On the Development of the Blowout Preventer PRA Model

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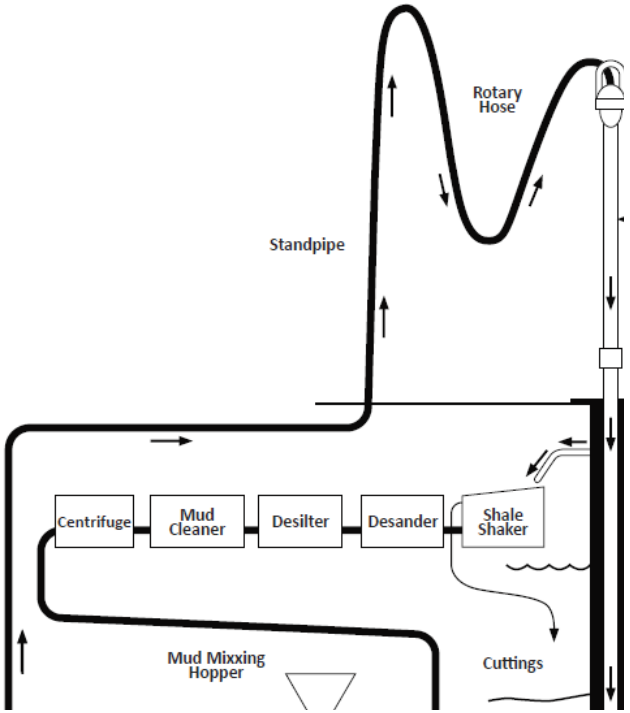
Agenda

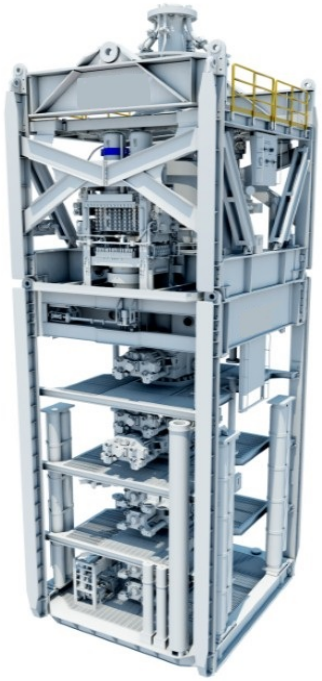
- Background – Offshore Well Control
- BOP System Description
- BOP PRA Model Development Process
- Results from the BOP PRA
- Summary

Offshore Well Control

Well control – a means of preventing uncontrolled influx of formation fluids, a kick, into the wellbore during drilling.

- **Primary well control - maintaining the fluid column hydrostatic pressure above the formation pressure**
- **Secondary well control - Blowout Preventer (BOP) system / barrier integrity**

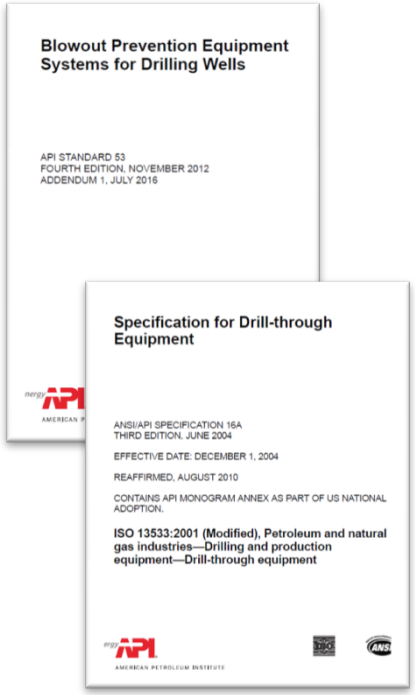




Why BOP PRA at Anadarko

- **Development of the 20,000 psi rated BOP equipment**
  - Anadarko 20K BOP equipment internal approval
  - Design selection of BOP control system
  - BSEE 20K BOP equipment approval

- **Gulf of Mexico Daily Rig Operations**
  - Anadarko internal approval for unplanned situations
  - BSEE “alternate compliance” approvals
    - BSEE 21 day BOP testing approval request
  - Reducing Human Factors risk
  - Identifying and justifying equipment upgrades



