Safety and Environmental Issues for FPSO Projects

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Agenda

- Formal safety assessment in design - why? how?
- Getting safety into the early design – inherently safe design
- FPSO major hazards
  - Hazard Management (Prevention, Control / Mitigate, Recovery)
  - Common concerns from Formal Safety Assessments (FSA)
- Environmental concerns and related issues

Formal Safety Assessment – Why?

- Major Accident Events will continue to occur.

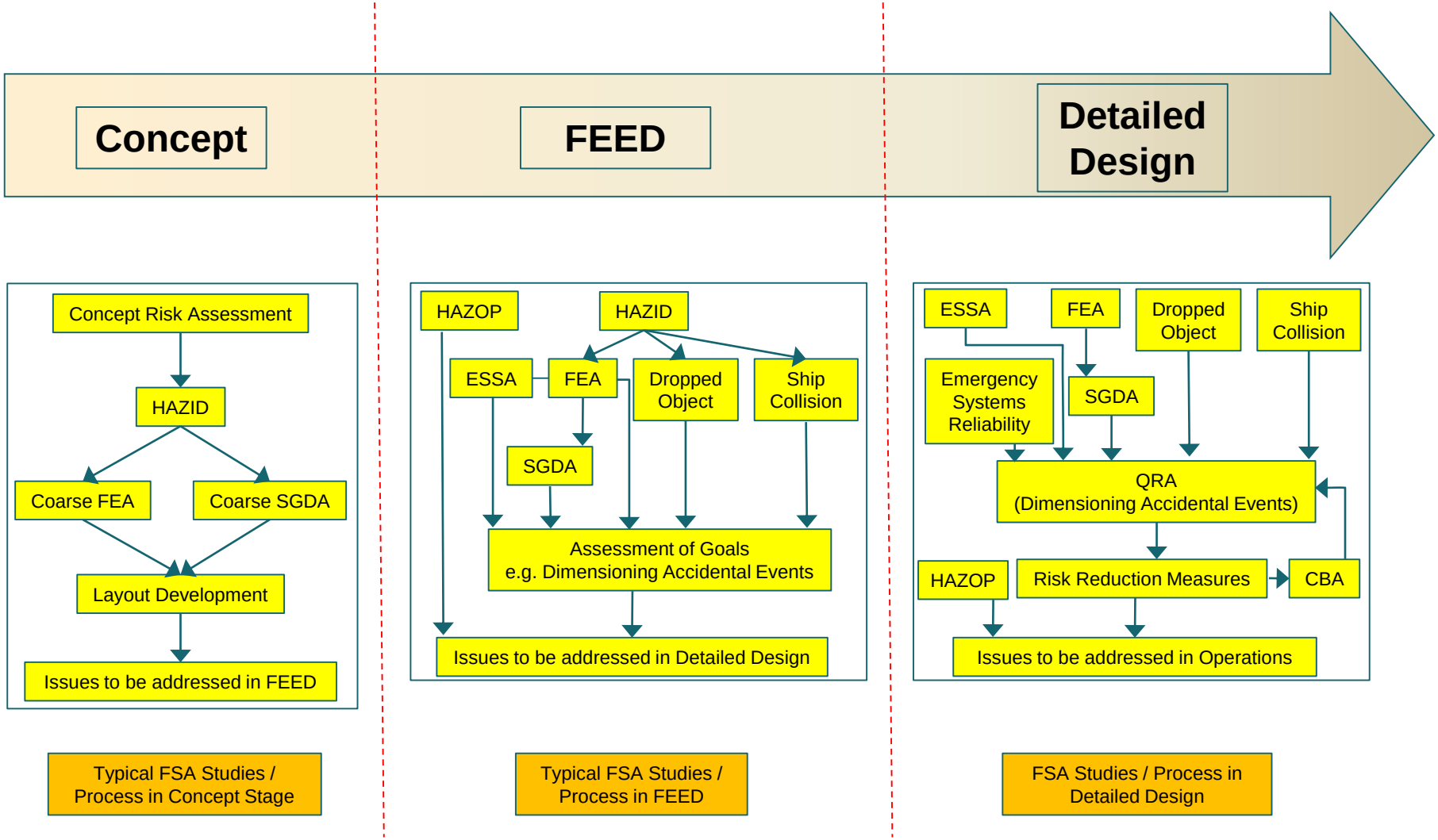
Ship Collision Followed by Major Fire

Cargo Tank Explosion

Riser Fire Engulfing Platform

- Safety evaluations carried out to confirm design achieves safety goals
- Primary aim is to pinpoint targets for risk reduction measures which can be assessed and included where reasonably practicable
- In this way safety analyses during design can reduce the frequency of accidents occurring and reduce the consequences of an accident
- FSA also contributes to ensuring safe and secure physical environment and in minimising pollution

Formal Safety Assessment – How?

