Reflections on the Gulf of Mexico disaster and other serious events in the offshore oil and gas sector from a risk assessment and risk management perspective

Keynote presentation

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PSAM 11 ESREL 2012
25 – 29 June 2012, Helsinki, Finland

Overview

Major hazard focus

- Background and challenges
- Brief history
- Trends in accidents & incidents
- Trends in modelling of major accidents
- Goal-setting regime
- Life-cycle perspective
- Main regulatory principles
- Modelling practices
- Could risk assessment have prevented Macondo?
- Barrier management
- Conclusions

Background

- Serious OO&G accidents since year 2000:
  - Capsize and sinking of Roncador P-36 (Brazil, 2001)
  - Burning blowout on Temsa field (Egypt, 2004)
  - Riser rupture and fire on Bombay High North (India, 2005)
  - Burning blowout on Usumacinta (Mexico, 2007)
  - Blowout on Montara field (Australia, 2009)
  - Burning blowout on Macondo field (US, 2010)
  - Pollution from well leak in Frade project, Campos Basin (Brazil, 2011)
  - Capsizing and sinking of Kolskaya jack-up during tow, (Russia, 2011)
  - Burning blowout on Endeavour jack-up platform (Nigeria, 12)
  - Uncontrolled well leak on Elgin platform in North Sea (UK, 12)
- Also several fatal helicopter accidents, during transit to offshore installations

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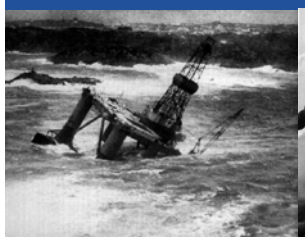
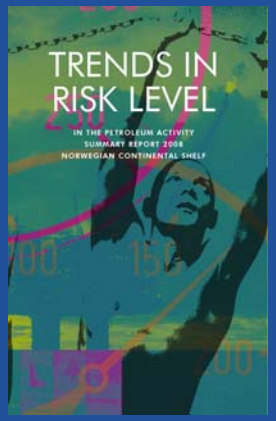
Recent trends worldwide – offshore

- 2001–10 compared to 1991–2000:
  - Notably fewer major accidents in earlier period
  - Most severe ever, the explosions and fire on Piper Alpha in the North Sea in July 1988 in previous decennium
- Is this total failure of risk management?
- Proof that risk based regulations do not function?
- Virtually all offshore regions are represented
  - Looking to the North Sea, North Atlantic, Norwegian Sea and Barents Sea
    - Most severe accidents occurred some 20 to 30 years ago
    - No severe accidents at all during the latest period



Risk Level project (N)

- Objective
  - Establishing a realistic and jointly agreed picture of trends in HES work
    - In order to support the efforts made by the PSA and the industry to improve the HES level within petroleum operations
- History
  - April 2001
    - 1. report issued, for period 1996-2000
  - January 2004
    - Responsibility for HES for offshore & onshore petroleum facilities taken over by Petroleum Safety Authority
  - April 2007
    - 1. report with 8 onshore plants included, based on 2006 data
  - 2010
    - Extension from risk to personnel to risk for spills to sea
  - Regular schedule
    - Annual reports (risk to personnel) issued in April
    - Separate spill report in September



www.ptil.no/rnnp

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Risk level project (RNNP)

- Major hazard risk one element of RNNP
  - Indicators suggest that major hazard risk has been reduced since year 2000
    - Precursor based indicators
    - Proactive ('leading') indicators based on barrier elements
  - On the other hand
    - Some installations are dramatically worse than average
    - Some are also exceptionally good
    - Large differences is a challenge for authorities
  - Modeling based on risk analysis R&D

Offshore risk management – success story?

- Impression
  - Norwegian & UK systems have been successful
    - Confirmed by Presidential Commission (US)
  - Large accidents have been avoided in NW Europe for long time
    - UK: after 1988
    - Norway: after 1985
- Is the situation so glorious as may be inferred from this?

