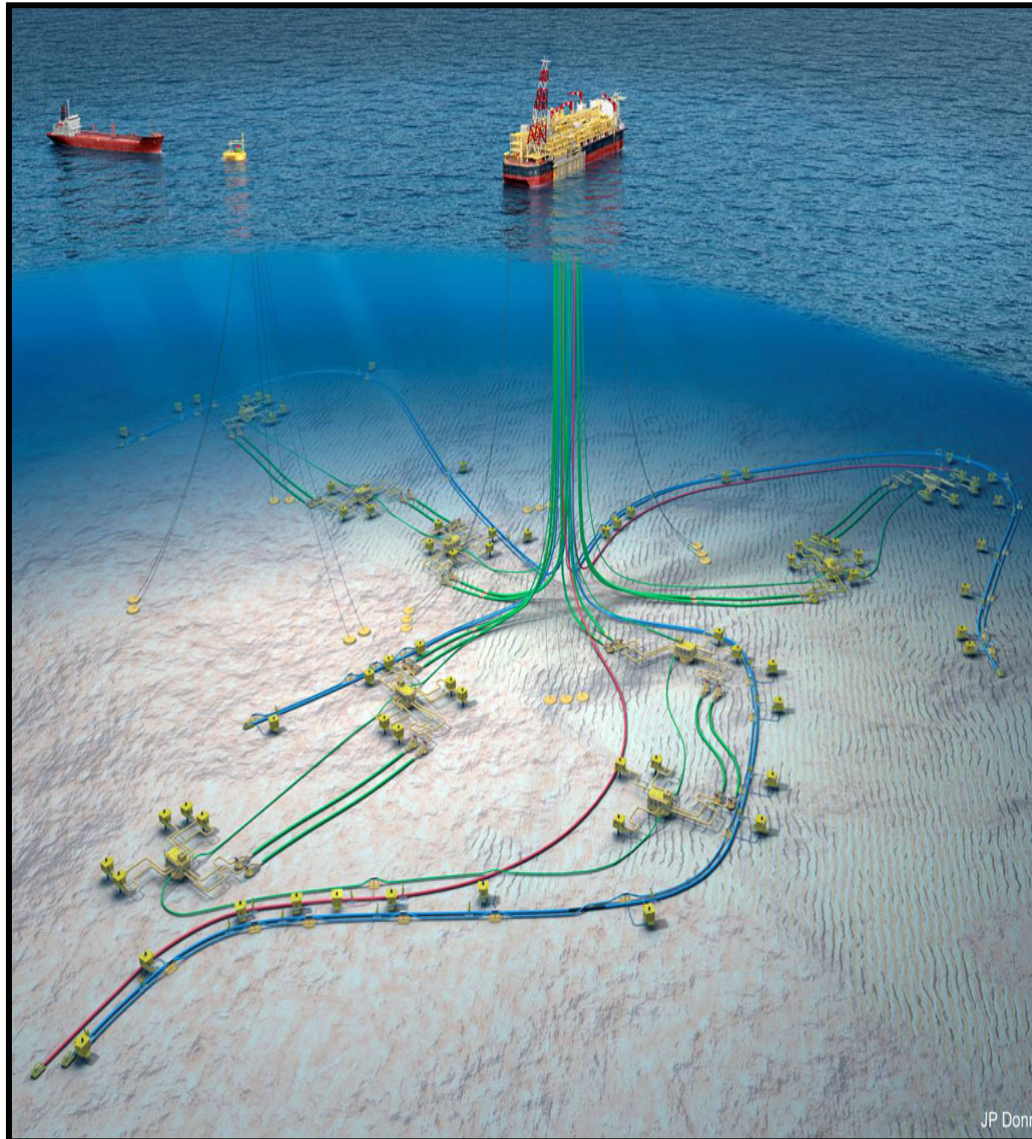


# Subsea Systems Engineering

Tricia Hill

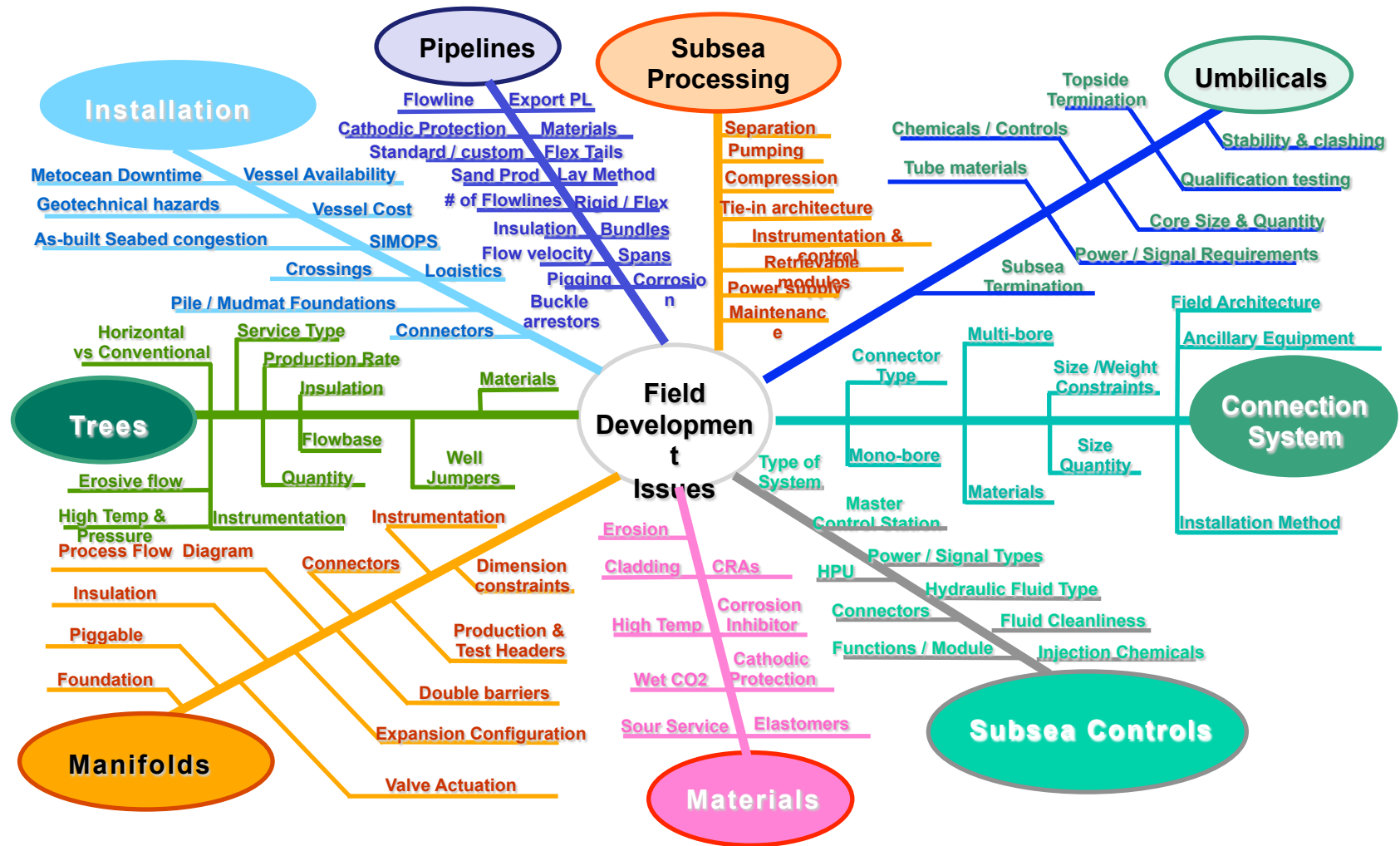
SUT Subsea Engineering and Operations Chair

# Presentation Topics



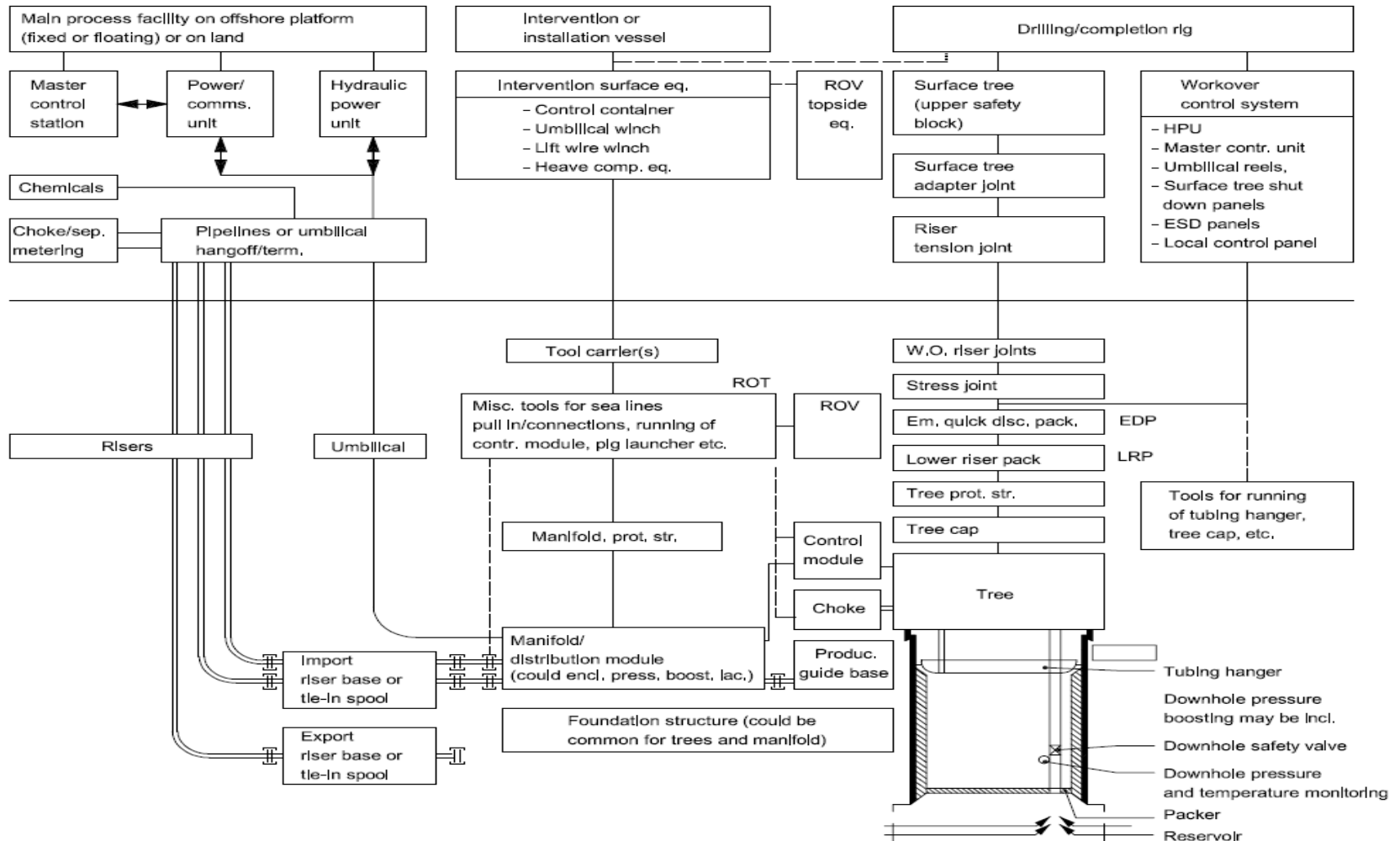
- Field Architecture Design Drivers
- Subsea System Components
- Riser Systems
- Export Systems
- Installation SIMOPS
- Emerging Technologies

# Potential Deepwater Field Development Issues



Each of these elements can effect some or all of the other elements.

