PSAM 14

PROBABILISTIC SAFETY ASSESSMENT AND MANAGEMENT CONFERENCE
September 16-21, 2018

OIL AND GAS INDUSTRY I SESSION

Modeling the Risk of U.S. Offshore Oil & Gas Exploration-Well Drilling, Commercial Nuclear Plants, and Human Spaceflight

Roger Boyer, Robert Cross - Johnson Space Center (JSC) Safety & Mission Assurance (S&MA)
Forrest Shanks, Mike Worden - Bureau of Safety & Environmental Enforcement (BSEE)
Robert Youngblood - Idaho National Lab (INL)

Introduction

- Nuclear power, offshore oil & gas exploration, and human spaceflight all have high consequence potential if something goes wrong
- Each has had at least one major incident that pointed to a need for improved risk assessment
  - Careful risk analysis is very important for technologies having complexity, uncertainty, and high consequence potential
- All rely on multiple barriers/controls/redundancy to minimize risk

Nuclear PRA Background

- The first commercial nuclear power station in the US went on line in 1958
- Siting, redundancy, and evaluation of worst case design basis accidents used to manage risk
- WASH-1400 first full scope PRA done in the 70's
- Three mile island accident revived interest in PRA
- NRC has moved towards risk informed regulation with PRA as a major input

US Offshore Drilling PRA Background

- Offshore drilling in the US started in 1896 off California
- Thousands of offshore wells have been drilled since, many in the Gulf of Mexico
- US offshore drilling, until recently, has relied heavily on qualitative risk assessment
- Macondo event in 2010 led the Bureau of Safety and Environmental Enforcement (BSEE) to explore the use of PRA with NASA
- Other areas of the world do use more quantitative techniques for offshore facilities, e.g. North Sea

Human Spaceflight PRA Background

- US human spaceflight had its first launch in 1961
- In the 60's, testing, testing, and more testing was used to ensure system/component reliability
- The Challenger accident in 1986 led NASA to explore the use of PRA for risk management
- Currently, NASA uses PRA requirements for Loss of Crew and Loss of Mission to evaluate vehicle designs and mission anomalies

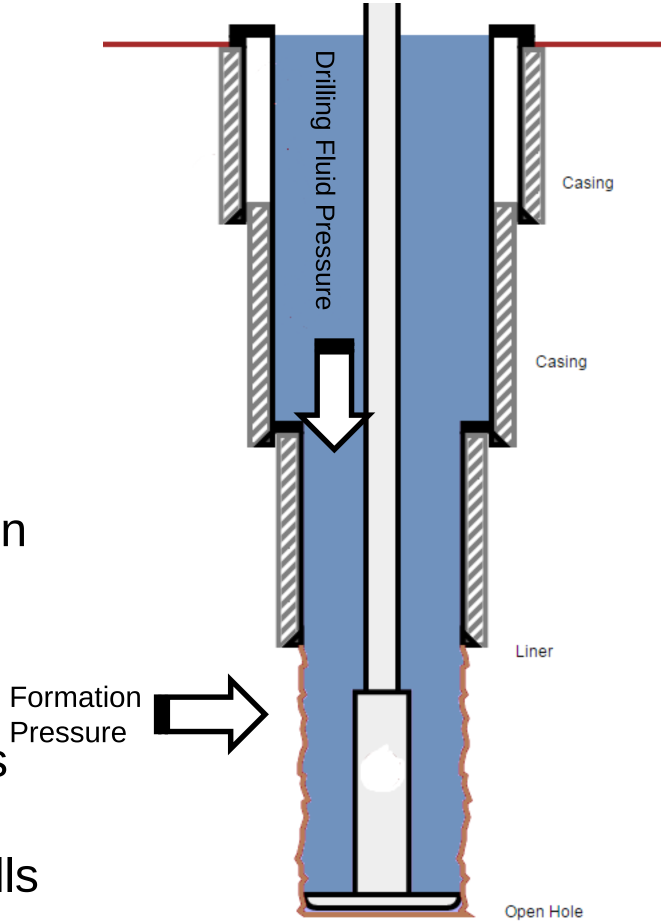
Nuclear Power:

- Where's the risk – Failure to cool the core, failure to contain radiological releases
  - Other risks such as shutdown risk during outages exist, but the main concern is at power.
- What events challenge the safety margin – Internal events that cause, or should cause, a reactor trip (e.g. turbine trip, loss of service water, etc.), external events (e.g. loss of offsite power, earthquakes, etc.)
- Key figures of merit – Core damage frequency, large early release frequency

Offshore Drilling Modeling Approach

<u>Offshore exploration drilling:</u>

- Where's the risk – In offshore drilling, an excessive pressure differential between the formation and the borehole can lead to a "kick," or an underground blowout
  - Other risks include offshore production facilities with similar potential consequences, dropped objects, etc.
- What events challenge the safety margin – Exploration wells have a higher level of uncertainty as to the conditions that may be encountered and challenges can come from under or overestimating the required drilling fluid density, equipment failures leading to loss of position, or severe weather. Getting more challenging with High Pressure/High Temperature wells (>350F, >15,000 PSI)
- Key Figures of merit – Expected casualties, Loss of containment frequency, expected spill volume



Human Spaceflight Modeling Approach

Human Spaceflight:

- Where's the risk– For human spaceflight, no one metric stands out that can be equated to the major concern.
- What events challenge the safety margin – Human spaceflight success is largely driven by functional reliability across a number of different functions (propulsion, life support, etc.). In addition, medical risks and external events may add significantly to risk, e.g. micrometeoroid and orbital debris (MMOD)
- Figures of Merit – Loss of crew probability, loss of mission probability

Key Similarities/Differences

Complexity:

- All three technologies involve highly complex equipment and human interfaces with both internal and external events to threaten safety margins. Redundancy is a key element of controlling hazards.

Potential Consequences of Failure:

- All three technologies involve the potential for loss of life. Nuclear power and offshore drilling also have great potential environmental consequences.

External Operating Environment:

- Very different environments for the different technologies.
  - Nuclear power plant environments are static and exhaustively studied.
  - Offshore exploration well drilling is remote and unique for each well. Geology is varied and water depths can be extreme.
  - Human spaceflight involves extreme environments from accelerations to microgravity to dealing with regolith (on the moon).
- Phenomenological events can be significant contributors to risk in all. e.g. nuclear – earthquakes, flooding, spaceflight – micrometeoroid/orbital debris, offshore – weather, borehole geology

Similarities/Differences

Human Interface:

- Humans critical in all three technologies.
  - Reactor trips are mostly automated, but humans in the loop for response.
  - For offshore drilling, humans critical for initially identifying challenges (i.e. kicks) to the operation as well as the response.
  - Human spaceflight is mostly automated for ascent aborts, humans critical for other operations (Shuttle landing, certain maneuvers).

Data:

- Data is most well developed for nuclear power, both component and external events. Human spaceflight and offshore drilling have component failure and external event data available, but collection/classification efforts could be improved.

Conclusions

- The potential consequences of failures in all three industries require that rigorous hazard identification and controls be employed.
- PRA has been found to be useful in nuclear power and human spaceflight. In the US, BSEE is exploring its use for offshore drilling
  - Human interaction is critical in all three technologies
  - Phenomenology is varied in all three, and also important to risk

Thank you for your attention!