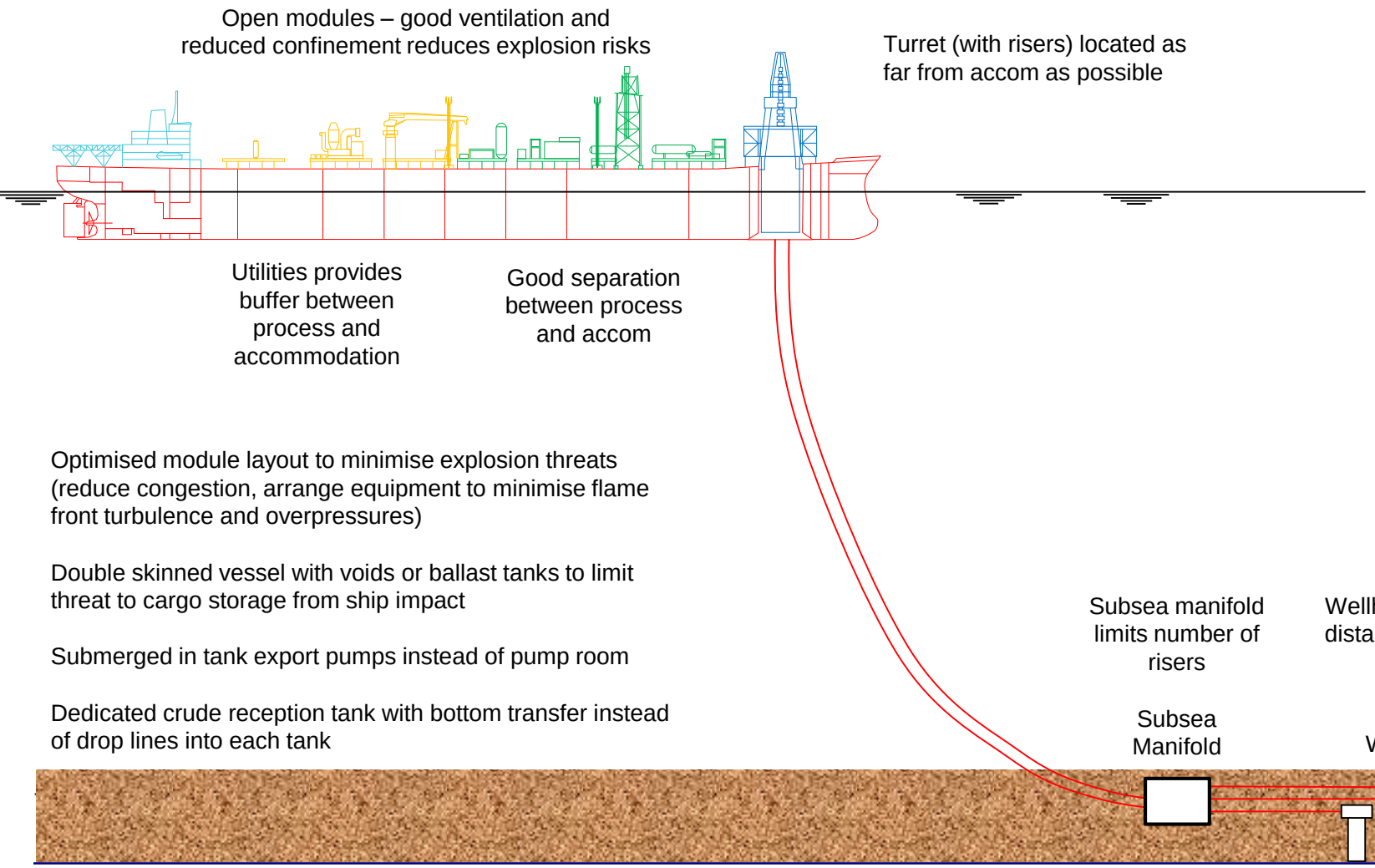


Building Safety into the Concept – Inherently Safe Design

- Minimise
- Substitute
- Segregate
- Simplify
- Intensify

- Fewer hazards
- Fewer causes
- Reduced severity
- Fewer consequences

Building Safety into the Concept – Inherently Safe Design Features / Options



Optimised module layout to minimise explosion threats (reduce congestion, arrange equipment to minimise flame front turbulence and overpressures)