# Typical elements in a subsea production system (API RP 17A Figure A.1)



**NOTE**

For satellite wells directly tied back to the platform, several of the above-mentioned elements are eliminated.



# Reference Subsea System Standards

API RP 17A — Design and Operation of Subsea Production Systems

API RP 17B, 17J, 17K, 17L1, 17L2 – Flexible Pipe & Ancillary Equipment

API SPEC 17D — Subsea Wellheads and Trees

API SPEC 17E — Production Umbilicals

API SPEC 17F — Production Controls

API RP 17G — Completion/Workover Risers

API RP 17H — ROV Interfaces & ROT Intervention Systems

API RP 17N — Subsea Reliability & Technical Risk Management

API RP 17O — High Integrity Pressure Protection Systems (HIPPS)

API RP 17P — Templates and Manifolds

API RP 17Q — Subsea Equipment Qualification

API TR 17TR4 — Equipment Pressure Ratings

API TR 17TR5 — Avoidance of Blockages in Production Control Systems

API TR 17TR6 — Attributes of Production Chemicals in Subsea Systems

API STD 2RD — Dynamic Risers for Floating Production

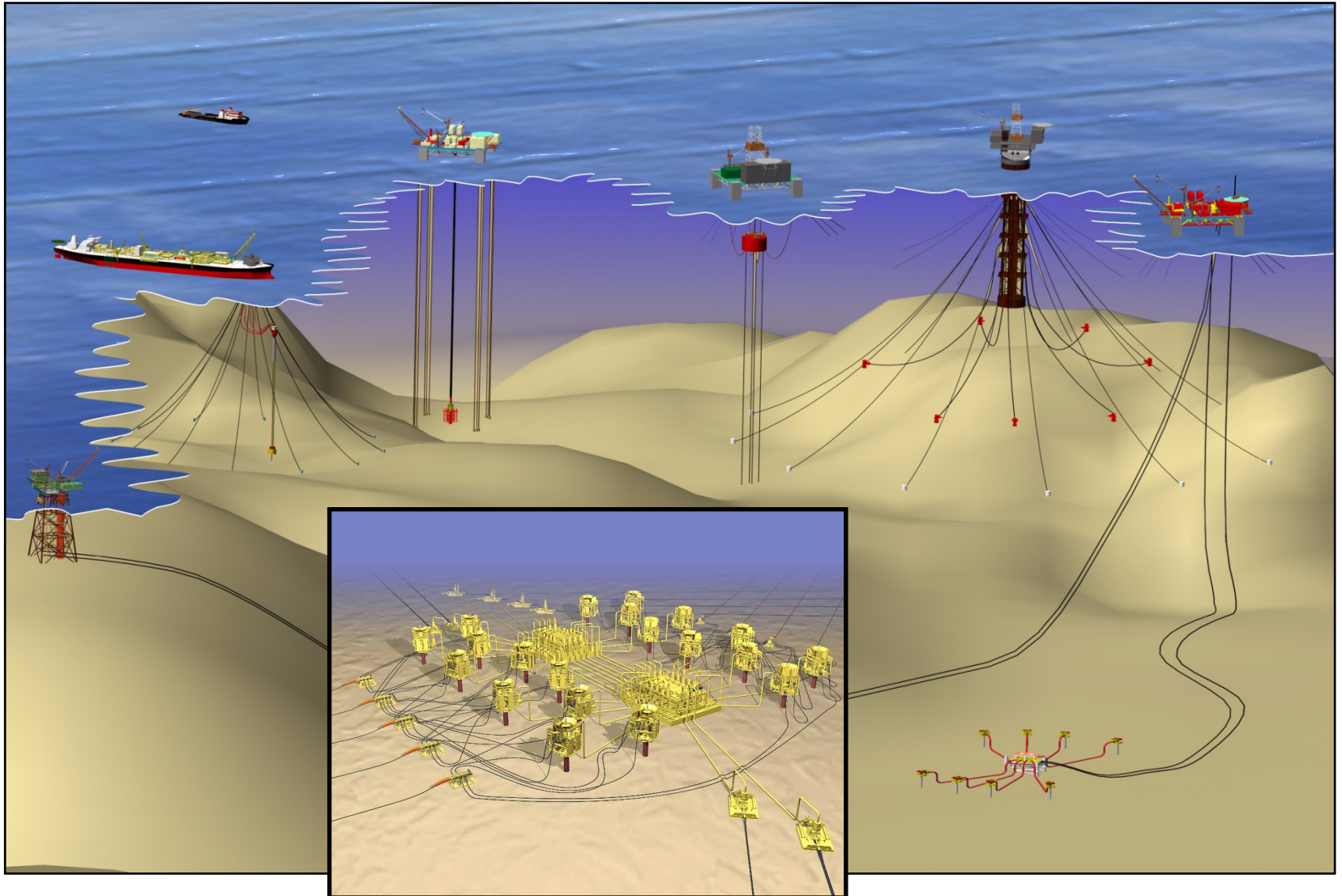
API SPEC 6DSS — Subsea Pipeline Valves

API RP 1111 — Design of Offshore Pipelines

And many more API, ISO, ASME, NORSOK, ETC

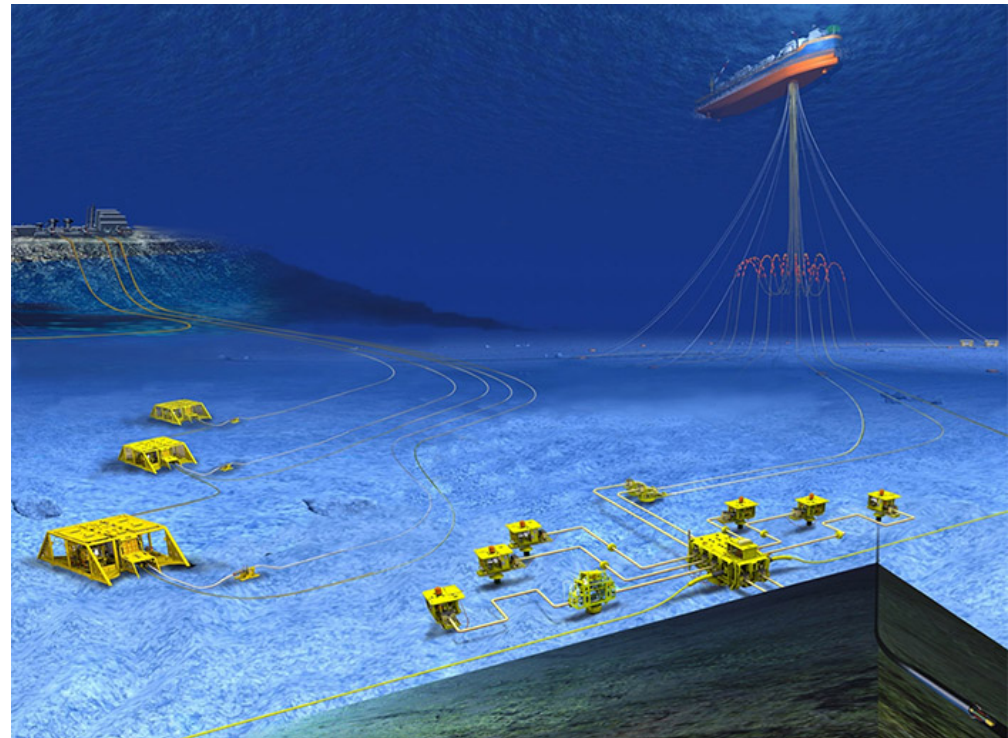
# Subsea Production Systems

## Design Basis Document / Basis of Design



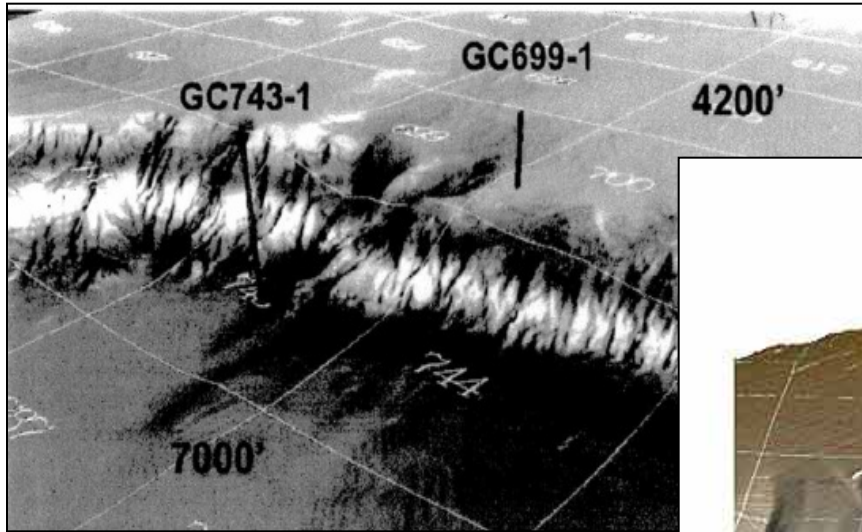
# System Design Drivers

- Production fluid properties
- Production profile
- Reservoir structure
  - Multiple drill centers
- Water depth
- Existing infrastructure
- Geographical Location
- Metocean
- Geophysical