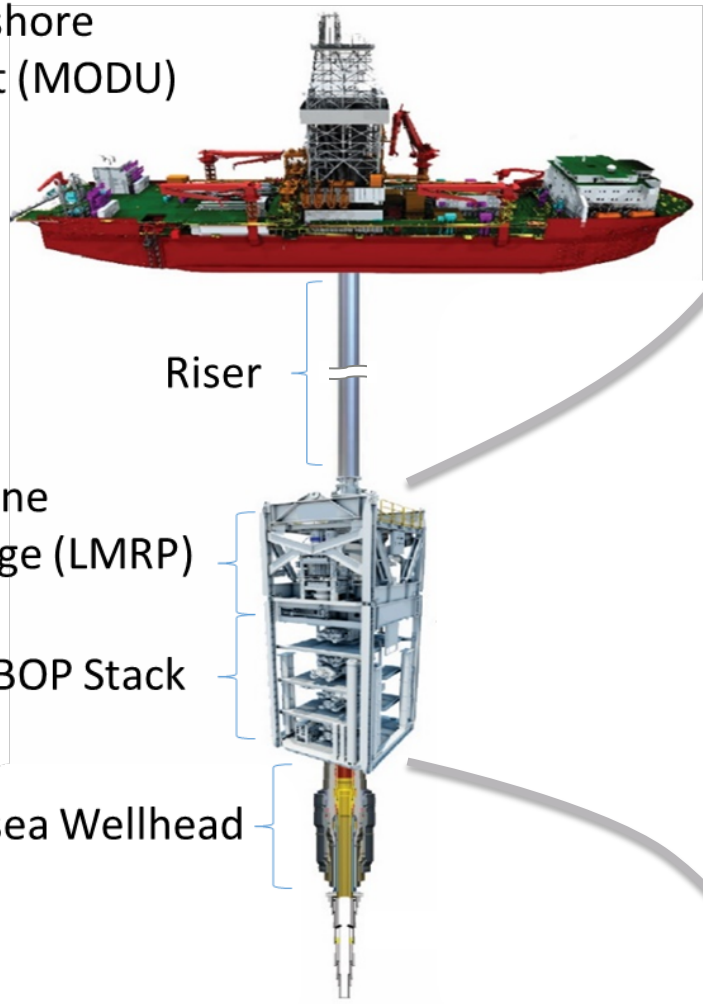
BSEE
Bureau of Safety and Environmental Enforcement