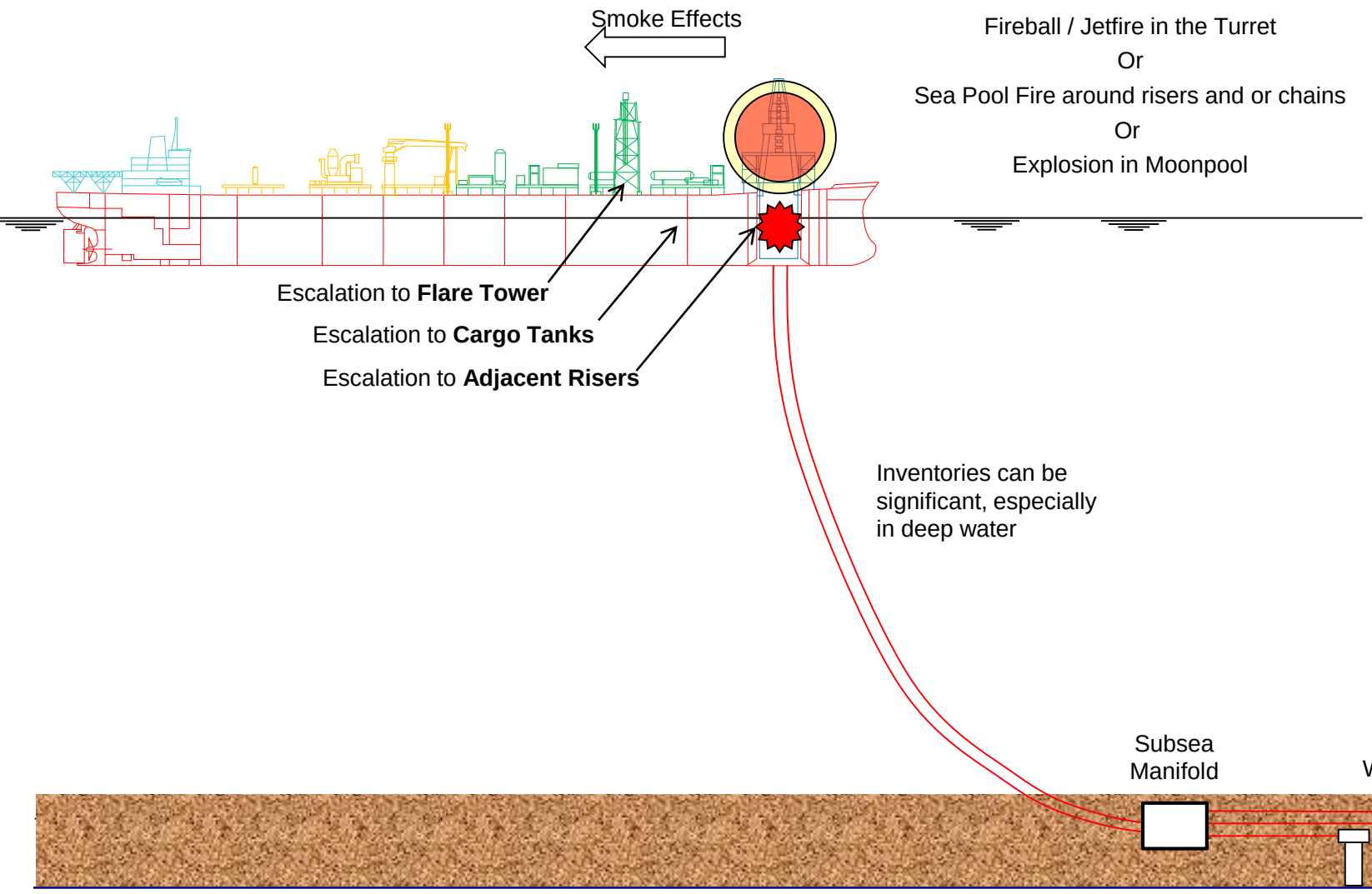
Double skinned vessel with voids or ballast tanks to limit threat to cargo storage from ship impact

Submerged in tank export pumps instead of pump room

Dedicated crude reception tank with bottom transfer instead of drop lines into each tank