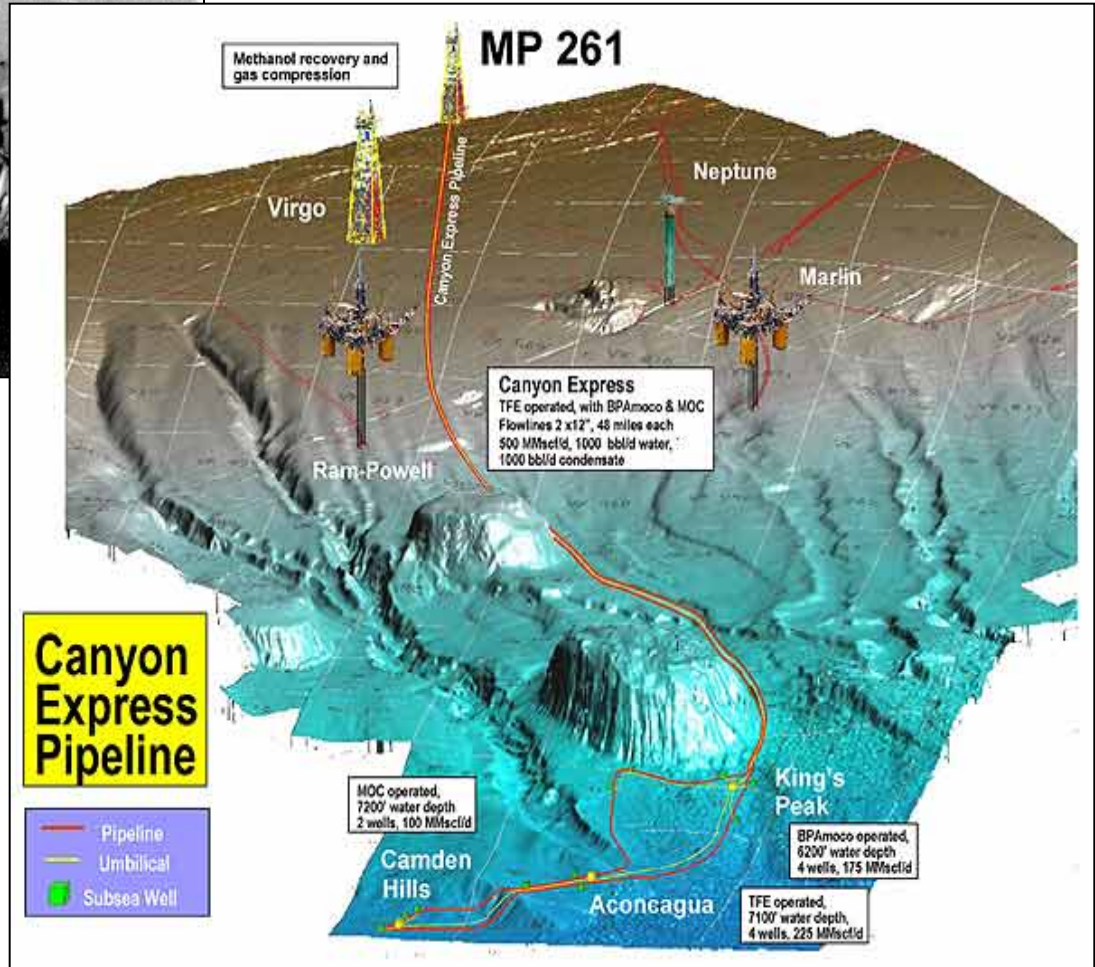




# Bathymetry



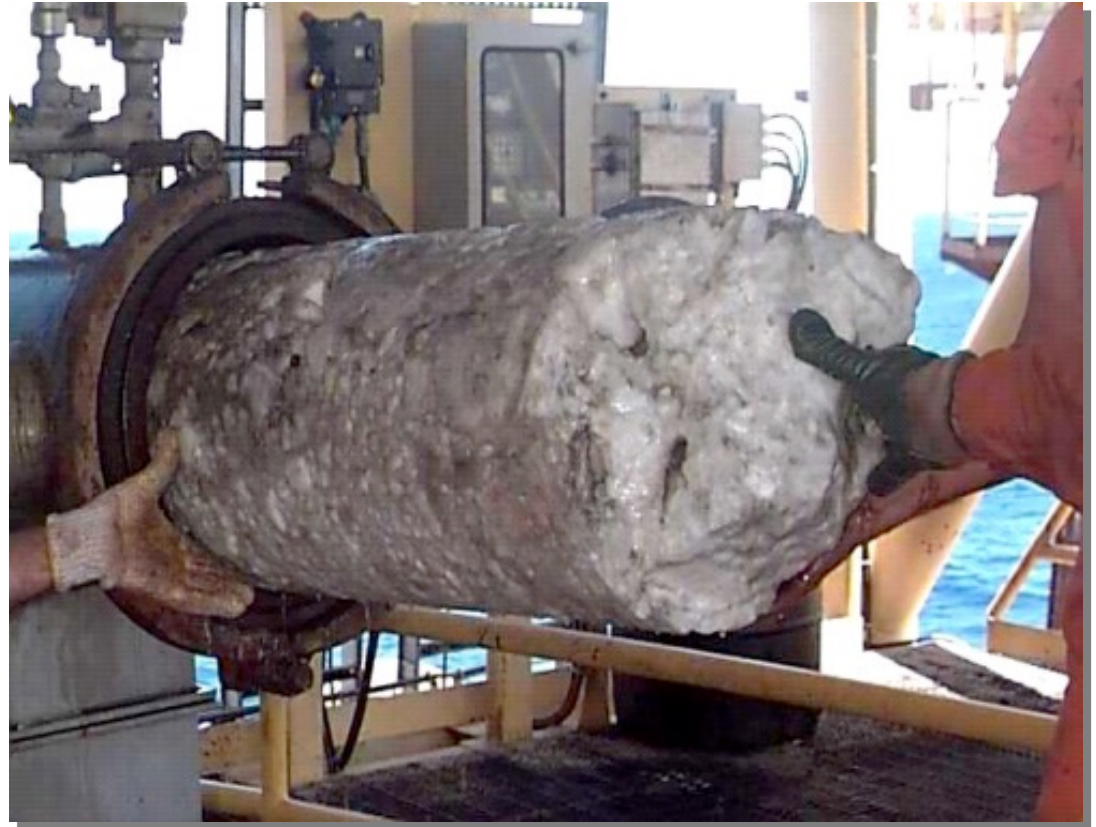
- Flowline Traps
- Slug flow
- Flowline Stability
- Mud flows
- Faults



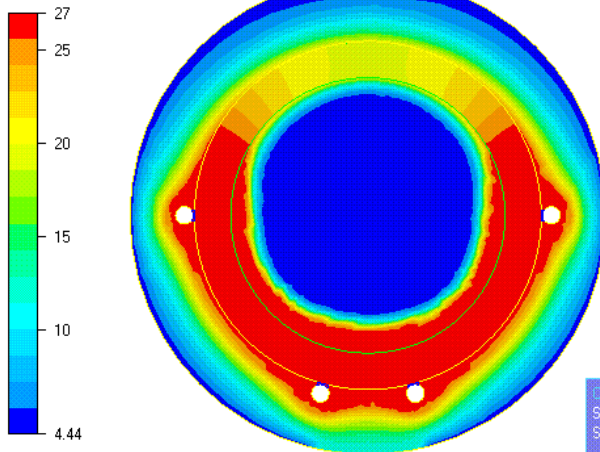
# Flow Assurance

## Potential Issues

- Hydrates
- Paraffin deposit
- Asphaltenes
- Corrosion control
- Pressure Drop
- Slug flow



CFDesign 4.1



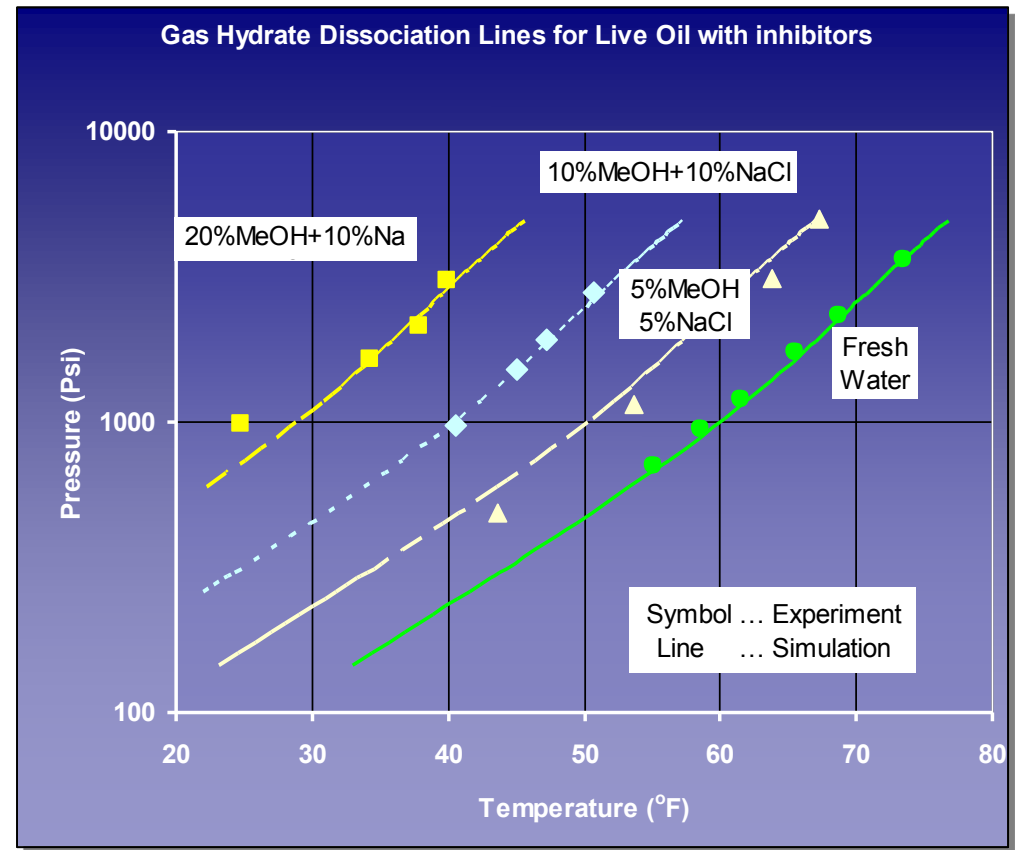
Time: 3600 (1 of 20)

CFDplay 6.1 2002-09-14  
Static Temperature  
SMN =4.440e+000 SMX =3.778e+001



# Flow Assurance

- **Prediction / Prevention**
- **Field Life / production profile**
- **Mitigation**
  - Thermal Management
  - Chemicals
- **Hydrate Remediation**
  - Pressure Reduction
  - Intervention/Chemicals
  - Heating



# Flowline Thermal Management

- Bonded Foam Insulation
- Wet polyurethane insulation
- Pipe-In-Pipe Insulation
- Bundled Pipes
- Active heating
- Operating Strategies & Procedures
  - Startup & Planned shutdown
  - Unplanned shutdown