Perspective: Alexander Kielland To Macondo

- Capsize and sinking of Alexander Kielland (Norway, 1980)
- Burning blowout on Macondo field (US, 2010)
- 30 years separation:
  - Capsize of the flotel Alexander L. Kielland in Norwegian North Sea
  - Burning blowout on Deep Water Horizon in US GoM
- Encompasses the development and use of risk assessments in risk management offshore

Brief history: Use of risk analysis (N)

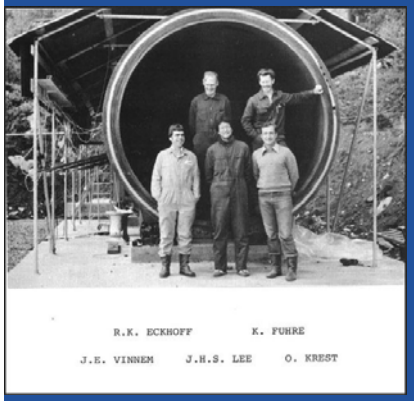
- Early start in late 1970s
- Regulatory requirement since 1981
- Approach initially based on practices in nuclear power plants
  - Usually no 3rd party personnel risk to consider offshore
- Development over time away from nuclear PSA approach
- QRA studies are not in the public domain
- Few cases where ethical controversies are known

- Offshore QRA
  - Focus on consequences (ignited HC leaks)
  - Limited focus on barrier failure probabilities
  - Causes of initiating events traditionally not covered

- NPP PSA
  - Focus on probability of defined scenarios
  - High focus on common mode & cause failures, etc
  - "Living PSA"

Brief history: Use of risk analysis

- Main application of risk assessments in the Norwegian industry in the 1980ties and 1990ties
  - Design tool, in order ensure that new installations had sufficient capabilities
    - To prevent major accidents and protect personnel in the case of such accidents
    - Significant investments in consequence modelling software tools, most well known is FLACS code



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Brief history: Use of risk analysis

- Official inquiry by Lord Cullen in the UK, following Piper Alpha accident in 1988
  - Recommended that QRAs should be introduced into UK legislation
    - Corresponding to the way as in Norway nearly 10 years previously
  - Parallel focus on documentation through Safety Case documents

Brief history: Use of risk analysis

- Safety case
  - Primarily a tool for risk management in relation to existing installations
    - Main focus on consequences, layout and mitigation barriers
  - Similar approaches also adopted by several other countries (Denmark, Canada, Australia,..) & Shell on a worldwide scale ('HSE case')
- Many countries, most notably US, still have prescriptive regulations

Events that made marks on history

- NPPs
  - Three Mile Island (1979)
  - Chernobyl (1986)
  - Fukushima (2011)
- Accidents that have had similar extensive impact for the offshore operations:
  - Capsize of Flotel Alexander L. Kielland, 1980
  - Capsize of Mobile Offshore Drilling Unit Ocean Ranger, ‘82
  - Explosion & fire on fixed production platform Piper A, ‘88
  - Burning blowout on Deep Water Horizon mobile drilling unit, 2010

Impacts on Standards and Practices

- Capsize of the flotel Alexander L Kielland
  - Basic safety training for personnel
  - Use of conventional lifeboats in severe weather
  - Construction safety
  - Barriers to prevent rapid capsizing following major structural damage

Impacts on Standards and Practices

- Capsize of drilling rig Ocean Ranger
  - Improvement of ballast system flexibility for stabilizing the unit in high inclination angles
  - Evacuation during severe weather conditions
  - Rescue of survivors following evacuation in severe weather

Impacts on Standards and Practices

- Explosion and fire on Piper Alpha
  - Active fire protection
  - Passive fire protection
  - Protection of Temporary Refuge (shelter area)
  - Barriers against high inventories in pipelines
  - Compliance with procedures & documentation

Trends in offshore QRAs (10–15 years)

- Very limited further development
  - Some further development of consequence tools
  - Precursor data and barrier performance data through RNNP (N)
- Development of tools and methods for incorporation of
  - Causes of initiating events within HOF envelop
    - HC leaks
    - Collisions with offshore vessels

Overall purpose
FPSO Operational Safety Project

- Develop models and tools for predictive human reliability analysis
- Test out methodology on selected case studies
- Illustrate results that may be obtained

Tandem loading configuration

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Objectives

- Demonstrate importance of HOF collision risk
- Identify and evaluate the important HOF factors
- Propose potential risk reduction measures relating to HOF

Sponsors:
ExxonMobil
HSE
Statoil
Navion

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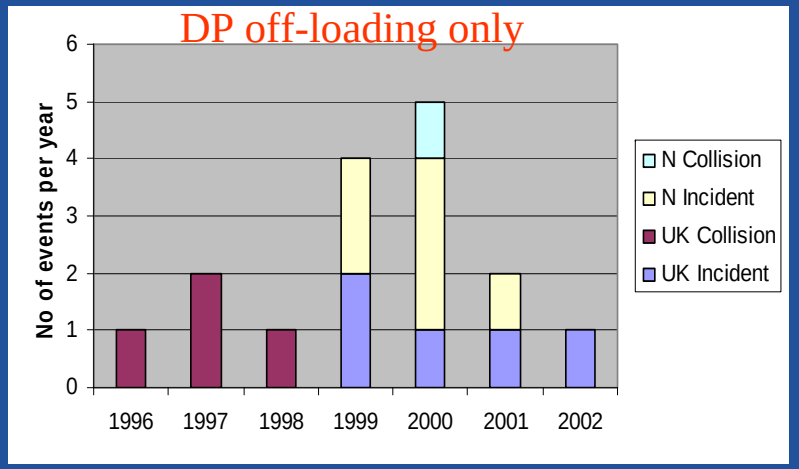
Importance