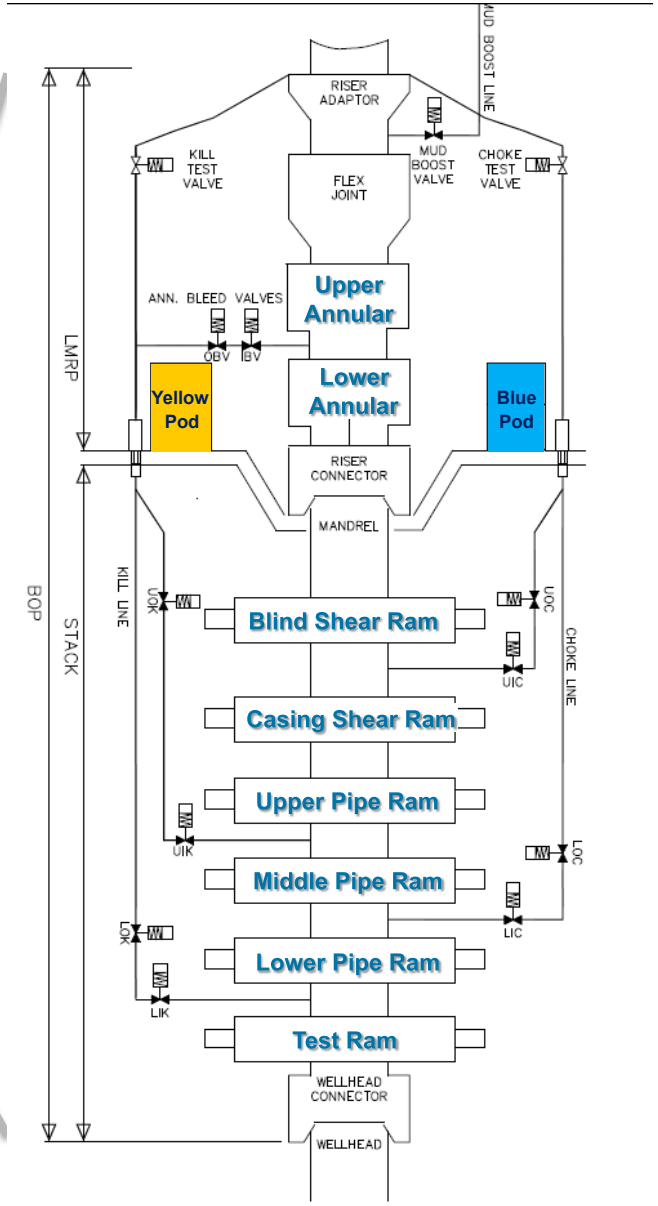
The Anadarko PRA Development

- **Space Act Agreement with NASA**
- **Small Anadarko internal team to coordinate the process**
  - Cogoto, Inc. and The Frontline Group
  - Supported by both process and equipment SMEs
- **Phased approach for the generic PRA Studies**
  - Blowout Preventer (BOP)
  - Dynamic Positioning System (DPS)
  - Integrated PRA Model (expanded BOP and DPS)

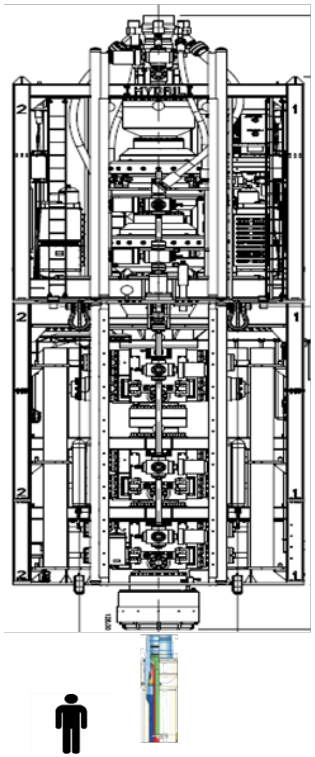
Drilling System: MODU and Subsea BOP

Mobile Offshore
Drilling Unit (MODU)