# Basic Subsea Hardware Components

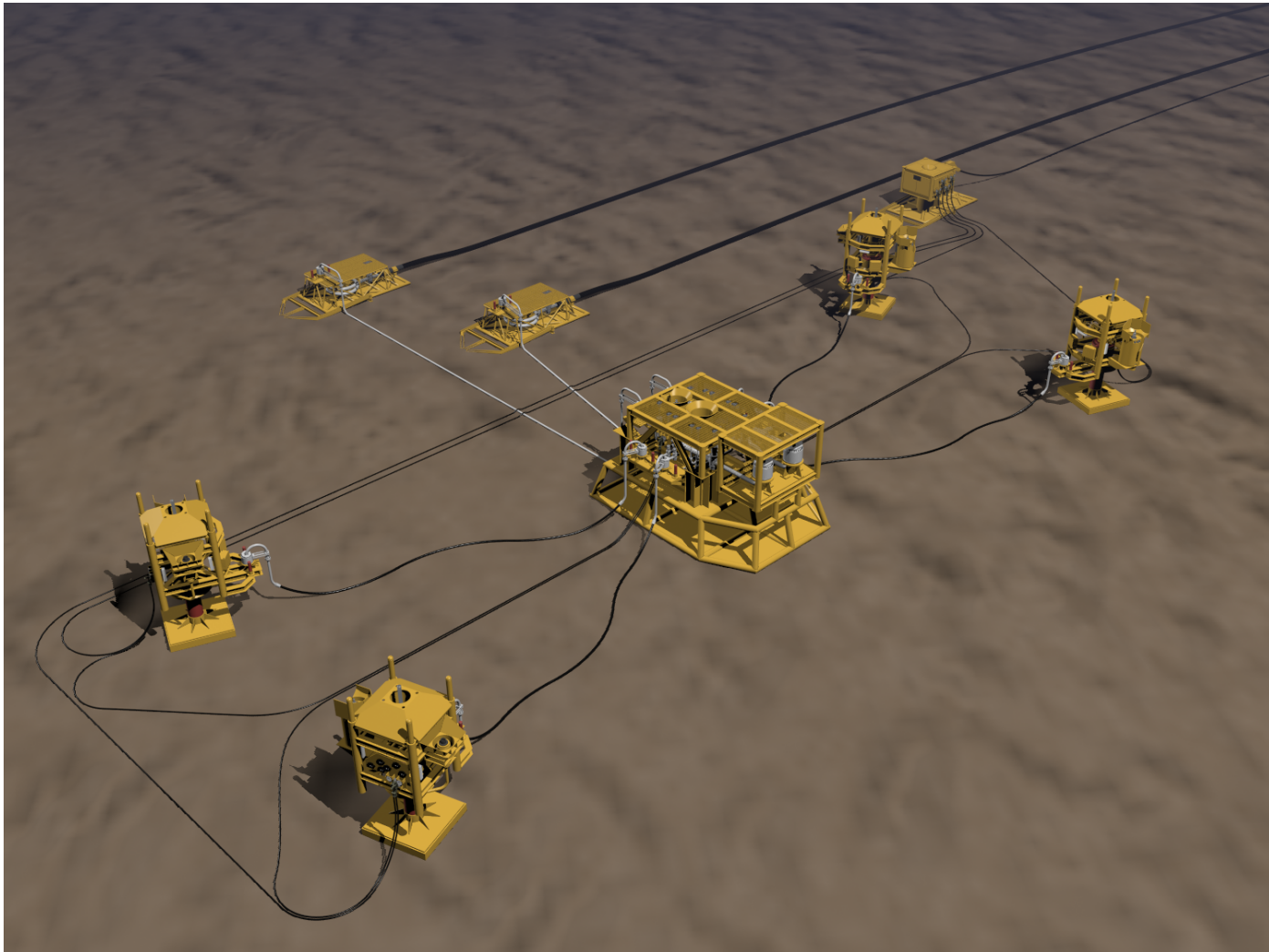
## Mature Technology

- Trees
- Manifolds
- Template Manifold
- Sleds
- Jumpers
- Umbilicals
- Controls
- Flowlines
- Risers

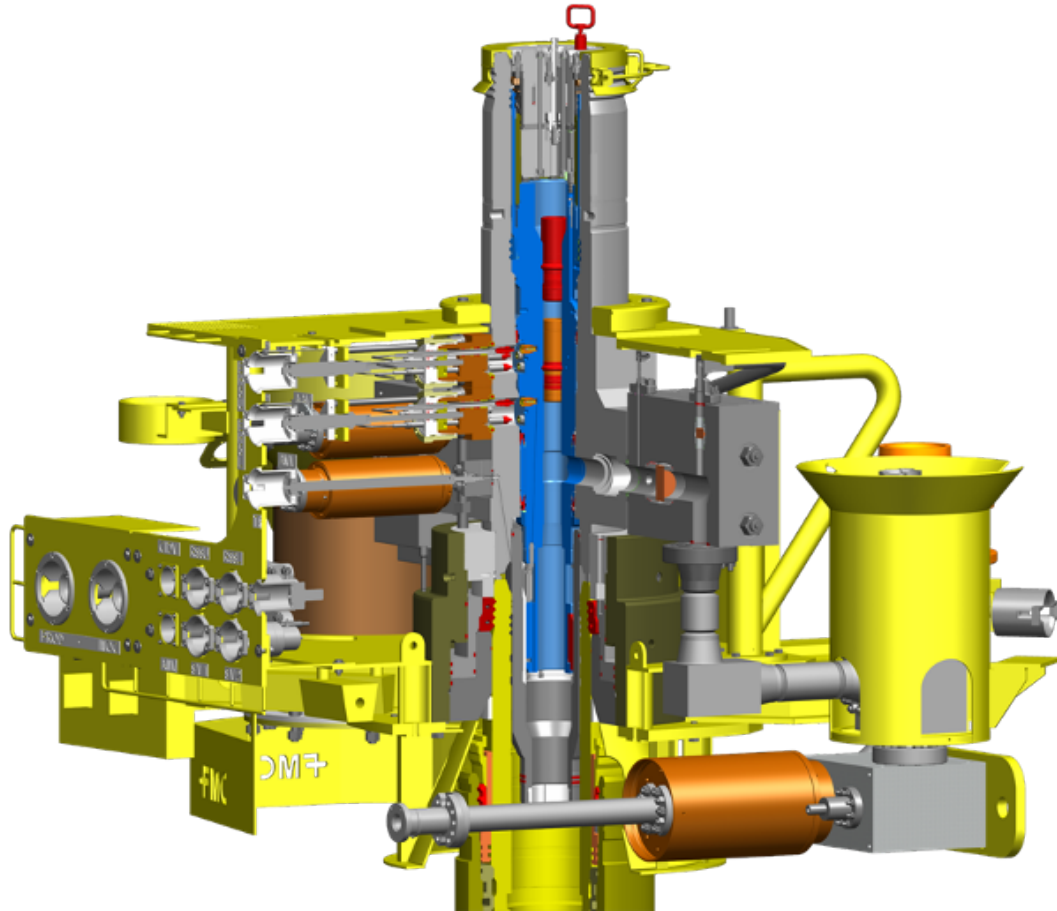
## Emerging Technology

- Subsea Separators
- Subsea Pumps
- Subsea Compressors
- HIPPS
- HP/HT

# Subsea Well Cluster, Trees, Manifold, Umbilical termination & Dual Flowlines



# Subsea Tree Functions

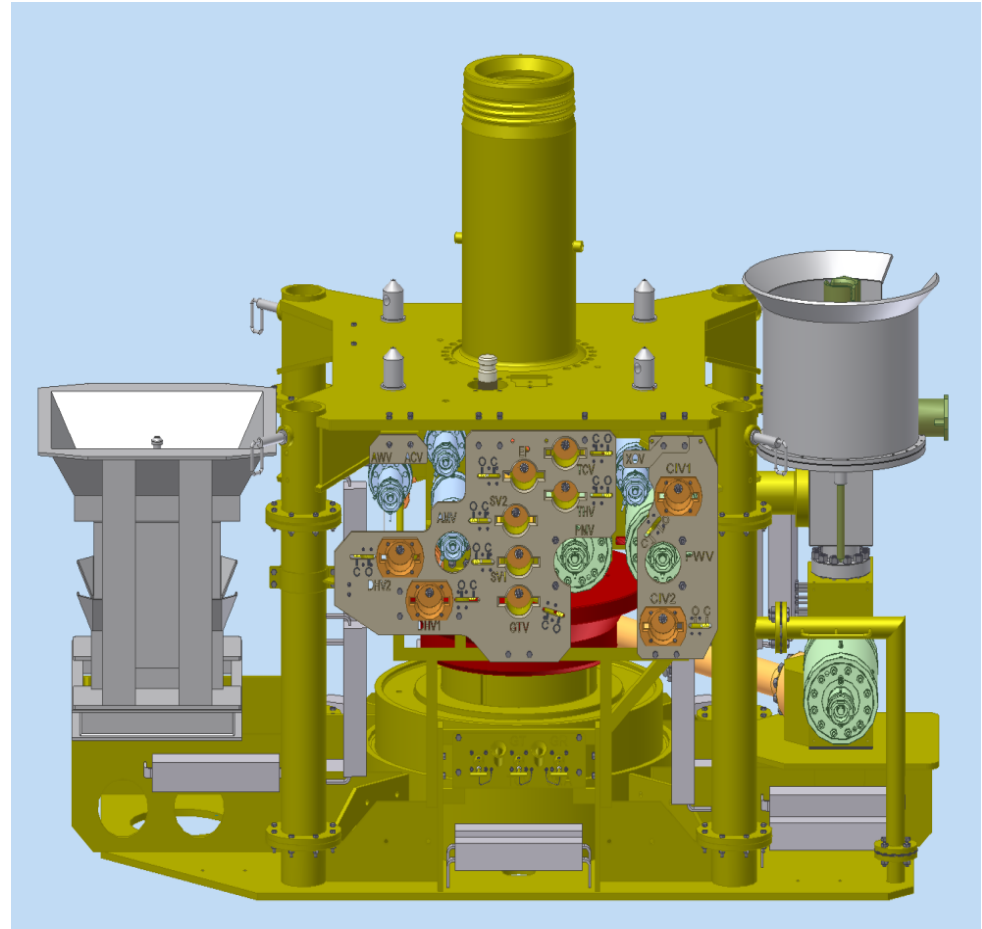


- Throttle flow to commingle with other wells
- Shut in production
- Isolate Tubing/Casing Annulus
- Interface with Subsea Wellhead
- Suspend Completion Tubing
- Provide Workover Access
- Chemical Distribution
- Actuator Hydraulic Control
- Actuator Pressure Compensation

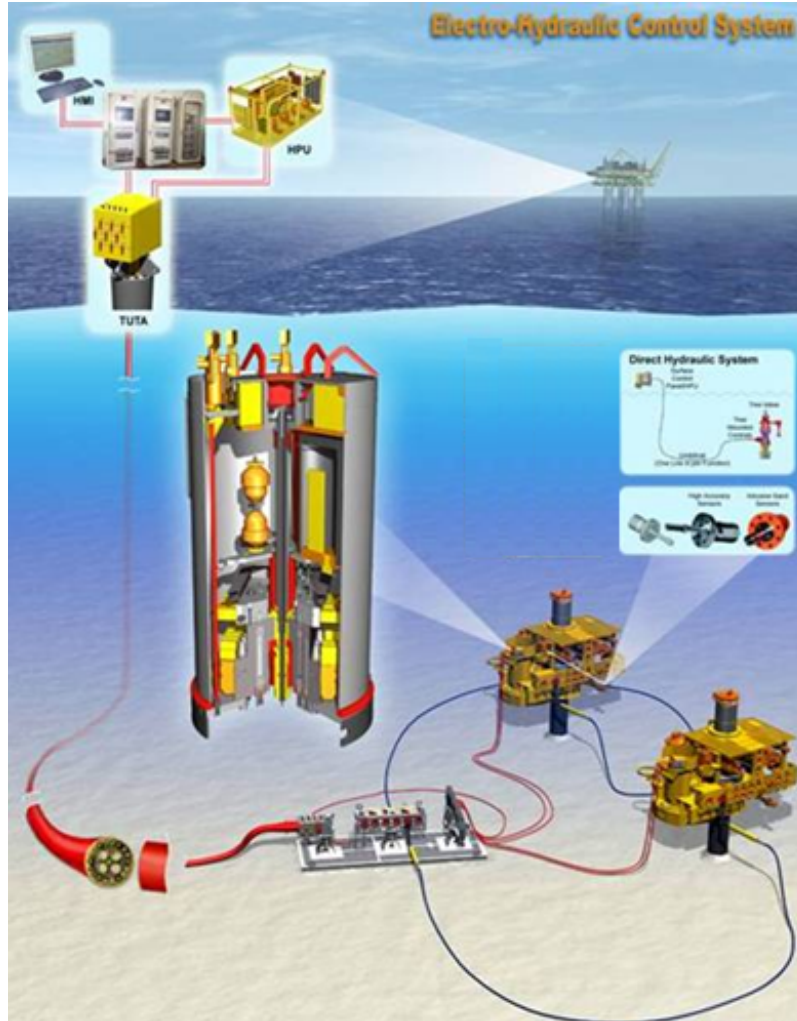


# Subsea Tree – Design Considerations

- Choke Valve
- Chemical injection
- Sensors
- Jumper Connection(s)
- Running Tool Access
  - Control Module
  - Choke insert
  - Jumper(s)
- ROV Interfaces
  - Physical
  - Visual / camera