FSPO Hazards

Risers Fire / Explosion



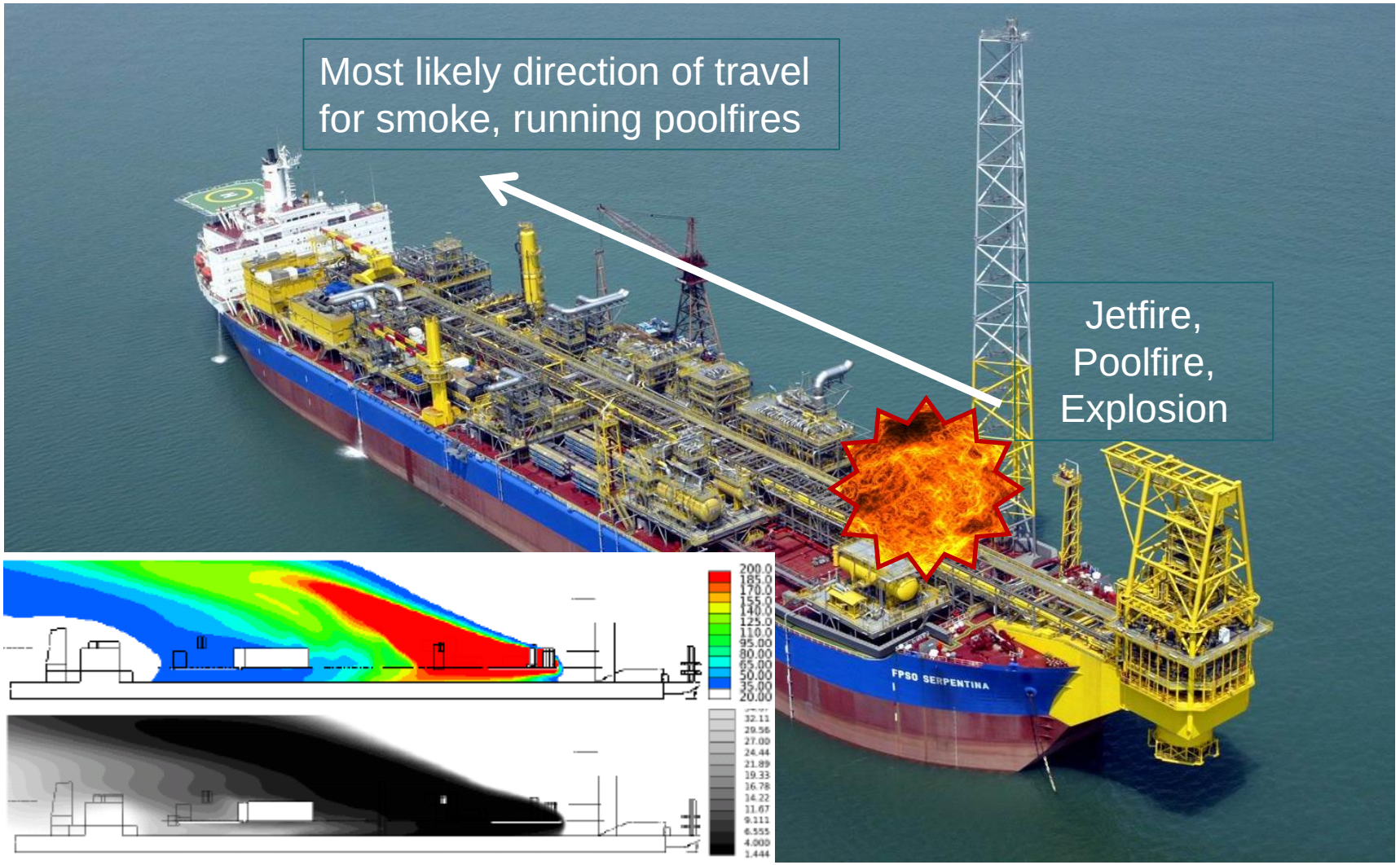
FSPO Hazards

Risers – Prevent , Mitigate/Control, Recover

- Prevention
  - Process integrity, Inherently Safe Design (ISD), minimise outboard leak sources, ignition control
- Mitigate / Control
  - Fire and gas / ESD system, pressurised TR / HVAC, intakes in safe location, TR fire/blastwall
  - Also possibly riser PFP, turret deluge, emergency disconnect, subsea isolation
- Recovery
  - Diverse, redundant escape routes, Protected TR, Redundant evacuation facilities
- FSA findings:
  - Potential for personnel to be trapped on turret upper levels – restrict access and ensure multiple diverse routes area available
  - If turret is close to accom then muster could be impaired – consider a pressurised tunnel in addition to evac facilities at opposite end of FPSO
  - Fire/blast rating of TR bulkhead should be based on results of FEA
  - Locating TR intakes in “safe” location is important – low on other side of accommodation from process
  - Avoid clear line of sight between topsides leak sources and outboard sections of riser