- Several incidents 1996–2001
- Low velocity impacts (high mass, up to 30 MJ)
- Cargo penetration unlikely
- Accident chain may imply very severe consequences
- After 2002, 2–3 minor accidents



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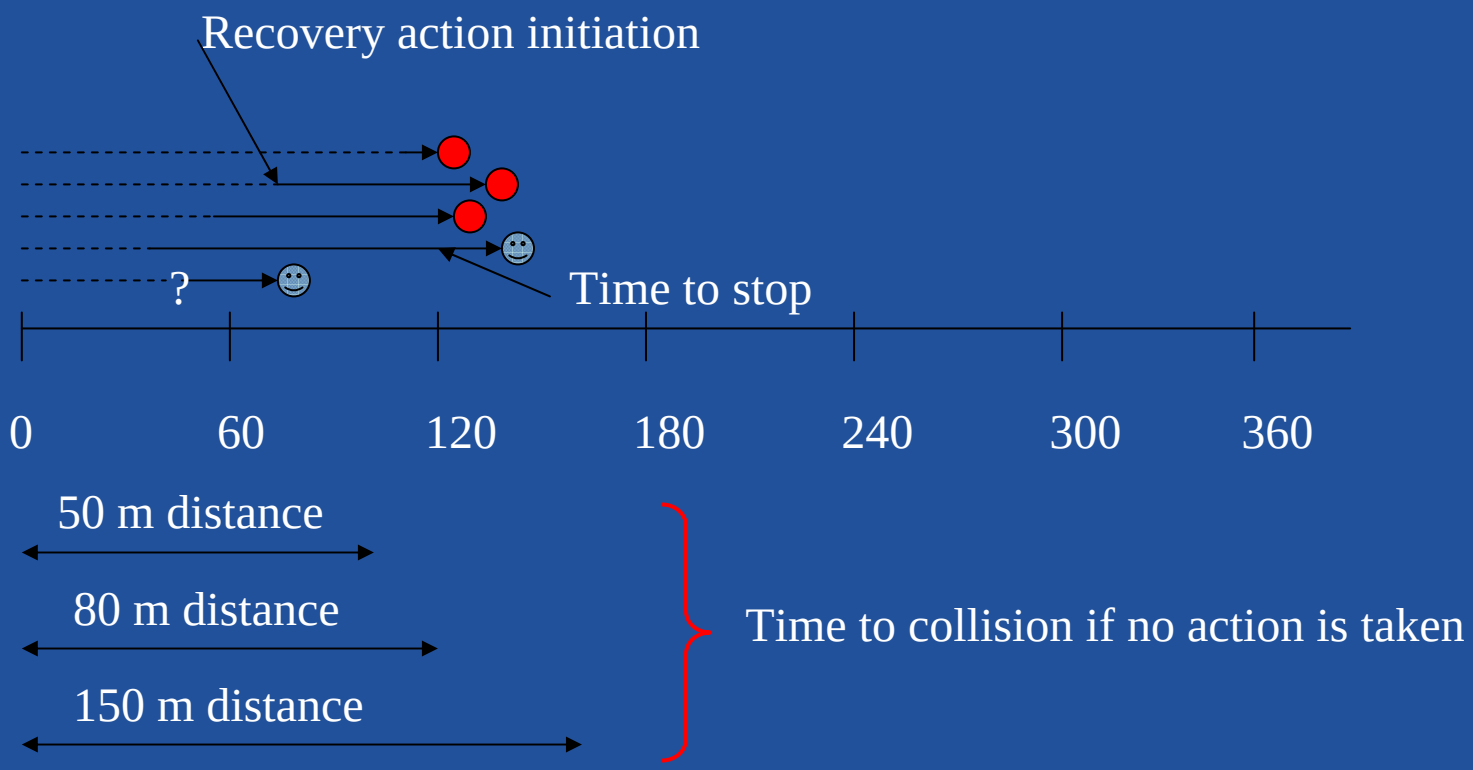
Comparison

Experienced times and maximum times available



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Risk Modelling, Integration of Organisational, Human and Technical factors (Risk_OMT)

