PRA Application to Offshore Drilling Critical Systems

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Outline

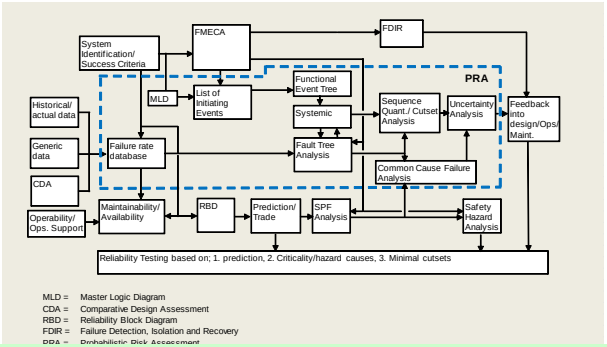
- PRA Methodology
- Applications of PRA to nuclear industry
- Applications of PRA to aerospace industry
- How can PRA be applied to oil & gas industry
- Macondo Accident Scenario
- PRA Methodology Comparison
- PRA management
- Conclusions

Probabilistic Risk Assessment

A systematic and comprehensive methodology to evaluate risks associated with complex engineering and technological systems.

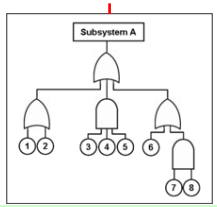
A quantitative evaluation of system safety

- Identification, selection, and screening of initiating events
- Definition and modeling of all scenarios
- Initiating and pivotal events modeling
- Data development and risk quantification
- Uncertainty analysis
- Risk importance ranking for risk reduction and communication

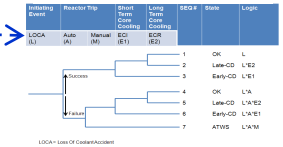


PRA Methodology and Applications

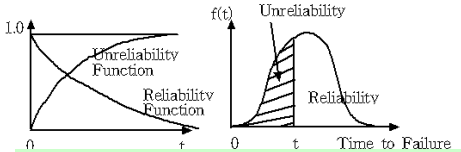
Master logic Diagram



Fault Trees



Event Trees



Uncertainty Analysis

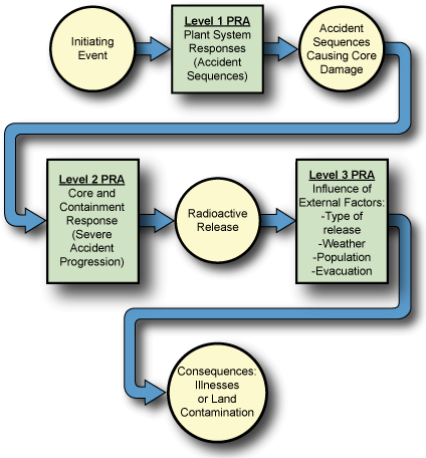
Application of PRA to Nuclear Industry

Three Mile Island Nuclear Station

LEVEL 1 PRA → The assessment of plant failures leading to core damage and the determination of core damage frequency (CDF).

LEVEL 2 PRA → The assessment of containment response leading, together with the results of Level 1 analysis, to the determination of release magnitudes and frequencies.

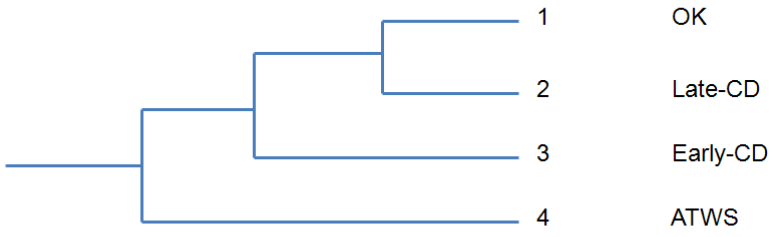
LEVEL 3 PRA → The assessment of off-site consequences leading, together with the results of Level 2 analysis, to estimates of risk to the public.