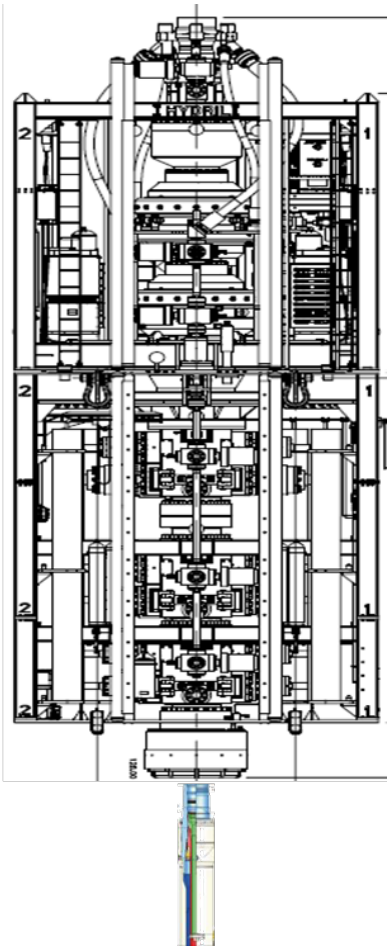




BOP System's Size



6th Gen BOP

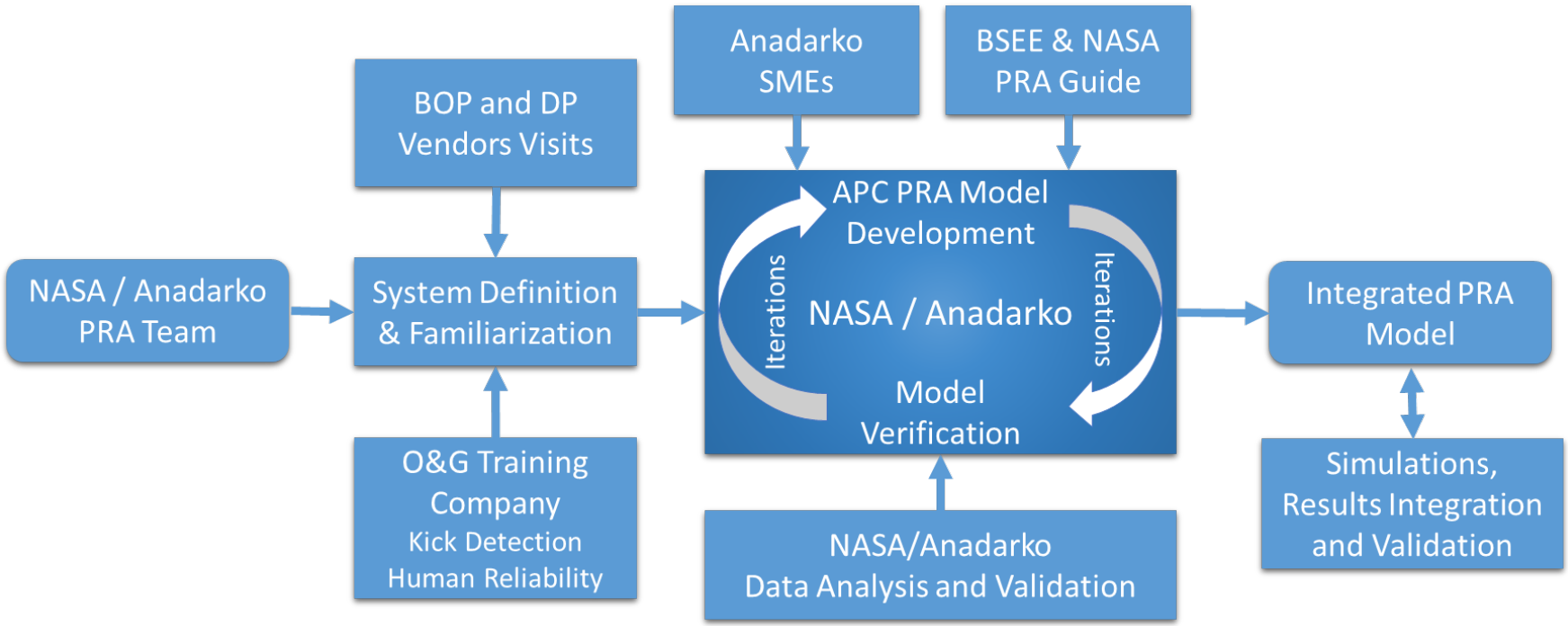


20K BOP

BOP Subsystems

Hydraulic Power Unit (HPU)