- Ambitions for the Risk_OMT programme:
  - Extension of verification of barrier performance
    - From existing technical focus into a focus where operational barriers have similar weight
  - Provide sound quantitative basis
    - for analysis of operational risk reducing measures
  - Learn how the best managed installations
    - are achieving performance of operational barriers
  - Propose key performance indicators
    - enable identification proactively when operational conditions are deviating from a high standard

Project sponsors (2007-11):

- **Norwegian Research Council**
- **Statoil**

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Dependencies

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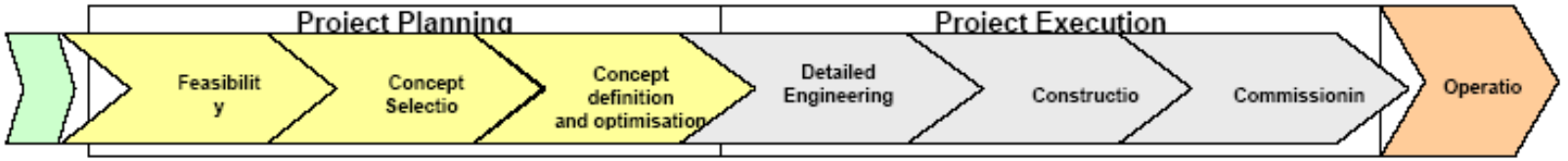
Use of Qualitative Studies

- Use of risk assessments in practice is strongly influenced by the use of qualitative studies for various purposes:
  - Hazard and Operability Study (HAZOP)
  - Safety and Operability Study (SAFOP)
  - Safe Job Analysis (SJA)
  - Preliminary Hazard Analysis (PHA)
  - Failure Mode and Effect Analysis (FMEA)

- Majority of resources to risk in lifetime
  - Insight into accident causation, prevention & mitigation
  - Motivating personnel involved in operations
- QRA main interest in remainder of presentation

Life cycle perspective

- The life cycle perspective is most obvious in Norwegian legislation, which apply for all phases of petroleum activity
- UK legislation has the same perspective
- The Norwegian legislation may be described as functional, risk-based (or risk informed)
  - Based on use of risk assessments in all phases



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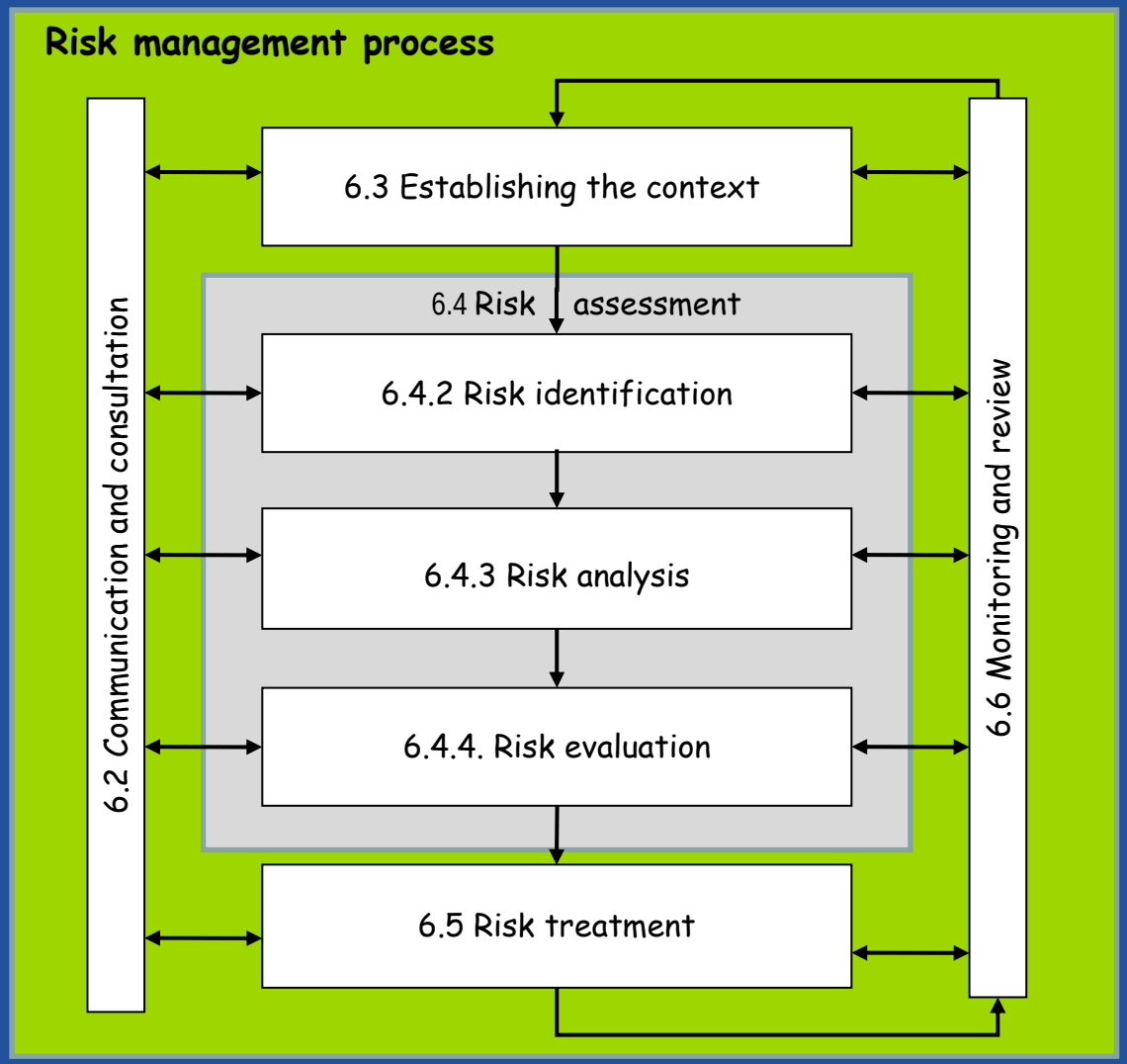
Offshore petroleum: Use of risk analysis