Event and Fault Tree Analyses

Functional Event Tree Example

Initiating Event	Reactor Trip	Short Term Core Cooling	Long Term Core Cooling	SEQ #	State
IE	RX-TR	ST-CC	LT-CC		

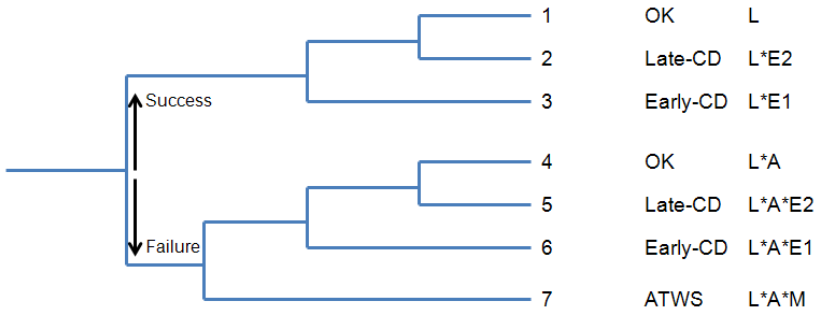


IE = Initiating Event
RX-TR = Reactor Trip
ST-CC = Short Term Core Cooling
ATWS = Anticipated Transient Without Scram

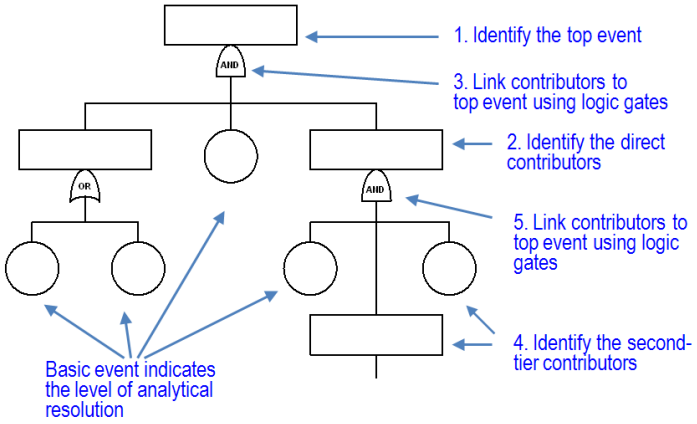
LT-CC = Long Term Core Cooling
SEQ = Sequence
CD = Core Damage

Systemic Event Tree Example

Initiating Event	Reactor Trip		Short Term Core Cooling	Long Term Core Cooling	SEQ #	State	Logic
LOCA (L)	Auto (A)	Manual (M)	ECI (E1)	ECR (E2)			



