shear drill pipe – can’t casing or tool joint

Could have used the second shear ram below – can cut through all

* How to do it better – suggestions
  + Bureau of Ocean Energy Management – government
    - Cementing program + casing design must be certified by registered professional engineer
      * Was designed adequately, but was not installed the intended way
    - Take more care examining BOP
  + American Petroleum Institute – industry body
    - Negative tests should be run in a specified manner
    - Make sure that what is in the bore of the BSR is something that is shearable
    - Test BOP before it’s put on the ocean bottom and continue to test it when it is on the ocean bottom
    - Make sure the ROV has sufficient hydraulic power to operate Rams
      * Had to bring in extra accumulators to operate the Rams
  + Lecturer suggestions
    - Second BSR – backup BSR and independently activatable
    - Independent BOP activation control (audio wave activation/sonor wave)
    - More comprehensive data from BOP (position of rams, contents of tubulars)
      * They couldn’t tell the status of the BOP (which rams were open/closed)
    - Real-time modelling of fluids + pressures in tubulars
    - Complete off-site transmission of data
      * Similar to black-box – what’s happening can be seen everywhere
  + Why not stop all of this?
    - ¼ of US oil production comes from deepwater oil fields
    - Outsourcing – other places are also doing deepwater
* Rather than who to blame, focus on how to fix the problem
  + Treat the problem as a systemic failure rather than an isolated failure