- QRA (quantitative risk analysis)
  - New development
    - Concept selection
    - Concept optimization
    - Engineering
    - Fabrication
    - Pre start-up (’as built’)
  - Operations phase
    - When modifications are implemented
    - Otherwise regularly (say every 3-5 years)
    - Prior to start of decommissioning
- Qualitative risk analysis
  - As design tool (HAZOP, etc)
  - As operational tool (HAZID, etc)

Goal-setting regime

- Implications of goal-setting approach:
  - Industry has more flexibility vis-à-vis fulfilling regulations & finding optimum solutions
  - Preventive and protective systems and actions may be tailored to relevant hazards
  - Models need to be available to distinguish between different levels of threats, and to tailor the solutions to the circumstances

ISO 31000 – Risk Management



- Also the basis for:
  - NORSOK Standard Z-013 Risk analysis and emergency preparedness assessment

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Main principles for HES legislation in Norway

- Internal control
- Functional, risk based regulations

- Initially implemented in petroleum sector
  - Considered to function well under NPD/PSA jurisdiction

- Adapted over time to societal safety in general
  - Does it function correspondingly well in this context?
  - No research appears to have looked at this

Internal control as basic principle

- Basic principle in HES regulations in Norway
  - Shall ensure that the activities are planned, organized, executed and maintained in accordance with applicable requirements
- Based on experience in petroleum sector, adopted in several other areas of societal HES
  - Good experience in petroleum sector

Internal control – challenges

- Internal control implies
  - Enterprises are the primary responsible for ensuring that requirements are adhered to, including laws and regulations
- Demanding control principle
  - Demands a technically competent and administratively strong authority
  - Most successful with enterprises with high competence level and high integrity

Experience with risk based regulations

- Petroleum industry
  - Mainly successful, some occasional challenges
  - Warning letter from PSA to all parties in 2007
    - Warnings about increasing trend of misuse
- Demanding approach, for enterprise, supervisory authority and public
  - Risavika LNG plant (N): total failure of risk based regulation
    - Severe flaws in enterprise's HES management
    - Unethical behaviour
    - None of the supervisory authorities have rectified defects
  - Several cases when public meets risk-informed regulations are challenging

Misuse of risk analysis in petroleum sector

- PSA:
  - Risk analysis primary use to identify & assess risk reducing measures in ALARP context
  - Risk analysis shall not be used to 'prove' acceptability of deviation from laws, regulations, standards, common practice, etc.
- HSE [UK] has made similar remarks
- Misuse
  - Was an issue in 1980s, with limited QRA experience
  - Reiterated warning in 2007

Robust regulations?