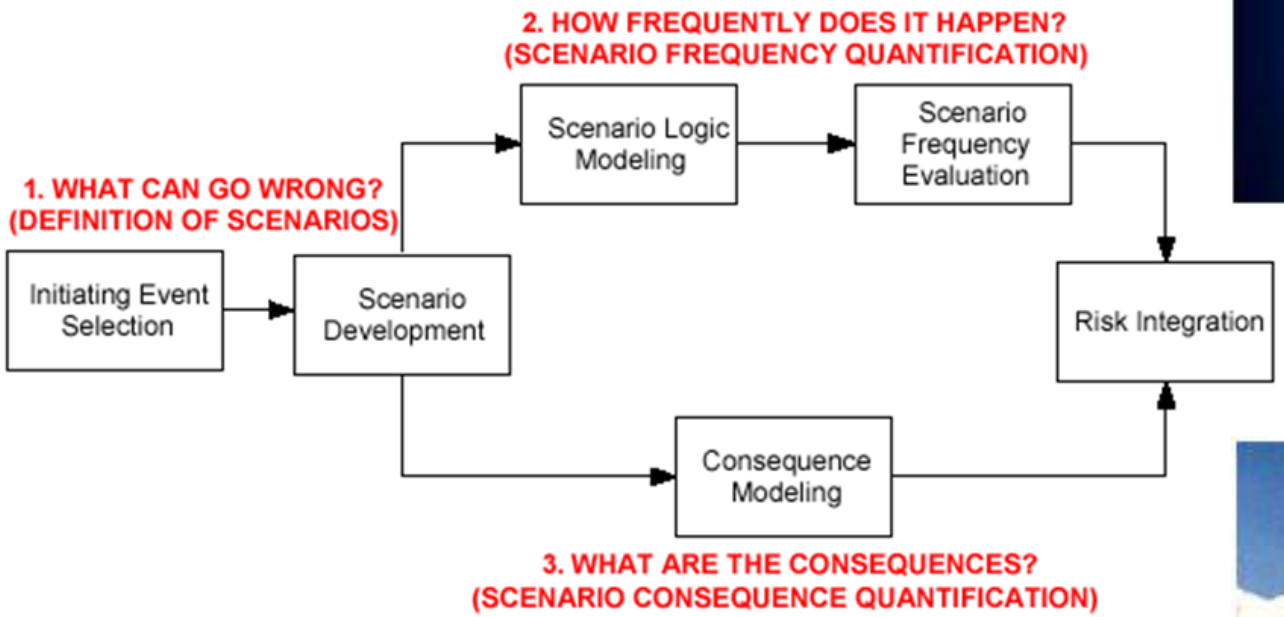
Building the Fault Tree



This document does not contain ITAR or EAR technical information

Application of PRA to Aerospace Industry

The essence of aerospace PRA



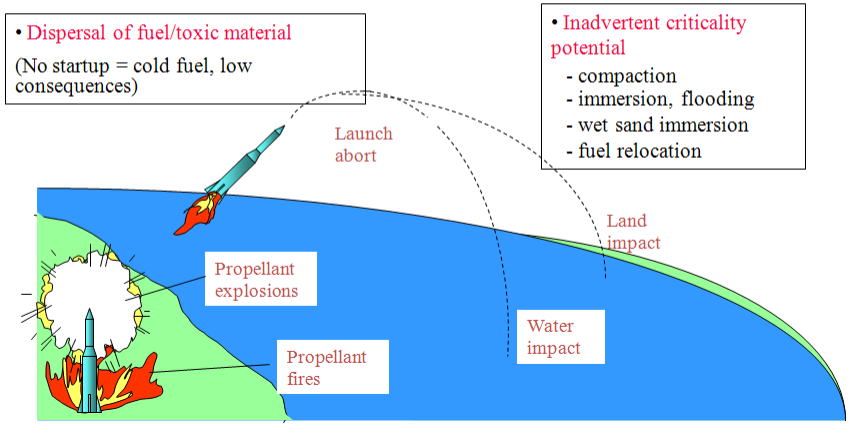
Space Shuttle Challenger Accident

Space Shuttle Challenger

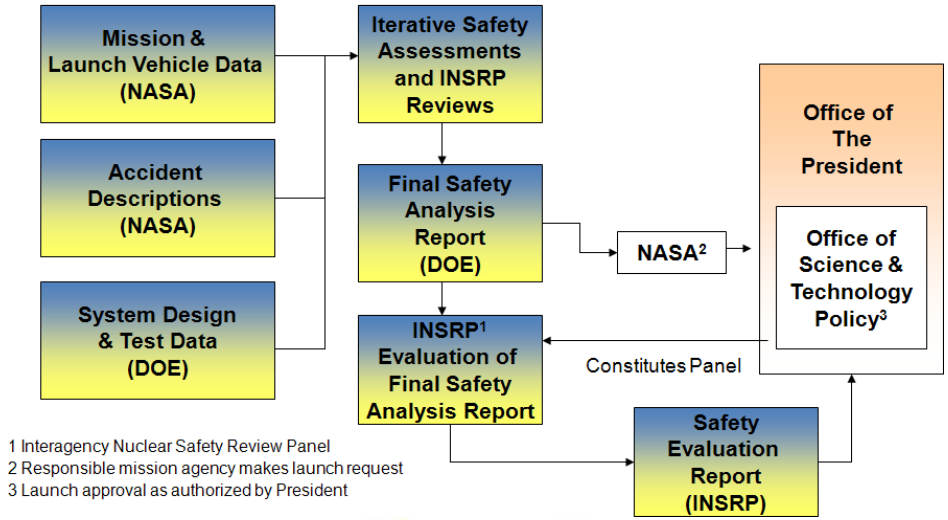
Payload Nuclear Safety

Nuclear Safety Issues

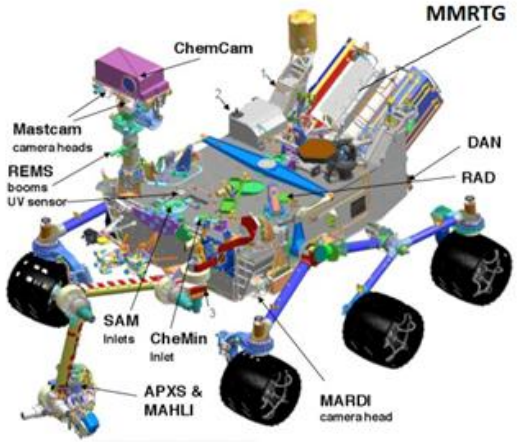