FSPO Hazards

Topsides Fire / Explosion



FSPO Hazards

Topsides – Prevent , Mitigate/Control, Recover

- Prevention
  - Process integrity, Inherently Safer Design, minimise dropped object threat, ignition control
- Mitigate / Control
  - Fire and gas / ESD system, pressurised TR / HVAC, intakes in safe location, TR fire/blastwall, module deluge, main deck foam deluge and monitors, bunding & drainage
  - Also possibly PFP on vessels & structures (e.g. Flare)
- Recovery
  - Diverse, redundant escape routes, Protected TR, Redundant evacuation facilities, escape equipment
- FSA findings:
  - Fuel gas to main power generation – potential for jetfire impacting accommodation
  - Jetfire impact on cargo tank tops where there is line of sight
  - Fire impact on flare, PFP may be required
  - Running poolfires could impact accommodation directly, transverse coaming
  - Gas build up below process modules (reduced ventilation in this area leads to potential for large gas volumes and high overpressures)
  - Possible need to protect LER (fire, blast rating)
  - Potential for trapping personnel on crane – protected escape routes, escape equipment
  - Potential for trapping personnel on elevated platforms. Restrict access to these areas.
  - Emergency systems (F&G, PA, firewater, emergency power etc) – redundancy of supply, fire resistant cabling etc

FSPO Hazards

Crude Oil Tanks – Fires & Explosions

- Largest single inventory, extensive thermal radiation, large amount of smoke
- Explosions through flammable atmosphere formation (e.g. IG failures, human error during tank prep) and ignition (static e.g. Tank washing, pyrophors)
- Escalation from other events (fire, explosion, impact)
- Environmental risk
- Intertank escalation

FSPO Hazards

Crude Oil Tanks – Prevent , Mitigate/Control, Recover

- Prevention
  - IG system, Process integrity, ISD, minimise dropped object threat, ignition control
  - Control of tank operations e.g. Offloading, inerting, gas freeing, etc
- Mitigate / Control
  - Very difficult to control
  - Main deck foam deluge & monitors
  - Pressurised TR HVAC intakes in safe location

- Recovery
  - Most likely response to COT fire will be to evacuate
  - Diverse, redundant escape routes, Protected TR, Redundant evacuation facilities, escape equipment
  - Trapping of personnel for'd more likely - forward protected muster location and evacuation facilities
- FSA findings:
  - Important to prevent escalation to COTs
  - Avoid line of sight between topsides release sources and COTs
  - Provision of double skinned hull to limit ship impact hazard e.g. Supply boat location
  - Avoid lifting over exposed COTs or protect
  - Note locations of cargo tank hatches with respect to potential main deck pool fire locations and ensure provision of fire rated seals

FSPO Hazards

Ship Collision

- Consequences of ship impact can be serious if COT ruptured
- Potential for sea pool fires and large environmental release
- Threats from:
  - Passing vessels (powered, drifting)
  - Supply boats (low energy)
  - Threat from shuttle tankers (high energy) – can impact stern directly and threaten accommodation

FSPO Hazards

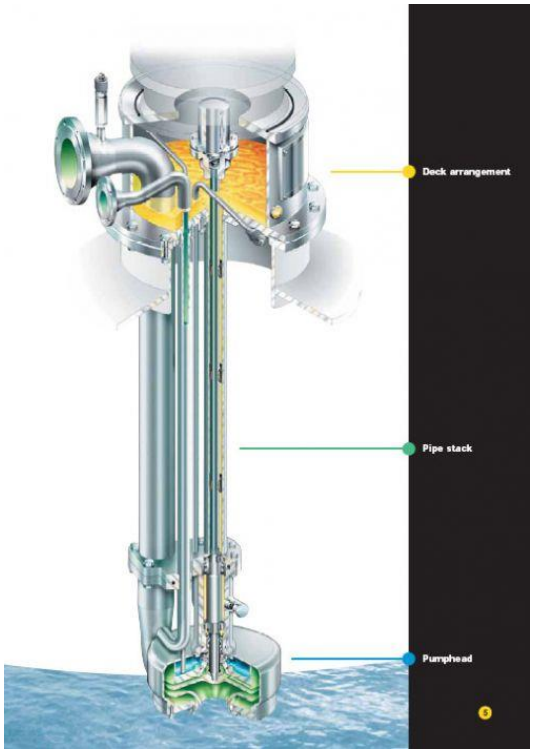
Ship Collision – Prevent , Mitigate/Control, Recover

- Prevention
  - Passing Vessel (communications, ARPA, standby vessel)
  - Supply Boats (operational controls)
  - Shuttle tanker (operational controls, optimise standoff distance)
- Mitigate / Control
  - Hull structural design
  - Double skinned vessel (ballast tanks, void spaces)
  - Supply boat operations e.g. Protect COT via void spaces, fendering
- Recovery
  - Passing vessels - should be some warning allowing emergency response
  - Low energy supply boat collisions – should be limited consequences
  - High energy shuttle tanker collisions – could cause serious damage e.g. to stern but may not cause a serious hydrocarbon release
  - Emergency disconnect?
- FSA Findings
  - Possible impact of exhausts / venting on supply boat ops