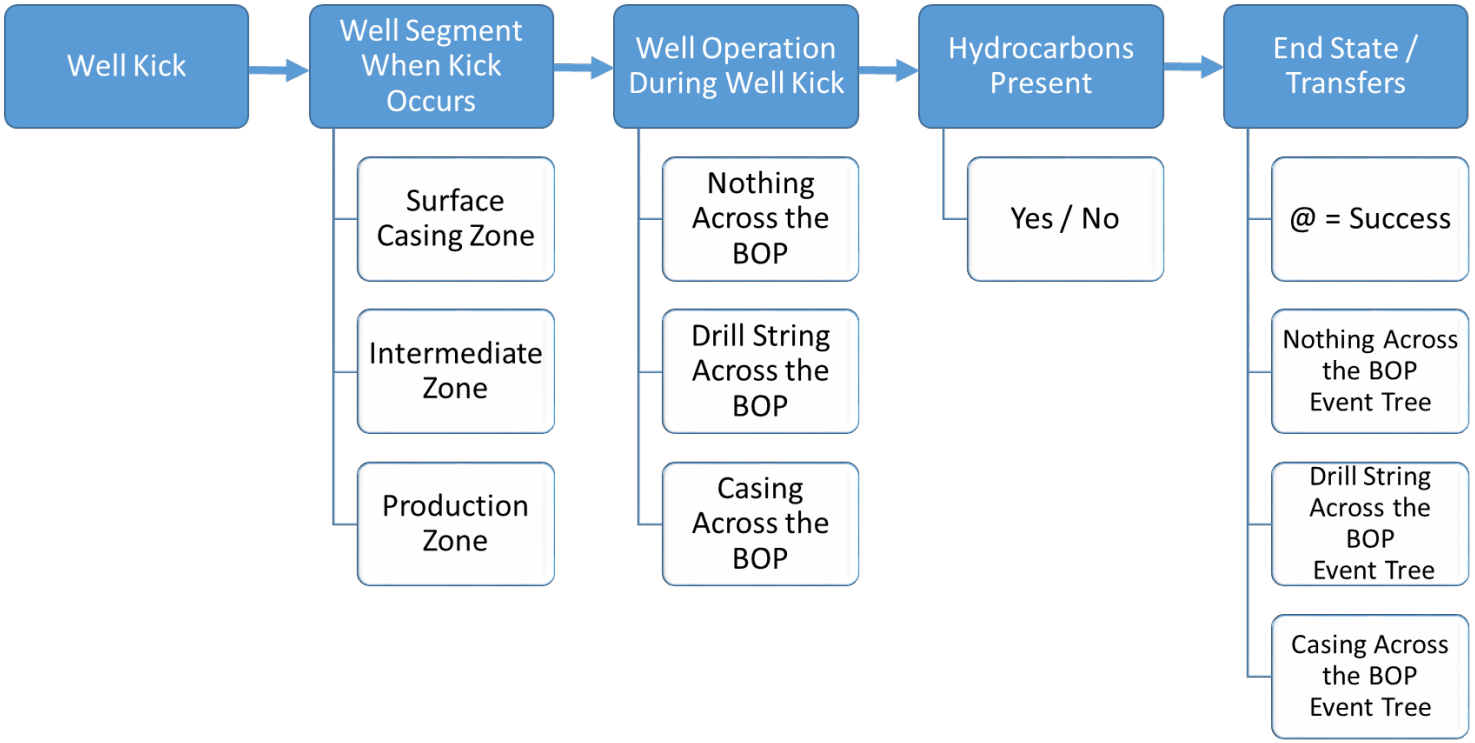
Integrated Model Development Framework



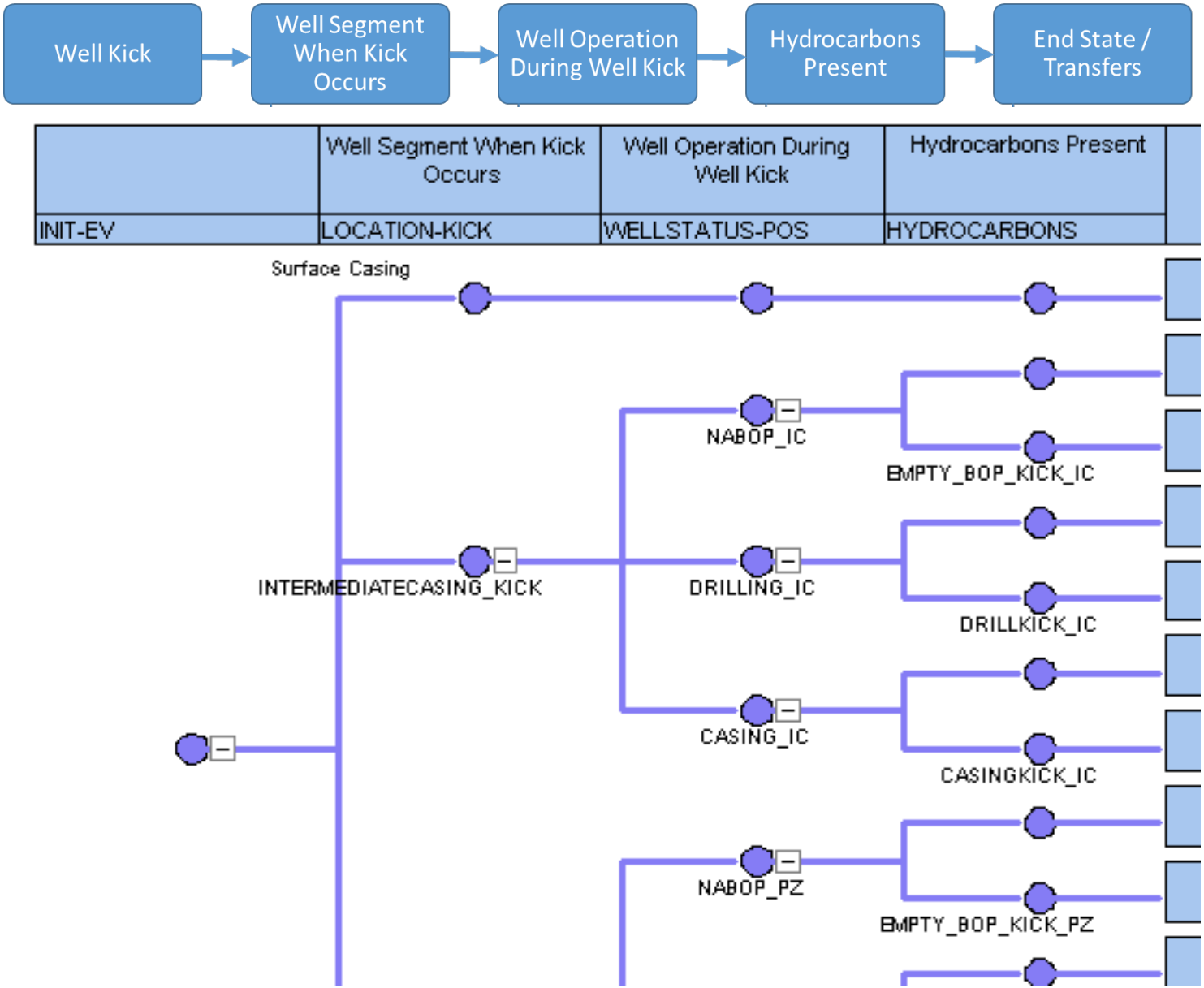
A collaborative and iterative process