- **Pre-launch/launch issues focus on startup and inadvertent criticality**



Nuclear Safety Review and Launch Approval Process



1 Interagency Nuclear Safety Review Panel
2 Responsible mission agency makes launch request
3 Launch approval as authorized by President

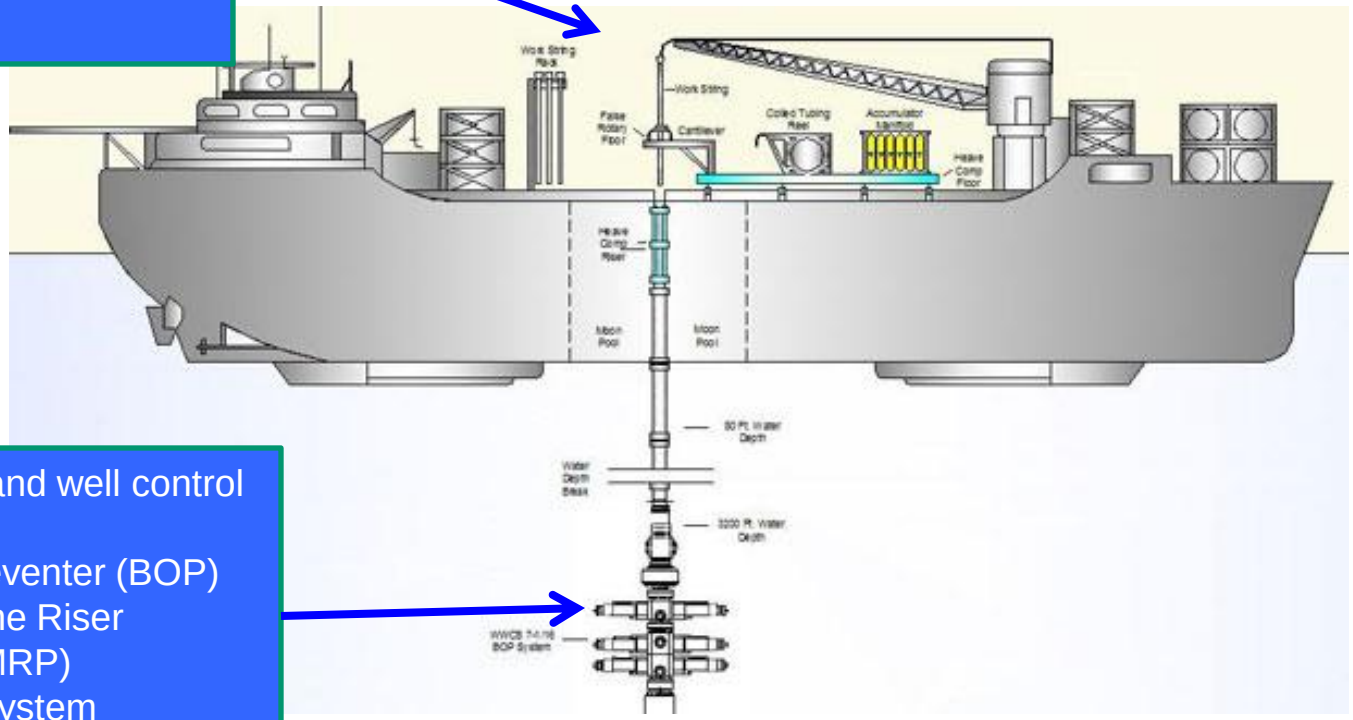


Mars Science Lab Rover Curiosity

PRA Application to Offshore Drilling Rig Systems

Rig surface systems:
- Gantry Crane
- Riser Elevator
- Draw Works
- Dynamic Positioning
- Etc.