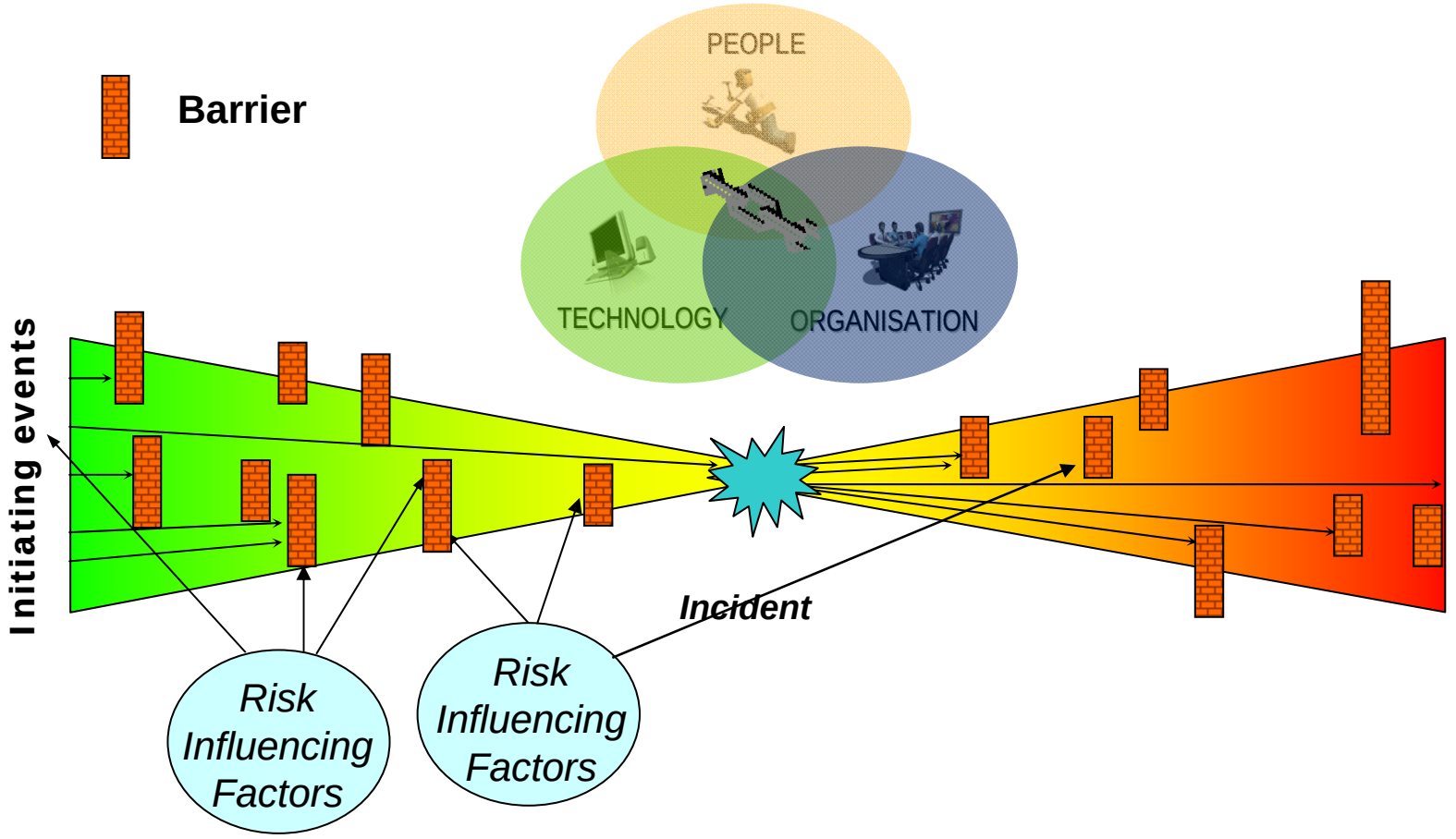
- Combination of internal control and risk-informed regulations appear to be fragile and far from robust combination for
  - Industry
  - Authorities

- No apparent focus in research

Modelling practices

- Hydrocarbon hazards
  - Causes of initiating events
  - Barrier systems reliability and availability

Modelling practices



Source: Statoil

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Modelling practices

- Hydrocarbon hazards
  - Causes of initiating events
  - Barrier systems reliability and availability
  - Fire & explosion load modelling
  - Event sequences and escalation
  - Structural fire & explosion response
  - Human fire & explosion response
  - Fatality risk

Could risk assessment prevented Macondo?

- Presidential Commission makes reference to North Sea legislation as possible model for US
  - ≈2 years after the accident:
    - no change so far
  - Some are sceptical that anything will change

Could risk assessment prevented Macondo?

- Reflections on this question
  - PSA has confirmed that Macondo accident could have occurred in Norwegian sector
  - Several incidents/accidents during 2004–10
    - Full blown subsea gas blowout in Nov. '04 on Snorre A (Norwegian North Sea)
      - Lack of compliance with procedures one root cause
      - Also one of success factors of the well killing operations

Could risk assessment prevented Macondo?