APC – Anadarko Petroleum Company
SME – Subject Matter Expert

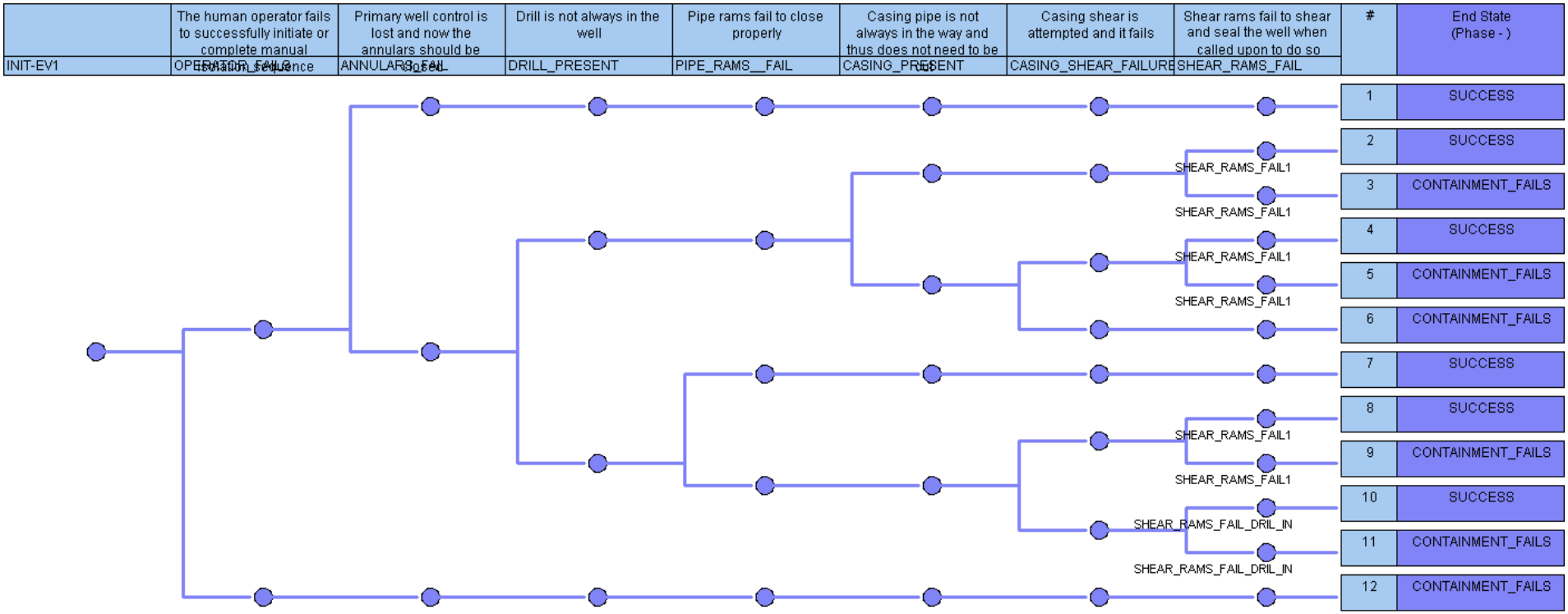
Well Kick Operational Conditions



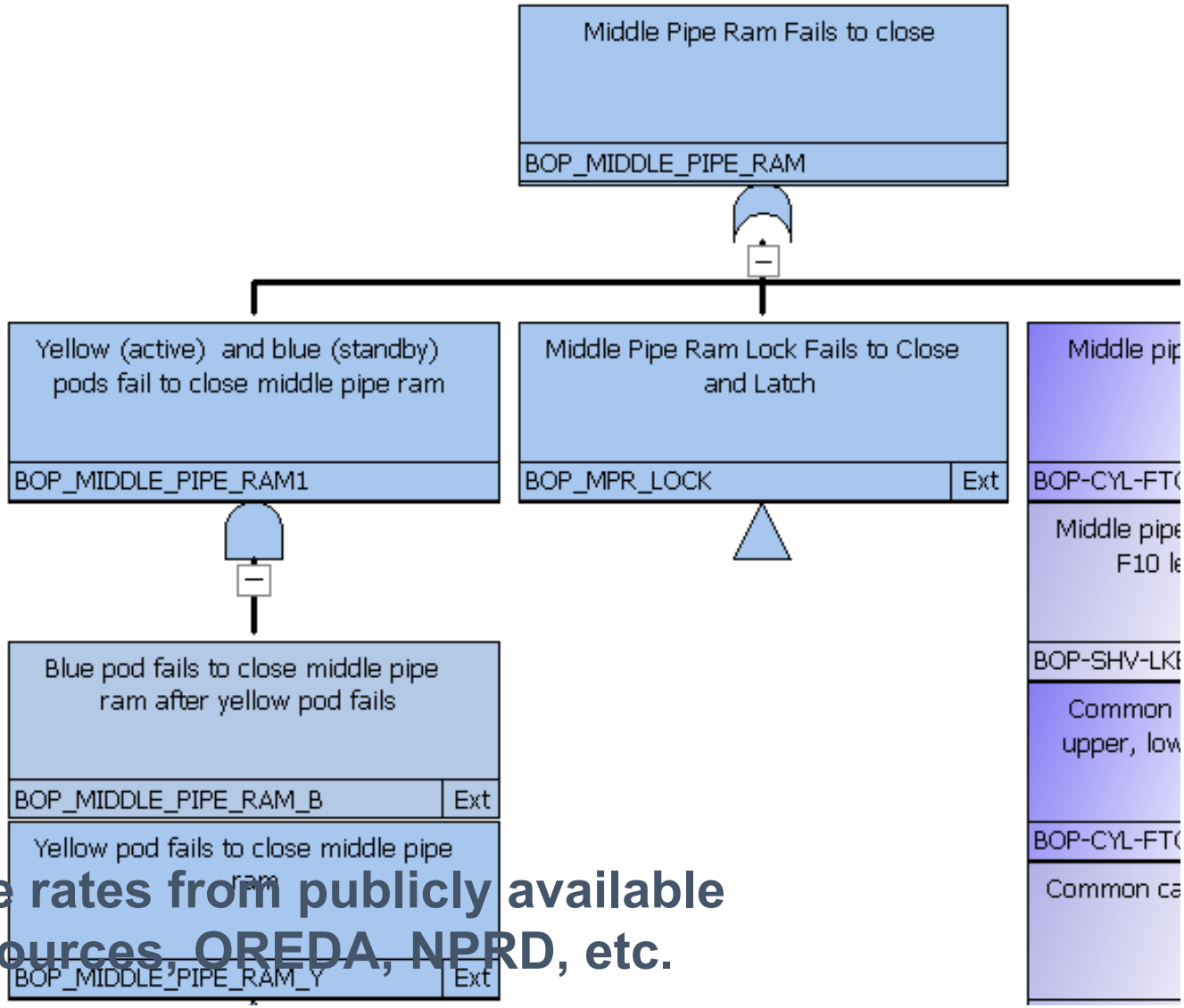
Well Kick Operational Conditions



Well Kick while Drilling Event Sequence



Example of a Top Fault Tree



Failure rates from publicly available data sources, OREDA, NPRD, etc.