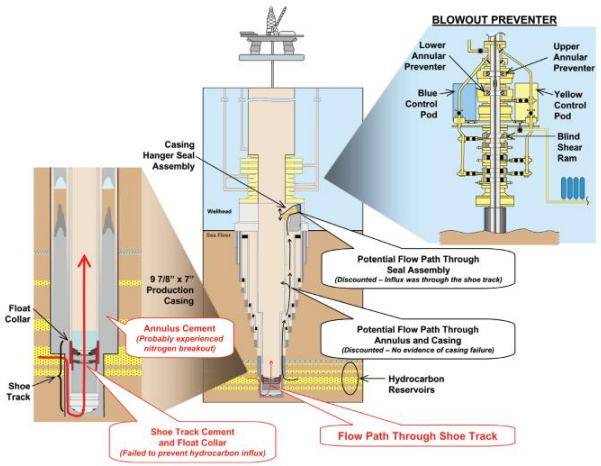
PRA methodology can be applied to Oil & Gas Systems to identify:
- Likelihood of undesired events
- Severity (magnitude) of the consequences

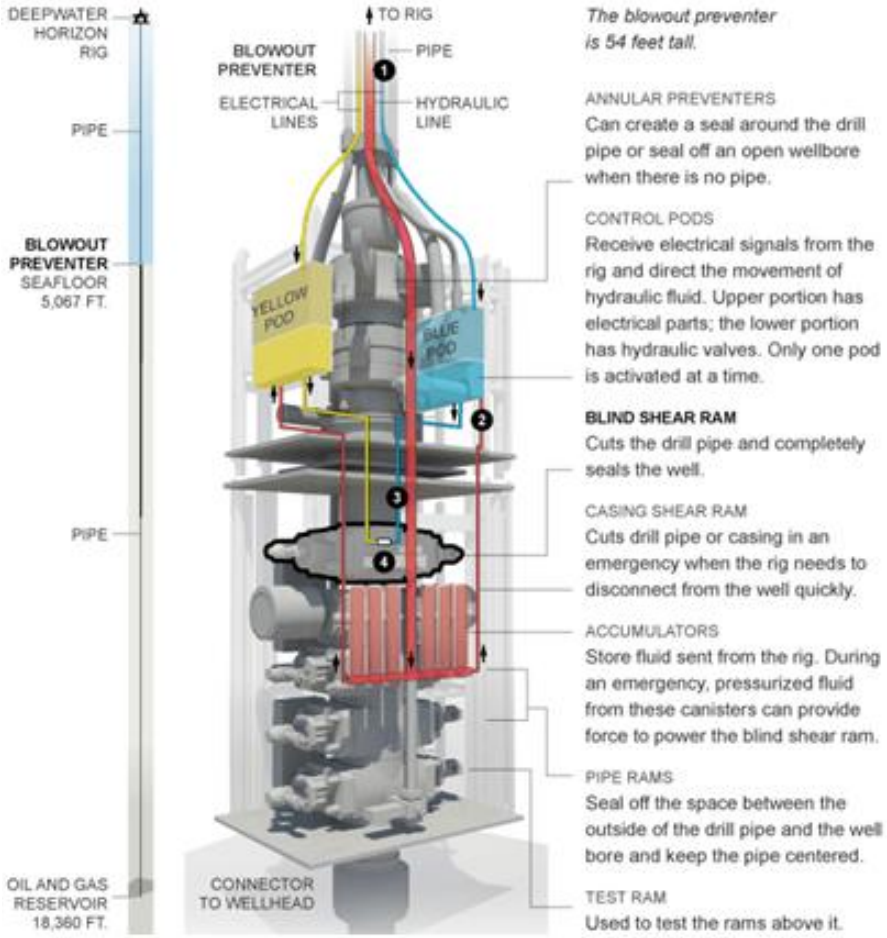


Rig subsea and well control systems
- Blowout Preventer (BOP)
- Lower Marine Riser Package (LMRP)
- Mud Flow System
- Etc.