- One of the common factors in recent well associated incidents & accidents:
  - Lack of proper risk assessment to
    - Identify criticality of various factors and deviations from plans & procedures that have to be made
- Common factor with the Macondo accident
  - Failure to assess risk as basis for MOC one crucial failure
- Effective management of major accident risk is strongly dependent on
  - Adequate modelling (i.e. insight) of hazard mechanisms
  - Stringent management of barriers throughout field life

Could risk indicators prevented Macondo?

- Parallel with Texas City refinery explosion, where occupational injury statistics had been used to monitor major hazard risk
- Deepwater Horizon had been 7 years without significant occupational injuries
- Norwegian petroleum industry (RNNP)
  - Indicator for blowout risk based on occurrence of kicks (influx from high pressure zones into wellbore)
    - Typically 1 per 20 regular wells drilled
      - Deepwater wells (possibly up to 1 per 3 wells)
    - Insufficient to monitor performance in well drilling

Could risk indicators prevented Macondo?

- Study in recent R&D project has shown:
  - Blowout probability strongly influenced by
    - Inadequate planning of well operations
    - Inadequate management of change during drilling operations
- How should indicators be defined?
- Even if we had indicators
  - Would they be able to identify in time?
    - Failures of well planning
    - Failures during management of change during drilling operations

Could risk indicators prevented Macondo?

- Reference to Snorre A gas blowout (2004)
  - Undetected failures
    - Reentry into well planned without realizing leaks in casing
    - Risk assessment bypassed due to lack of resources
    - Failures were not detected before operations started
  - Unignited gas blowout
    - No injuries, no spill
    - Top kill within few hours, before ignition
      - Ignition could have caused total loss of installation and very extensive spills
- No indicators were able to identify well planning failures
- Is indicators the right way to go?

Could risk indicators prevented Macondo?

- Skogdalen et al.: possible use of major accident risk indicators to prevent accidents like Macondo
  - Many essential barrier elements are operational
    - Evaluation of the negative pressure test, which is one of the examples of the crucial misinterpretation of the tests
  - On every occasion that the drilling crew were supposed to make decisions balancing efficiency and risk (Pres. Com.)
    - Decided in favour of efficiency
      - thereby each time increasing the risk of a blowout
      - at the end failed to detect indications that there was a serious problem under development

- It appears very demanding to develop indicators that could have picked up this development

Risk assessment of drilling and well operations

- PSA has repeatedly claimed that risk assessment tools used by the Norwegian petroleum industry are not suitable for operational decision-making
  - Survey (PSA, 2009–10) pointed to need for further development of risk analysis tools
    - Usable as input to day-to-day decisions on installations; minor modifications, maintenance and interventions
  - Same observation would be applicable also for drilling operations

- Large difference between the NPPs and offshore installations with respect to development of online risk monitoring

Risk assessment for operational decision-making

- Simplistic or detailed modeling?
- Illustration
  - Decisions on how to install long process lines
    - Alt. A: Welding work
      - implies increased ignition risk during installation
    - Alt. B:, 'Cold' installation methods, flanged connections
      - may increase leak probability over remaining life cycle
- Can robust decisions be made without detailed modeling?