# Controls System

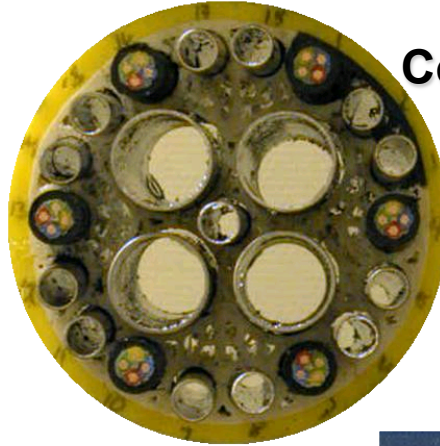


## Design Considerations:

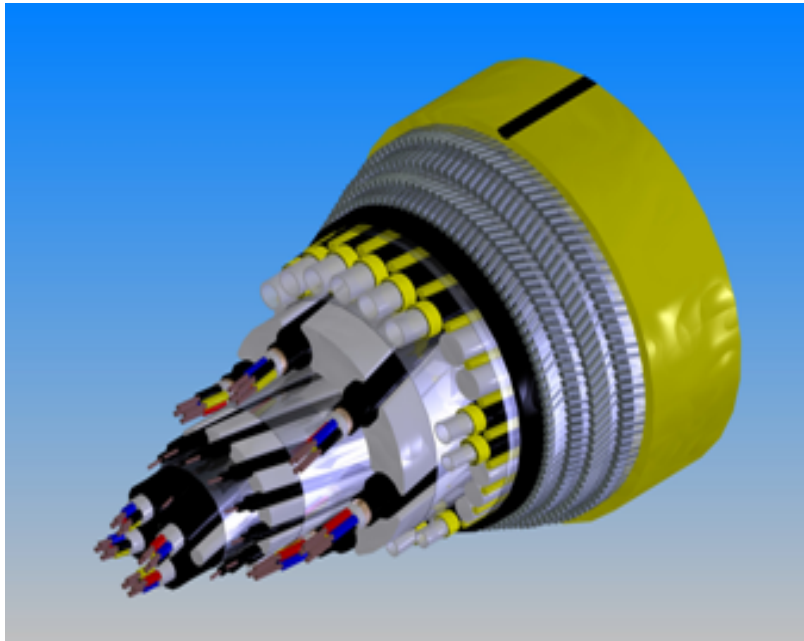
- Water Depth
- Offset Distance
- Number of Wells
- Well Management Philosophy
- Redundancy
- Chemical Injection Control
  - Metering topside / subsea
- Phased/Future Developments
- Hydraulic & Electrical Umbilicals
  - Separate or combined

# Umbilical Service

- Hydraulic power
- Chemicals
- Electrical
- Gas lift
- Fiber Optics



**Combination Umbilical with  
Electrical Control Cable**



**Armored Steel Tube Umbilical**



**Integrated Service Umbilical**

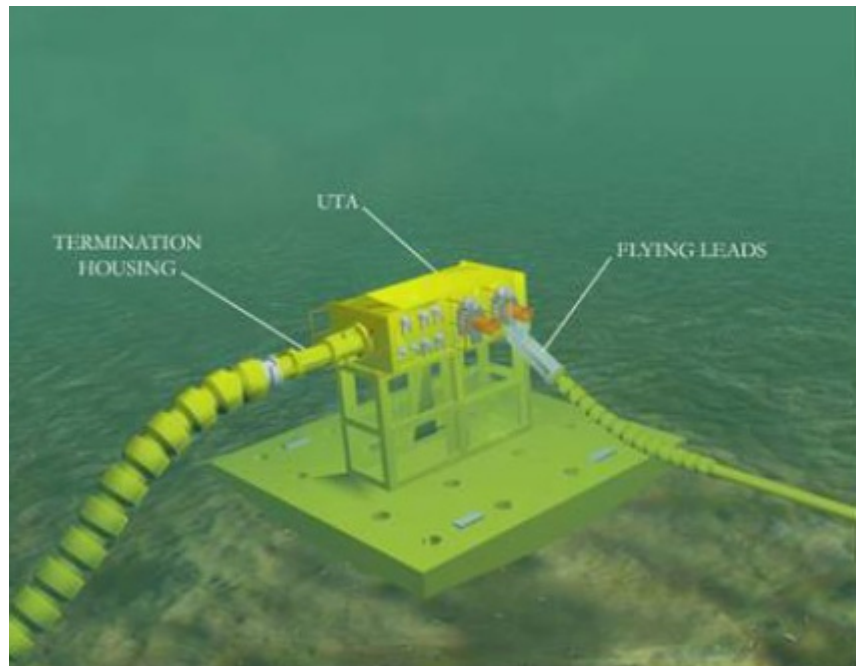
# Subsea Umbilical Termination Assembly (SUTA)





# Flying Leads: Local Interconnections

- Hydraulic & Chemicals
- Steel Flying Lead for deepwater (SFL)
- Electrical Flying Lead (EFL)
- Fiber Optics





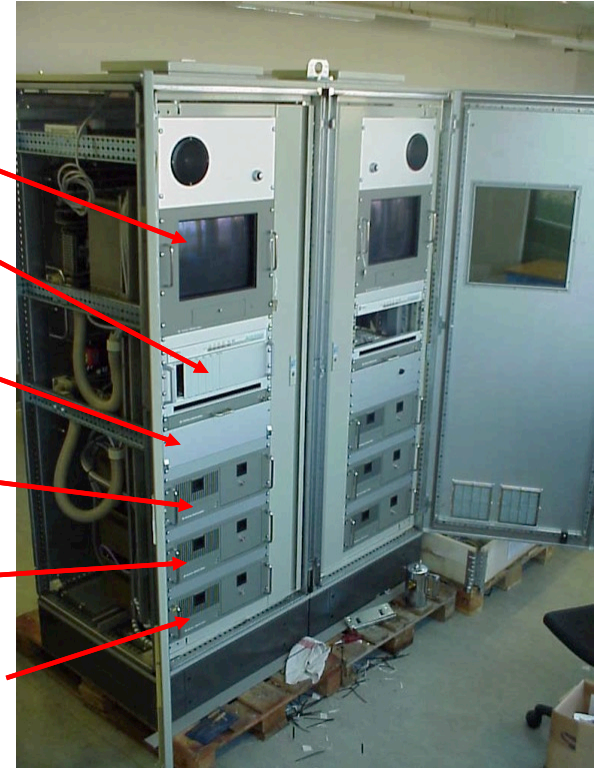
# Subsea Controls - Types of Systems

## DRILLING

- Direct Hydraulic
  - One hydraulic line / valve
- Piloted Hydraulic
  - One pilot line / valve
  - One hydraulic supply line



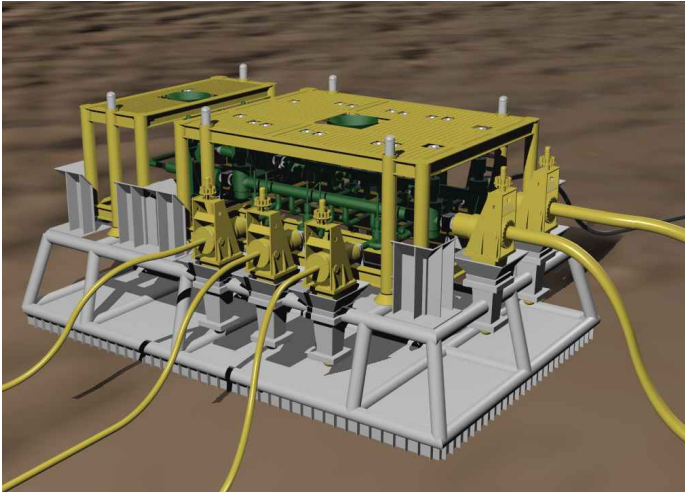
- Monitor**
- Keyboard & Mouse**
- Modem Rack**
- View Server**
- Control Server**
- Comms Sever**



## PRODUCTION

- Electro/Hydraulic
  - One hydraulic supply line
  - Electric solenoid valve / valve

# Subsea Manifolds Commingle Production

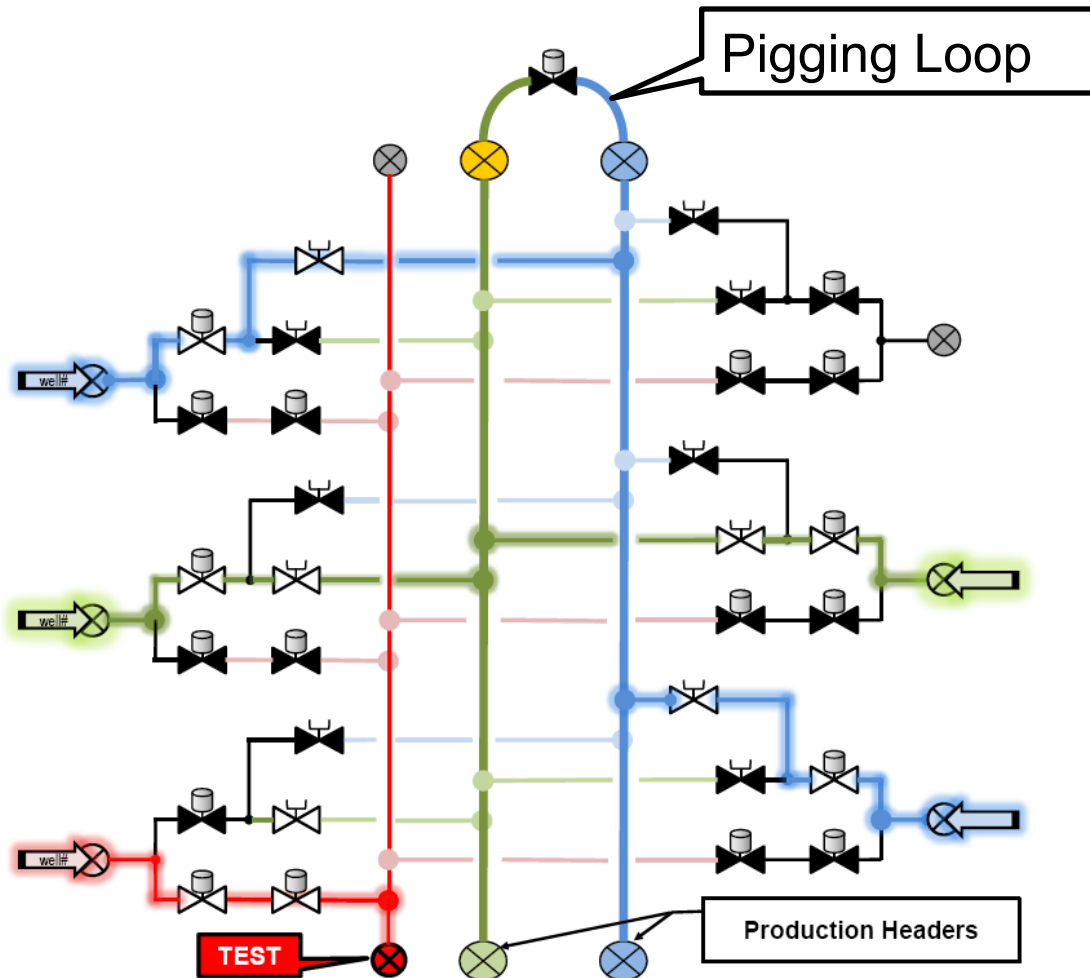


## Design Considerations

- Working Pressure
- Number of Well slots
- Piping & Valve arrangement
- Valve actuation
- Instrumentation & controls
- Expansion Capability
- Pigging Requirements
  - Barred tees
  - Pigging loop
- Installation
  - Pile
  - Mudmat