FSPO Hazards

Pump Room / Engine Room Fires & Explosions

- Common threat on FPSOs, trading tankers etc
- Fuel gas releases (explosion and fire), diesel or crude releases (pool fires)
- Enclosed spaces, reduced ventilation, congested / confined areas leads - explosion threat (especially pump room)
- Proximity to the accommodation and lifeboats
- Engine room / accommodation space ventilation systems can be shared – smoke migration
- Escape can be difficult, tackling fires can be difficult
- Other hazards include releases of toxic gas in confined space e.g. inert gas, nitrogen.



FSPO Hazards

Pump Room / Engine Room – Prevent , Mitigate/Control

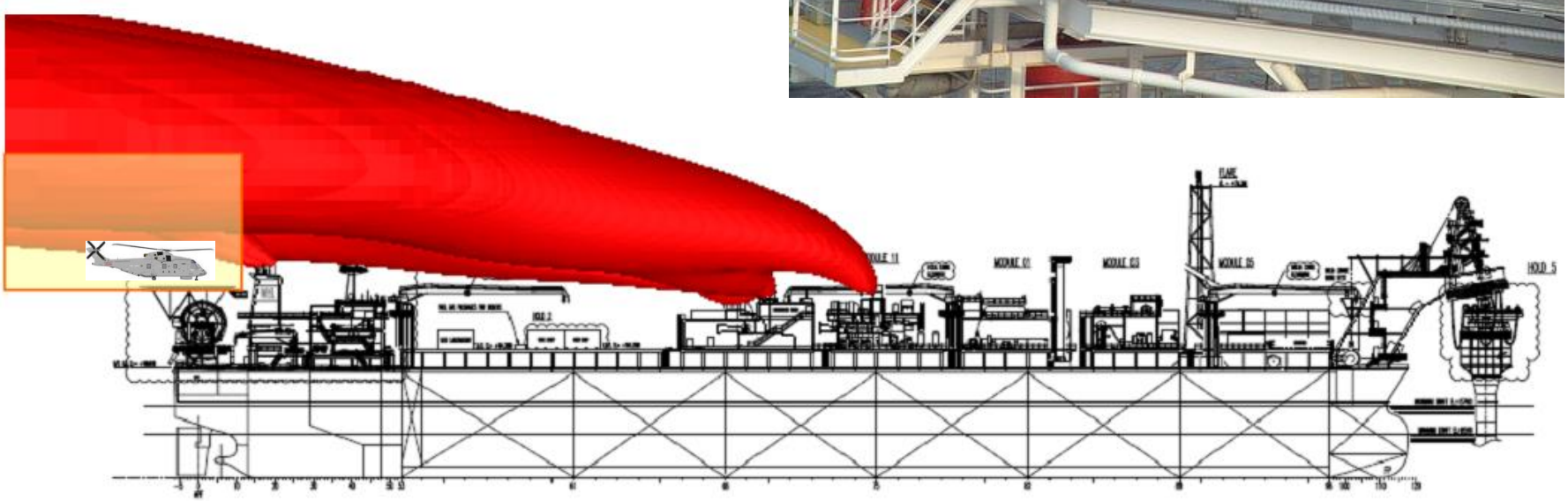
- Prevent
  - Process integrity, ISD, ignition control, use of non-combustible materials
  - Operational controls e.g. Housekeeping
- Mitigate / Control
  - Fire and gas detection, ESD System, fixed extinguishing systems (e.g. inergen, CO2, high expansion foam), manual firefighting, restrict access to pump room space
- Recovery
  - Multiple diverse escape routes from engine/pump room,
  - Redundant evacuation facilities
  - Muster to alternative location on main deck for example
  - Emergency planning

- FSA Findings:
  - Pump room challenges – control threat by restricting access, provide escape equipment or escape trunk, provide means of removing injured parties (winch)
  - Can remove pump room threat by designing space out e.g. submersible export pumps
  - For'd muster locations should be protected and have comms facilities (internal & external)
  - Release of extinguishment should be strictly controlled

FSPO Hazards

Helicopter Operations

- Crew changeover, shuttling operations
- Threat during flight, take off / landing
- Threat to installation – helicopter crash, refuelling facilities
- Exhausts / venting impact on heli-ops
- Structures / obstructions impact on heli approach
- Increased trips / flight duration increases risks