PRA Methodology can Help Identify Potential Accident Scenarios

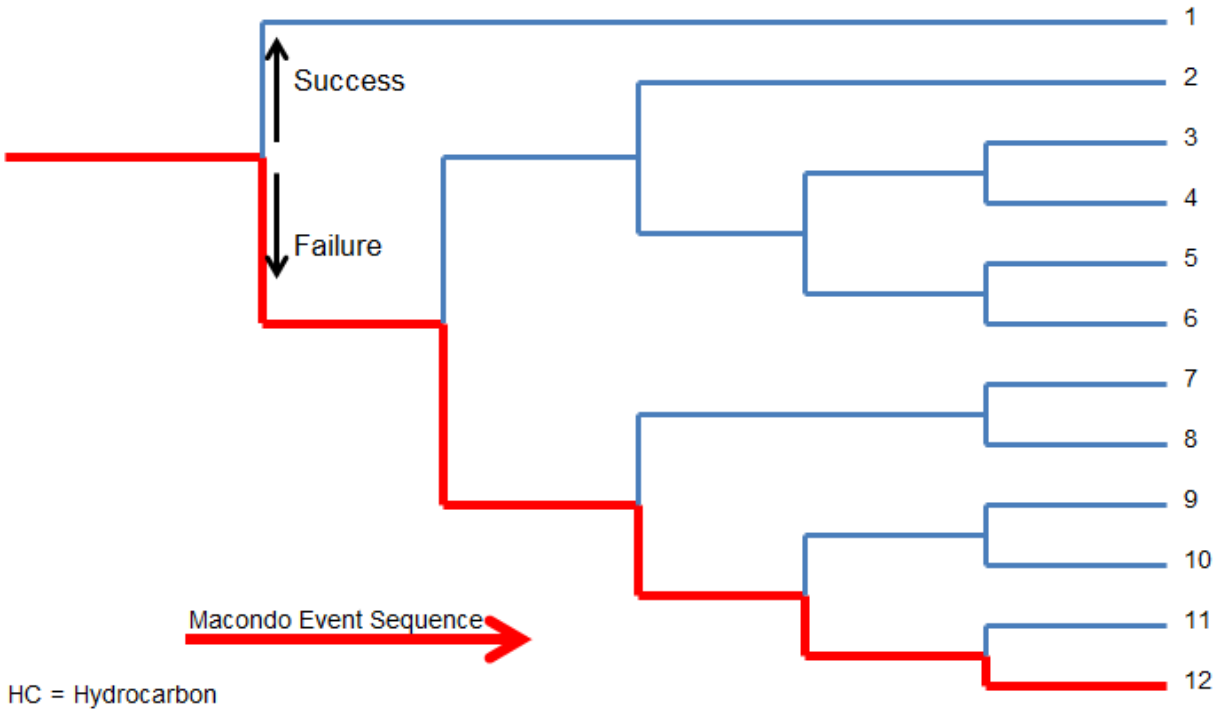
Macondo accident scenario could have been identified using PRA methodology





Deepwater Horizon Sample Functional Event Tree*

Hydro-carbon leakage through annulus cement barrier	Well Integrity	Well Hydrostatic Control	Well flow Control	Hydro-carbon Release Control	The BOP Emergency Function	SEQ #	State	Logic
Leak (L)	WI (W)	WHSC (H)	WFC (F)	HCRC (R)	BOPEF (B)			