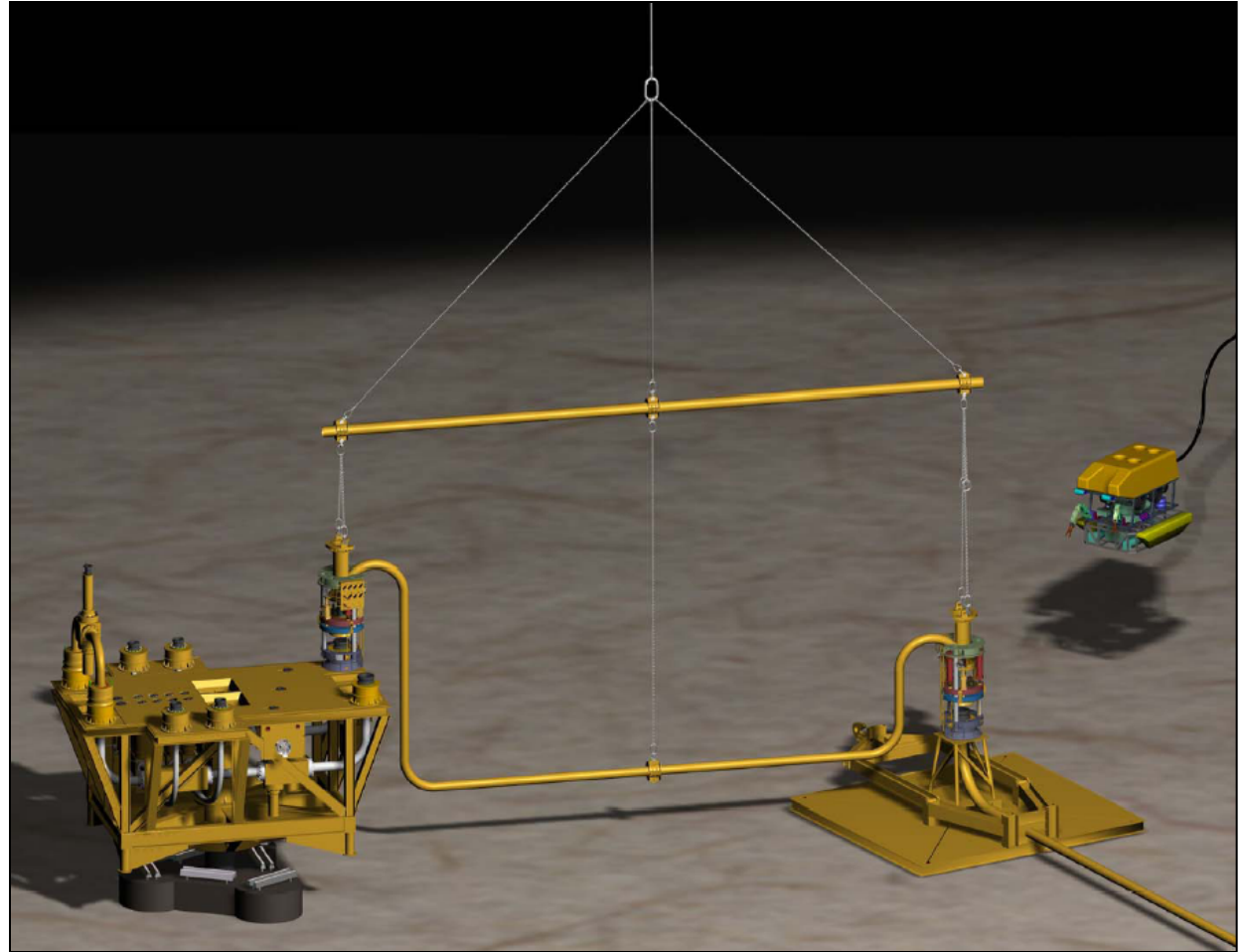
# Manifold Piping

## Production & Test Management



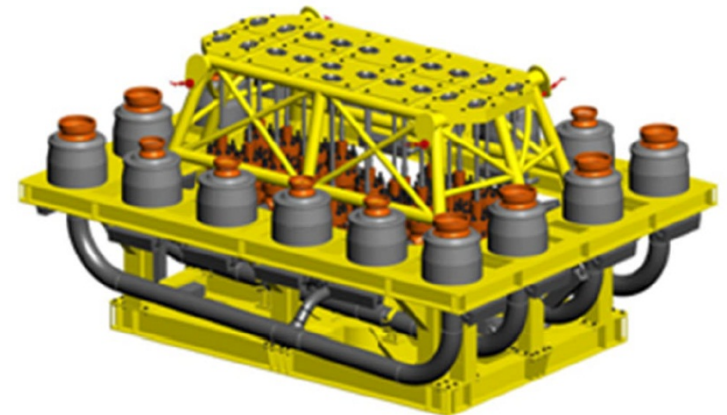
# Jumper Connection System

- Conduit types:
  - ✓ Pipe
  - ✓ Flexible
- Connector types:
  - ✓ Collet
  - ✓ Clamp
  - ✓ Other
- Running Tool:
  - ✓ Soft landing
  - ✓ Coarse Alignment
  - ✓ Lock / Unlock
- Seal Replacement
- Fabrication Fixtures:
  - ✓ Metrology
  - ✓ Testing



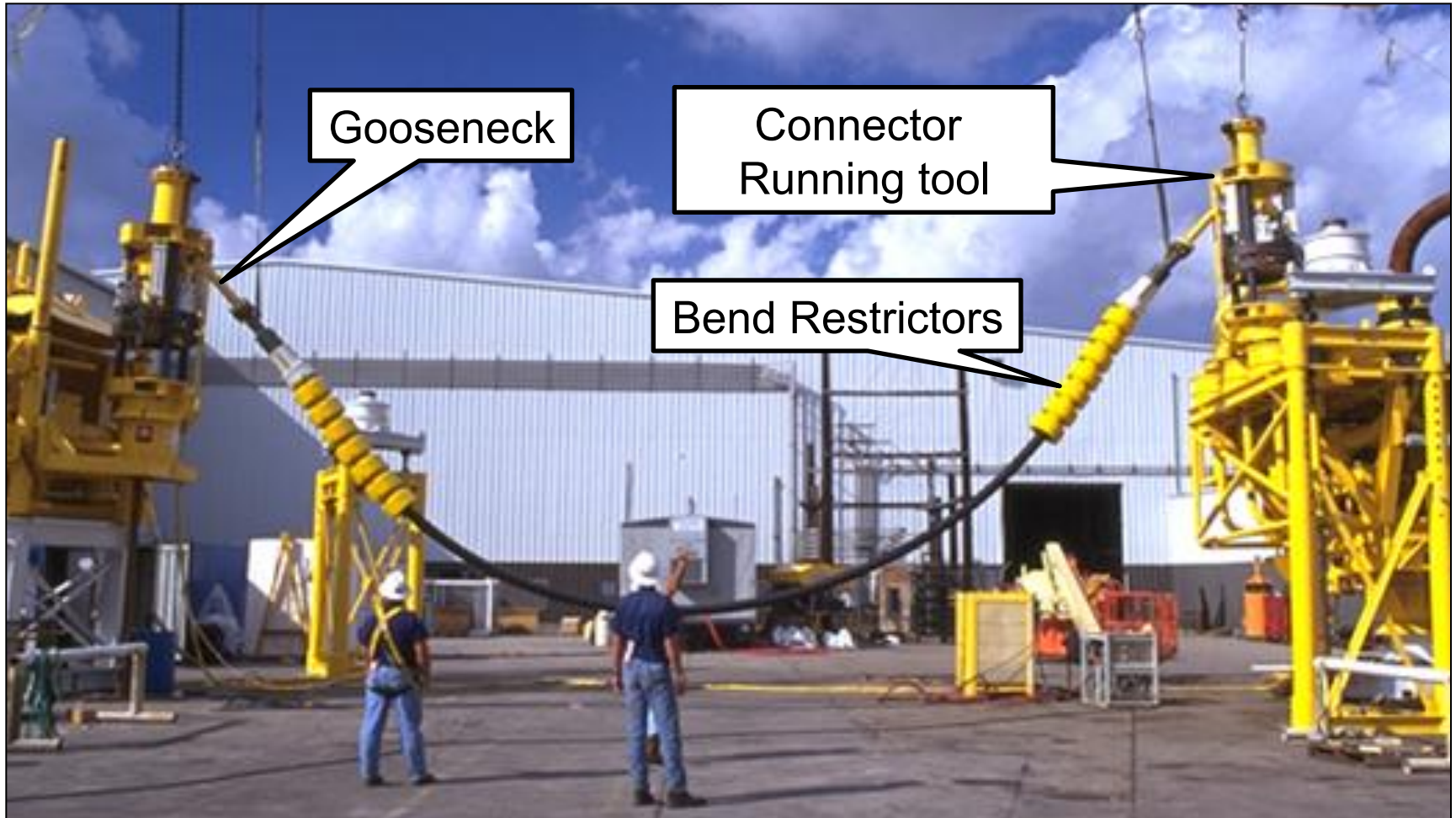
# Jumpers Connect....