FSPO Hazards

Helicopter Operations – Prevent, Mitigate / Control, Recover

- Prevent
  - Control of contractors
  - Design (prevent exhaust / venting impacts, structures impact, codes & standards e.g. Navaids etc)
  - Refuelling facilities integrity and operations control
- Control / Mitigate
  - Helideck fire teams, fire fighting facilities
  - Refuelling - manned operation, control of ignition, firefighting response etc
- Recover
  - Emergency response plans including rescue and recovery facilities
- FSA Findings
  - Exhaust impacts (power generation, boilers etc) on the helideck should be considered at an early stage

FSPO Hazards

Dropped Objects

- Supply boat operations – main deck cranes, aft stores, turret cranes etc
- Dropped objects / swinging loads impacting:
  - Personnel
  - Topsides process
  - Cargo storage
  - Subsea infrastructure
- Fire / explosion threat
- Threat to critical safety equipment
  - Fire Main
  - Cables
  - Flare Pipework

FSPO Hazards

Dropped Objects – Prevent, Mitigate / Control, Recover

- Prevent
  - Control of contractors
  - Equipment certification, inspection / testing / maintenance regime
  - Personnel training and operational controls
  - Design of laydown areas / lifting facilities to avoid interactions
- Control / Mitigate
  - Laydown area design & rating
  - Dropped object / swinging load protection (topsides process or Safety Critical Elements, subsea, Cargo Oil Tanks)
  - Operational controls e.g. minimise lift heights
  - Heavy lift – additional controls
- Recover
  - Dependant on consequences
  - e.g. Loss of containment or not
  - Evacuation, Escape and Rescue facilities

FSPO Hazards

Marine Hazards (Loss of Weathervaning, Loss of Stationkeeping, Loss of Stability, Structural Failure/Severe Weather)

- Loss of Weathervaning
  - Equipment failures
- Loss of Stationkeeping
  - Equipment failures, Severe weather
  - FPSO travels outwith the acceptable riser limits – riser releases;
  - Ultimately FPSO breakout
- Loss of Stability
  - Equipment failure, Human error
- Structural Failures
  - Equipment failures, Severe weather

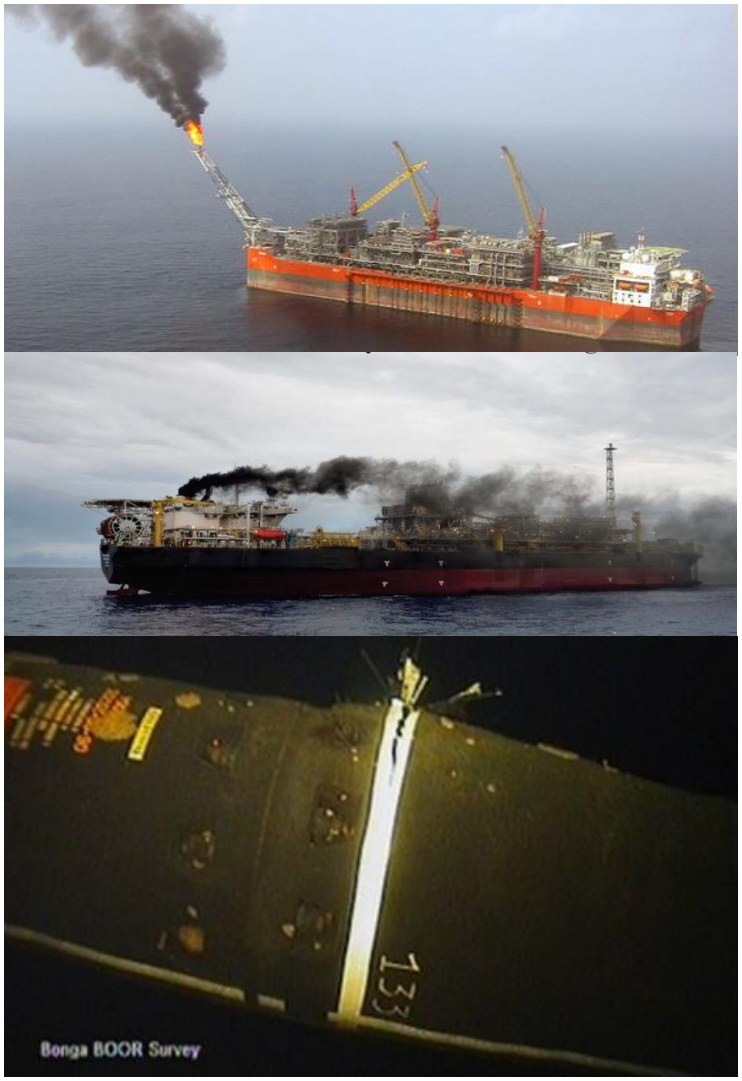
FSPO Hazards

Marine Hazards – Prevent, control / Mitigate, Recovery

- Main focus on prevention
  - System integrity, maintenance and testing, training and competency
  - Operational constraints e.g. severe weather constraints
- Control / Mitigation
  - Dependent upon consequences e.g. If loss of hydrocarbon containment occurs
- Recovery
  - EER facilities, Emergency response plans, Rescue and recovery facilities