Risk assessment of drilling and well operations

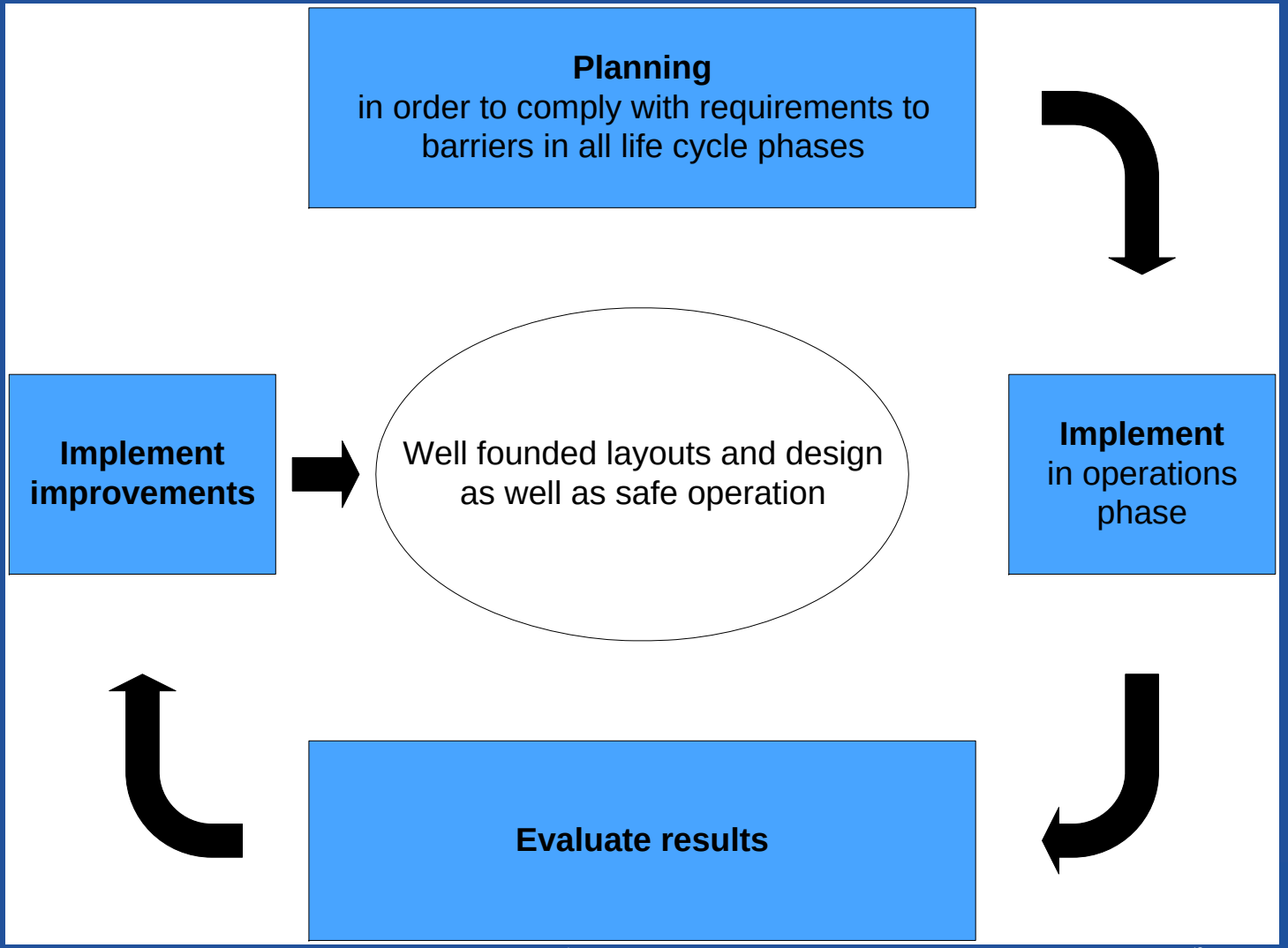
- Online risk monitoring for management of operations, maintenance and modifications to facilitate decisions relating to:
  - When a leaking valve needs to be repaired (example)
    - Whether it needs to done immediately in order to control the major accident risk
    - Whether it can wait for some time for the next scheduled plant shutdown

- Online risk monitoring of drilling and well operations is altogether another league
  - Models are not available at all
  - Extensive research effort is needed to develop suitable models

Barrier management

- PSA in follow-up after the Macondo blowout proposed also development of a scheme for barrier management
- Barrier failures were also obvious on the Deep Water Horizon mobile drilling rig, such as failure of blowout preventer (BOP)
- Lack of proper management of barriers is also common in the Norwegian industry (PSA)

Barrier life cycle perspective



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Barrier management

- Management of barriers (ref. PSA) dependent on proper modelling in planning phase
  - Implies that inadequacy of risk models for drilling and well operations will also prevent the basis for barrier management to be established
- Lack of proper risk models will also limit how well risk indicators could be developed

Conclusions

- Prevention of major accidents most effectively through risk-informed decision-making
  - US & others should follow after UK & Norway
- Probably not a coincidence that severe accidents and incidents
  - Have occurred worldwide during the last ten years
  - Not in NW Europe

Conclusions

- Threat from EU to 'throw out' all the good experience in UK and Norway
  - Directive proposal apparently mainly aimed at environmental spill protection
- Step back from risk-informed to compliance basis
- Industry is probably partly to blame
  - No focus for many years to develop suitable risk based tools, especially for drilling and well operations

Conclusions

- Modelling of barrier performance is area where substantial improvement is needed
  - Grossly inadequate, especially for drilling
- Improvement of risk-informed management of major hazard risk in day-to-day decision-making

Conclusions

- Can major accidents be eliminated?
  - No, one can occur tomorrow even if the probability is very low
- Risk-informed decision-making more advanced for process plant operation
  - Even in this area we have identified significant development needs
  - Drilling and well operations less well developed
- Possibility to learn from NPPs