- Trees
- Flowlines
- Manifolds
- Subsea Processing
- Sleds
- Export pipelines

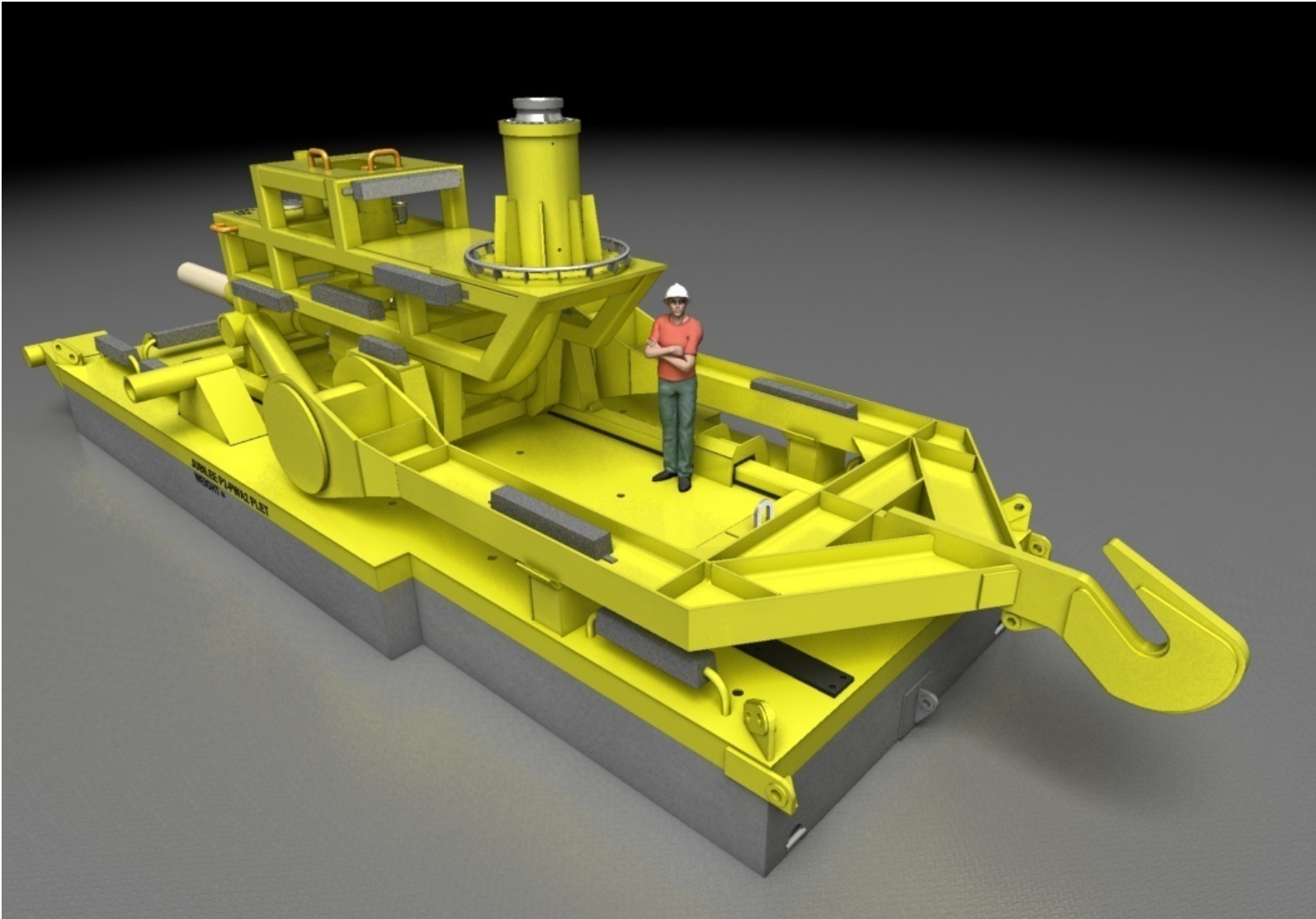




# Flexible Jumper



# Pipeline End Termination (PLET)



# Round Trip Pigging

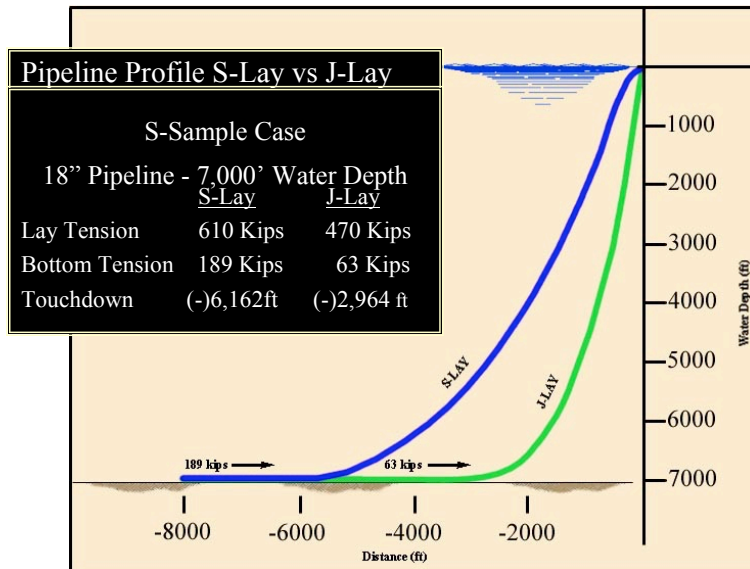


- Topside launchers and receivers
- Able to circulate hot fluid prior to startup
- Able to depressurize up & downstream of hydrate plug



# Flowline Design Considerations

- Hydrostatic Collapse
- Flow Assurance
- Hydrographic survey
  - Route survey
  - Avoid hazards
- Crossings



- Installation
  - S-Lay
  - J-Lay (record deepwater)
  - Reel-lay
- Wet buckle (buckle arrestors)
- Pipeline Repair



# Deepwater Riser Systems

## Riser Functions:

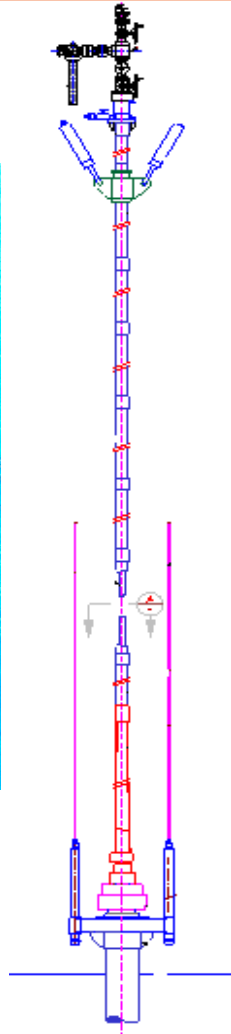
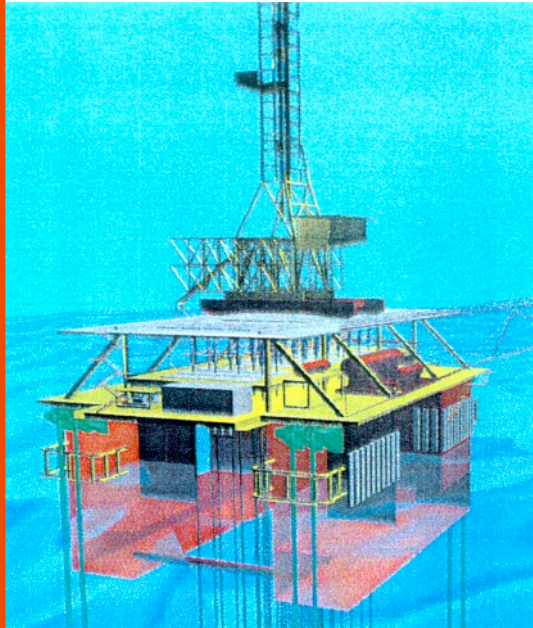
- Drilling
- Workover
- Production
- Injection
- Export

## Riser Types:

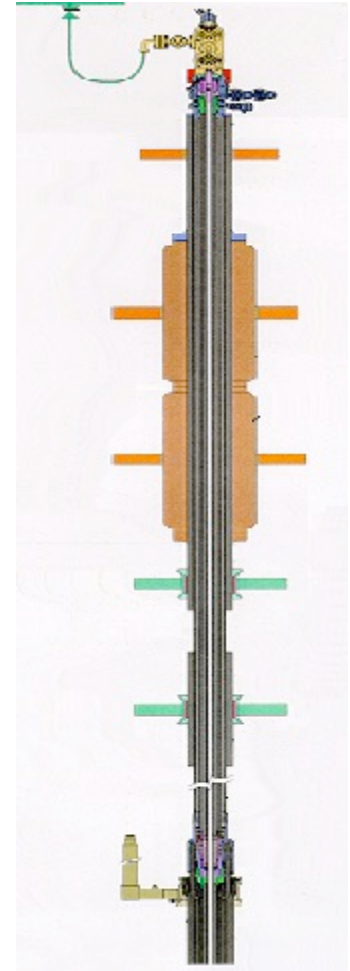
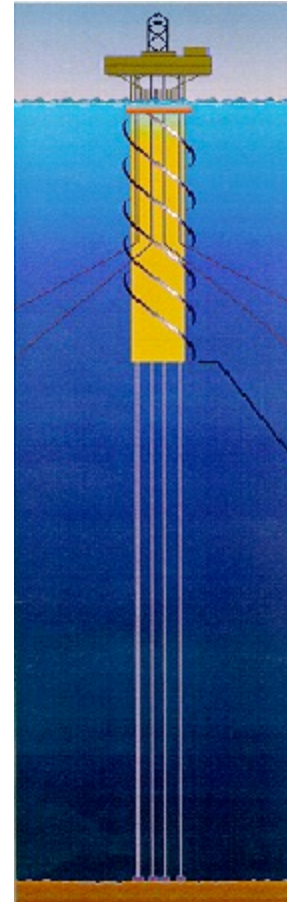
- Top Tension
- Flexible
- Steel Catenary
- Hybrid