Environmental Considerations

- Continuous Discharges
  - Combustion products from power gen (SOx & NOx)
  - Oil/Chemicals in produced water
  - Volatile Organic Compounds (VOCs) - normal operations or offloading - Particularly IG Vents
  - Operational spills during maintenance
- Accidental Spills / Discharges
  - Flaring
  - Process Spills
  - Riser/Pipeline breaches
  - Ship Collision
  - Structural Failure

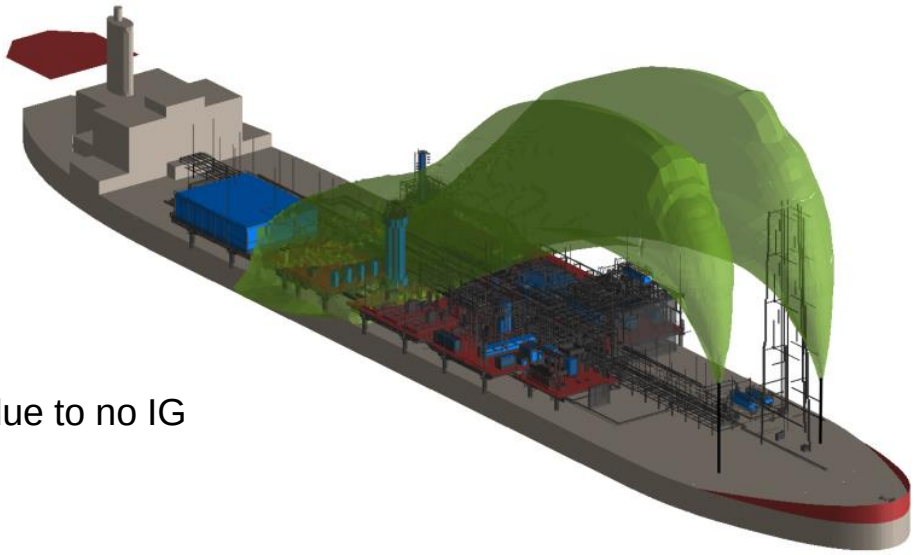


Environmental Threats

Tackling VOCs

Hydrocarbon Gas Blanketing & Recovery

- Hydrocarbon gas e.g. process gas used to blanket cargo tanks
- On some designs crude storage is used as a final separation stage
- Low pressure gas recovered from storage to compression train
- Most widely used particularly on NCS
  - Statoil - Asgard A (1999), Norne (2002)
  - Exxon – Jotun (2003), Balder (2004)
  - PGS Petrojarl – Varg 2006
  - Marathon – Alvheim 2008
- Pros
  - Simple System & Operation
  - Reduces need for anti-corrosive materials due to no IG
  - Reduces threat of heavy vapour slumping
- Cons
  - There may be issues due to non-availability of gas e.g. for start up or due to available volumes of gas (e.g. As fields deplete)
  - Issues can be managed by having IG back up



Inert Gas vs Blanket Gas

	Safety		Environmental	
Event/Hazard	**IG**	**Blanket Gas**	**IG**	**Blanket Gas**
1. Gas release from HC header.	Same	Same	Worse	Better
2. Gas release from PV breaker.	Worse	Better	Same	Same
3. Gas release from VRU/topsides equipment.	Same	Same	Same	Same
4. Air ingress to cargo tanks.	Worse	Better	Same	Same
5. Static discharge risk when loading.	Worse	Better	Same	Same
6. Crude stabilisation.	Same	Same	Same	Same
7. Gas blow-by to cargo tanks.	Worse	Better	Same	Same
8. HC back up gas supply fails open.	Better	Worse	Same	Same
9. Cargo tank overfilling.	Better	Worse	Same	Same
10. Offloading rate exceeds design.	Worse	Better	Worse	Better
11. Low production rate limits offloading rate.	Same	Same	Same	Same
12. Prolonged process shutdown.	Better	Worse	Worse	Better
13. Restart after shutdown.	Same	Same	Worse	Better
14. Static discharge during COW.	Worse	Better	Same	Same
15. Tank entry for maintenance.	Same	Same	Same	Same
16. No blanket gas at initial start-up.	Better	Worse	Worse	Better
17. No blanket gas when disconnected.	Better	Worse	Worse	Better