1	OK, No Leak Thru Shoe Track	L
2	Leak detected, WHSC applied	L*W
3	Failure of WFC, HC flow up thru riser	L*W*F
4	HCRC failure, late release overboard	L*W*F*R
5	Initial Blowout, controlled BOPEF	L*W*F*R
6	BOPEF failure, late loss of rig	L*W*F*R*B
7	OK, BOP prevents HC release	L*W*H
8	Partial release, early fire/exp. overboard	L*W*H*B
9	Early blowout, cntl'd by HCRC and BOPEF	L*W*H*F
10	Early blowout, failed BOPEF, HC release	L*W*H*F*B
11	Early blowout, cntl'd BOPEF	L*W*H*F*R
12	Early blowout, fire explosion, loss of rig	L*W*H*F*R*B

*** Based on information provided in the BP Deepwater Horizon Accident Investigation Report, 9/8/10**

Comparison of PRA Applications across the Different Industries

PRA Level	Nuclear	Aerospace	Offshore Oil
1	•Systems analysis •Core Damage Frequency Evaluation •Consequence analysis •Uncertainty analysis •CDF = 1.0E-04/RY*	•Space shuttle systems analysis •Calculate probability of loss of vehicle •Calculate probability of loss of crew •Uncertainty analysis •LOCV = 1/65 flights	•Rig systems failure analysis •Subsea systems failure analysis •Hydrocarbon release frequency evaluation •Consequence analysis •Uncertainty analysis •Loss of Rig = ?
2	•Containment analysis •Containment failure modeling and probability •Uncertainty analysis •Probability of release to atmosphere = 1.0E-05/ RY**	NA	NA
3	•Radionuclide release modeling •Source term calculations •Human fatality estimates •Environmental damage estimates •Uncertainty analysis	•Nuclear safety analysis for space nuclear power systems (Cassini, MMRTG) •Radionuclide release modeling •Source term calculations •Human fatality estimates •Environmental damage estimates •Uncertainty analysis	•Hydrocarbon release modeling •Environmental damage estimates •Uncertainty analysis •Severe release of Hydrocarbons to environment = ?
External Events	•Earthquake •Flood •Fire •Wind •Sabotage •Aircraft Impact	•Micrometeorite/ Orbital Debris (MMOD) •Sabotage	•Earthquake •Hurricane •Object/ iceberg/ vessel impact •Sabotage •Aircraft Impact

CDF = Core Damage frequency
RY = Reactor Year
LOCV = Loss of Crew and Vehicle
*Ref. NUREG/BR-0058, Rev. 4
**Large Early Release Frequency (LERF)

PRA Management Among Different Industries

PRA Level	Nuclear	Aerospace	Offshore Oil
Regulatory Agencies	•NRC (Commercial) •DOE (Government)	•NASA (Shuttle Flights, ISS) •Air Force (Unmanned Rocket launches) •DOE (Nuclear payloads)	•Primary O&G Regulatory Agency= BSEE? •EPA •US Coast Guard •DOT
Industry Representatives	•INPO (EPIX Database)	NA	•API/COS (API 17N)
PRA Management Approach	•Defense in depth •Risk Informed Approach •Living PRA	•Risk Informed Approach •NASA SRP Review •Presidential Approval on nuclear payloads •AF Range Safety Approval (MSPSP)	•Defense in depth? •Risk Informed Approach? •Living PRA?

NRC = Nuclear Regulatory Commission
DOE = Department of Energy
INPO = Institute of Nuclear power Operations
EPA = Environmental Protection Agency
DOT = Department of Transportation
EPIX = Equipment Performance and Information Exchange

ISS = International space Station
SRP = Safety Review Panel
AF = Air Force
MSPSP = Missile Systems Prelaunch Safety Package
BSEE = Bureau of Safety and Environmental Enforcement
API = American Petroleum Institute
COS = Center for Offshore Safety

Conclusions

- A standard risk management approach such as PRA will be able to help oil and gas industry, especially offshore oil drilling improve safety and reduce hazard risk
- PRA analysis for offshore drilling and production operations (as well as onshore) can benefit from the nuclear and aerospace industries past experience
- Oil and gas regulatory agencies (e.g., BSEE) can identify target frequencies for consequences such as:
  - Loss of rig due to fire/explosion
  - Severe release of hydrocarbons to the environment
- Oil and gas Industry representative agencies such as API can develop failure rate databases that can be used by the entire industry and utilized in the oil rig PRA