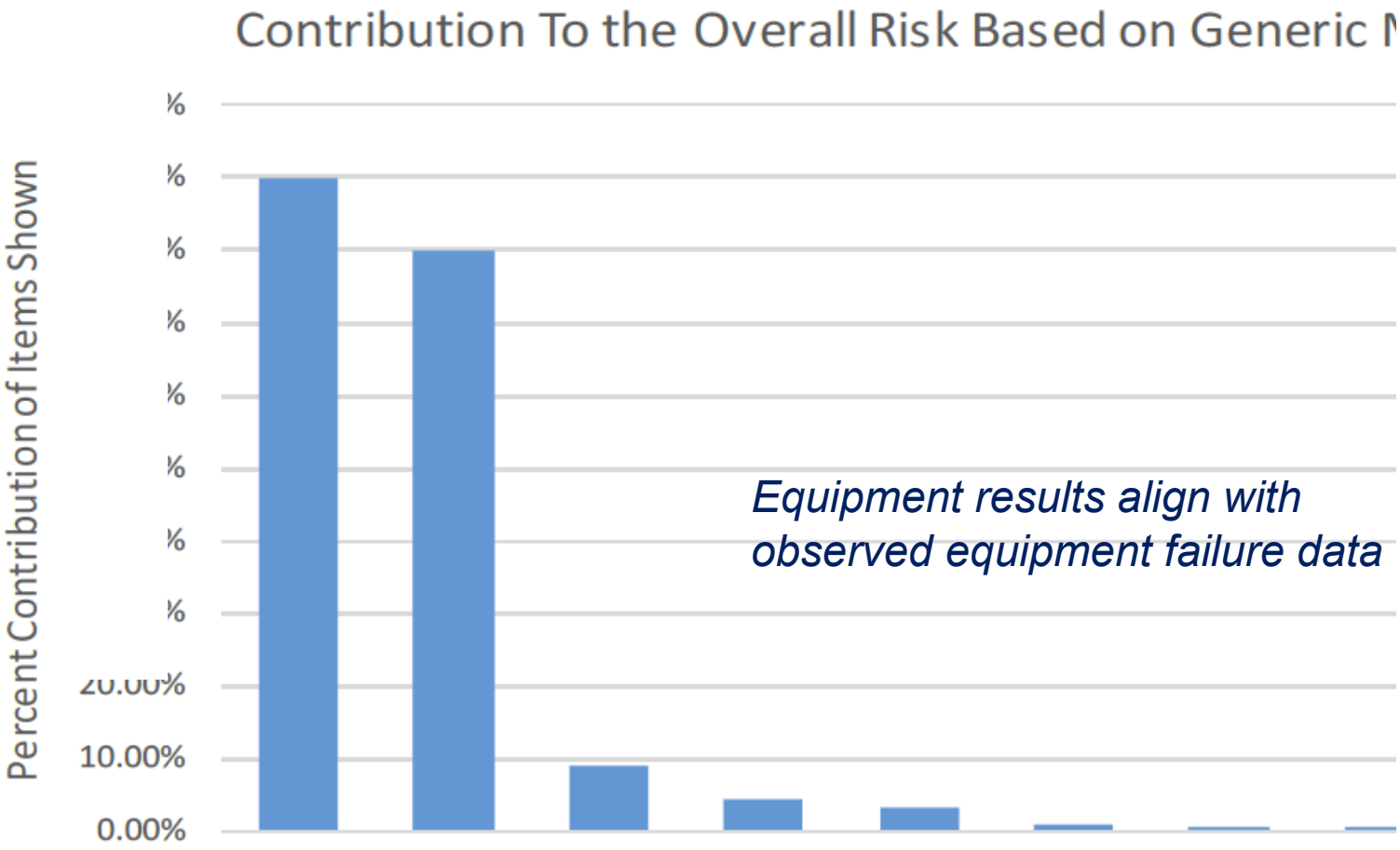
Human Reliability Analysis on Critical BOP Operations

- **Utilized CREAM for the HRAs**
- **HRA Scenarios:**
  - Kick detection and BOP closure response
  - Switching between the Yellow and Blue Pods
  - Initiating an Emergency Disconnect
- **Engaged Maersk Training for the kick detection and response HRA**

BOP PRA Highlights

- **Initiating Events: Well Kick and Loss of Position**
- **End States: Loss of Containment of Formation Fluids and Closure of BOP as the successful state**
- **Multiple Event Trees were developed as part of this analysis**
- **170 Fault Trees**
- **Over 1100 Basic Events, e.g.**
  - Solenoid / Pilot Valves Failure to Open
  - Shuttle Valves Leaks Externally
- **Over 17,000 cut sets generated from the model**
  - Using a truncation limit of 1E-10

Generic Model's Overall Results



Summary of Results

- **For the current model, the human is the largest contributor to the overall risk, thus confirming the O&G experience**
  - What was not expected was the magnitude of the human's contribution to the overall risk
- **Equipment contribution was not as significant as was expecting**
  - Multiple redundancies reduce the impact of equipment failures
- **The generic model has proven to be great starting point for specific MODU and BOP PRAs**

Lessons Learned

- **Assure adequate upfront time for familiarization of both the system and the process**
- **Engage process experts from outside of the industry for a different perspective and internal experts with knowledge of both O&G and PRA methodology**
- **Establish a standardized and simplified naming convention**
- **Expect multiple updates and iterations to improve the PRA model**
  - Using a collaborative process and phased approach to model development

Thank you!