# Top Tension Riser Configurations

## TLP System

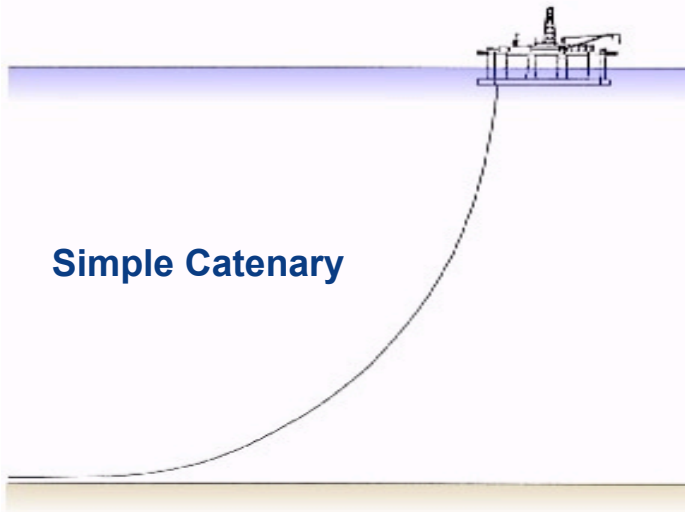


## Spar Buoy System

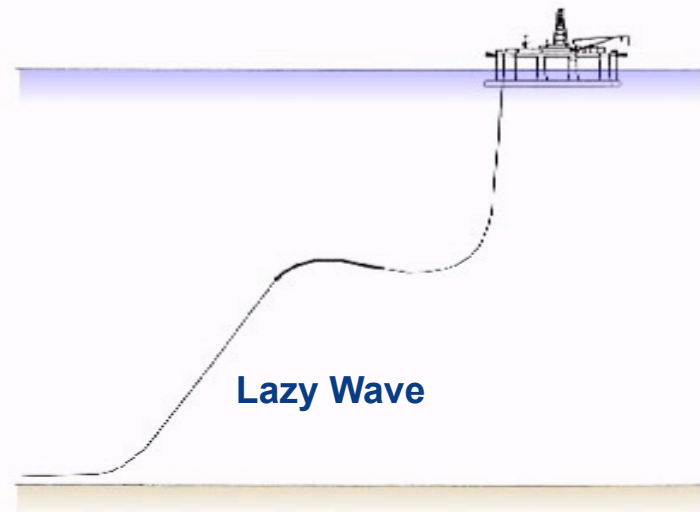


# Flexible Riser Configurations

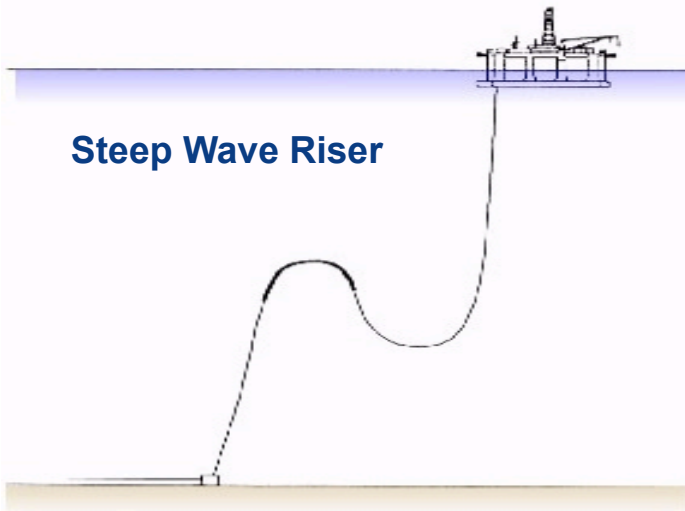
**Simple Catenary**



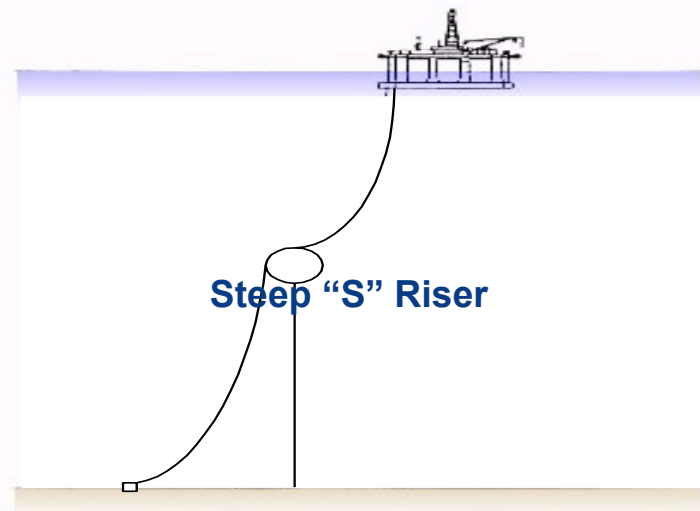
**Lazy Wave**



**Steep Wave Riser**

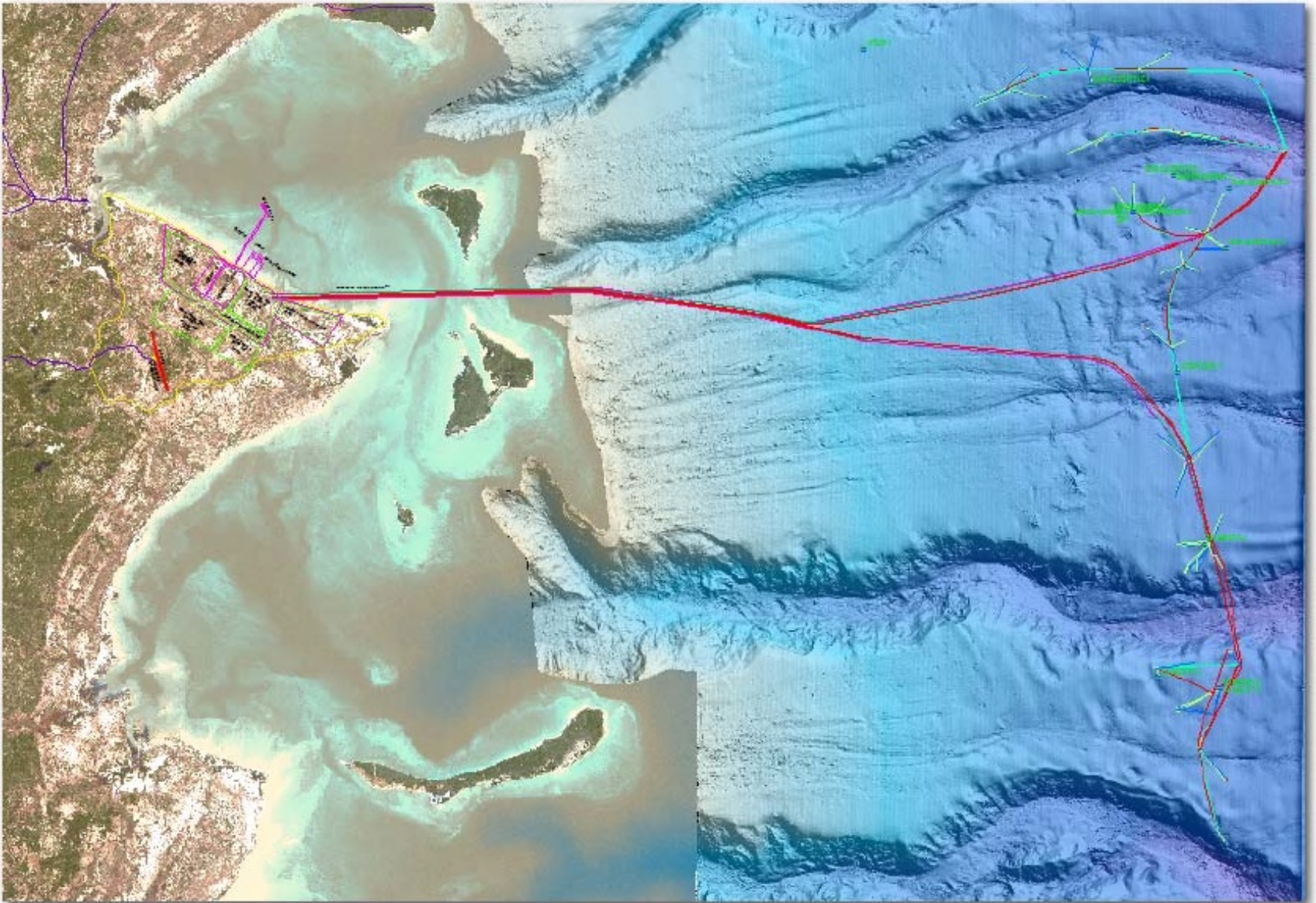


**Steep "S" Riser**





# Export Pipelines





# Flowline versus Pipeline

## Production Flowline

- Higher pressures
- Smaller bores
- Produced fluids change with time
- Flow Assurance issues:
  - Water
  - Asphaltines
  - Wax
  - H<sub>2</sub>S
  - Wet CO<sub>2</sub>
  - Corrosion

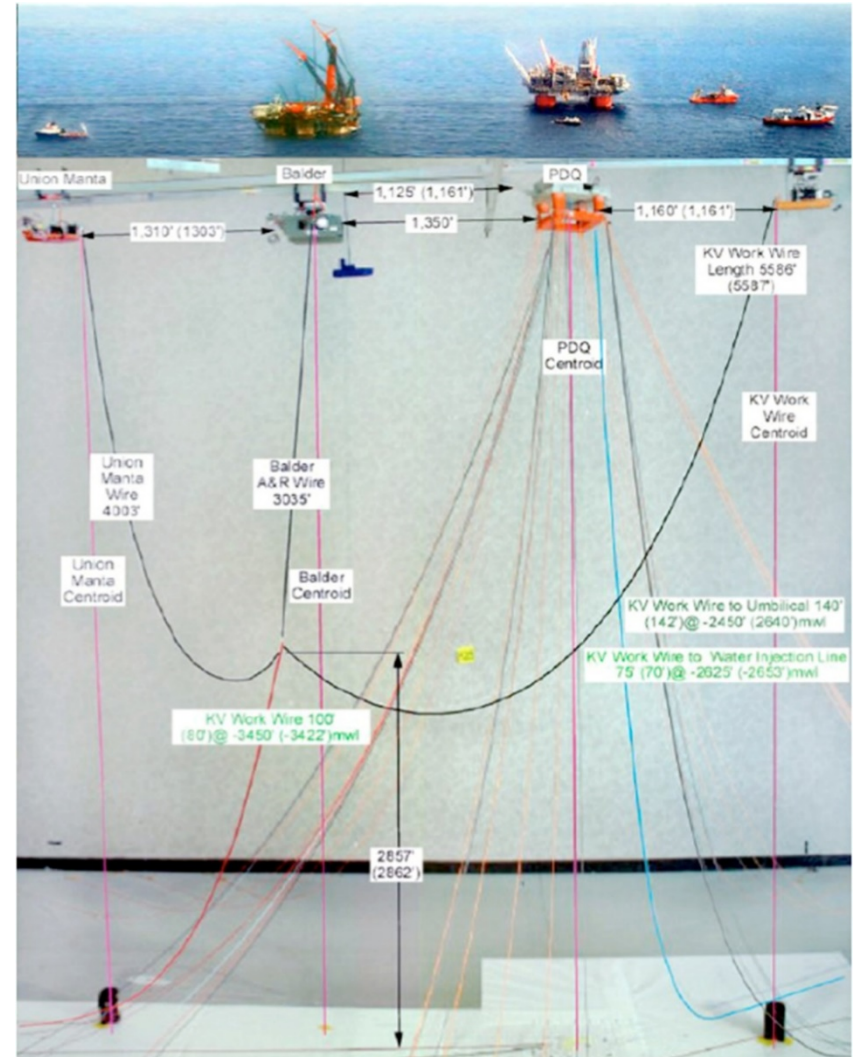
## Export Pipeline

- Pressure controlled (pumps & compressors)
- Larger bore
- Longer distances
- Single phase, clean (separate oil & gas)



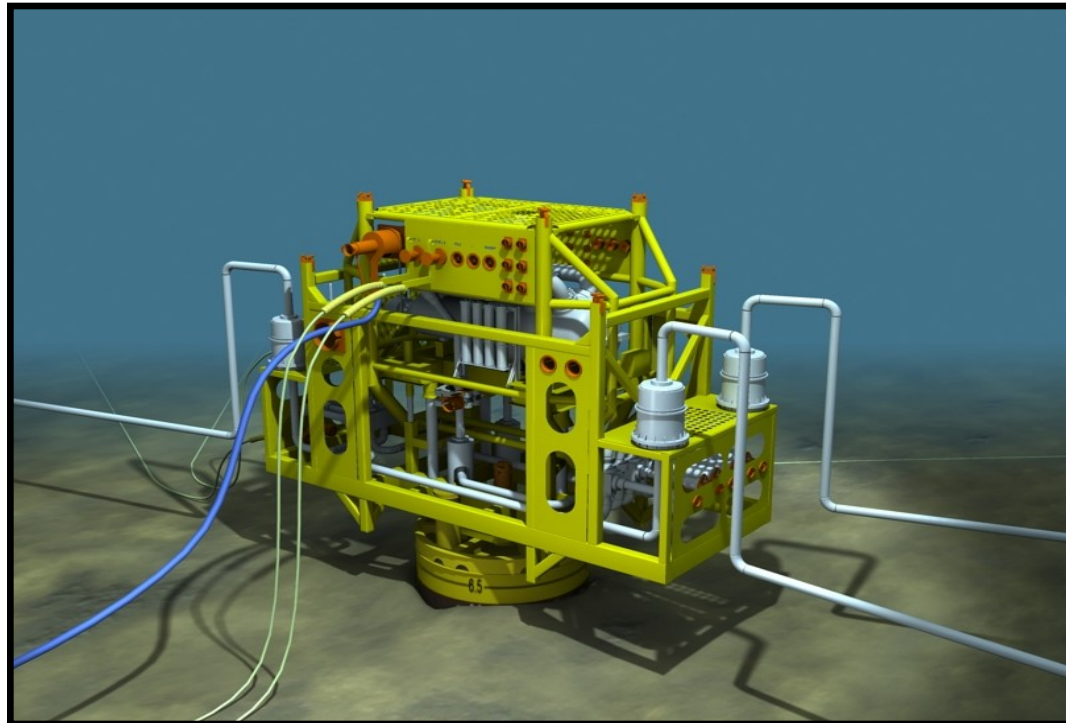
# GoM Deepwater Installation - SIMOPS

- Vessel coordination, position, and control
- Dropped objects
- Weather window
- Loop Currents
- Potential clash (tight clearances) between following items during PLET retrieval and installation:
  - Risers
  - Umbilicals
  - Vessels
  - Flowlines
  - Lifting Cables
  - Mooring lines

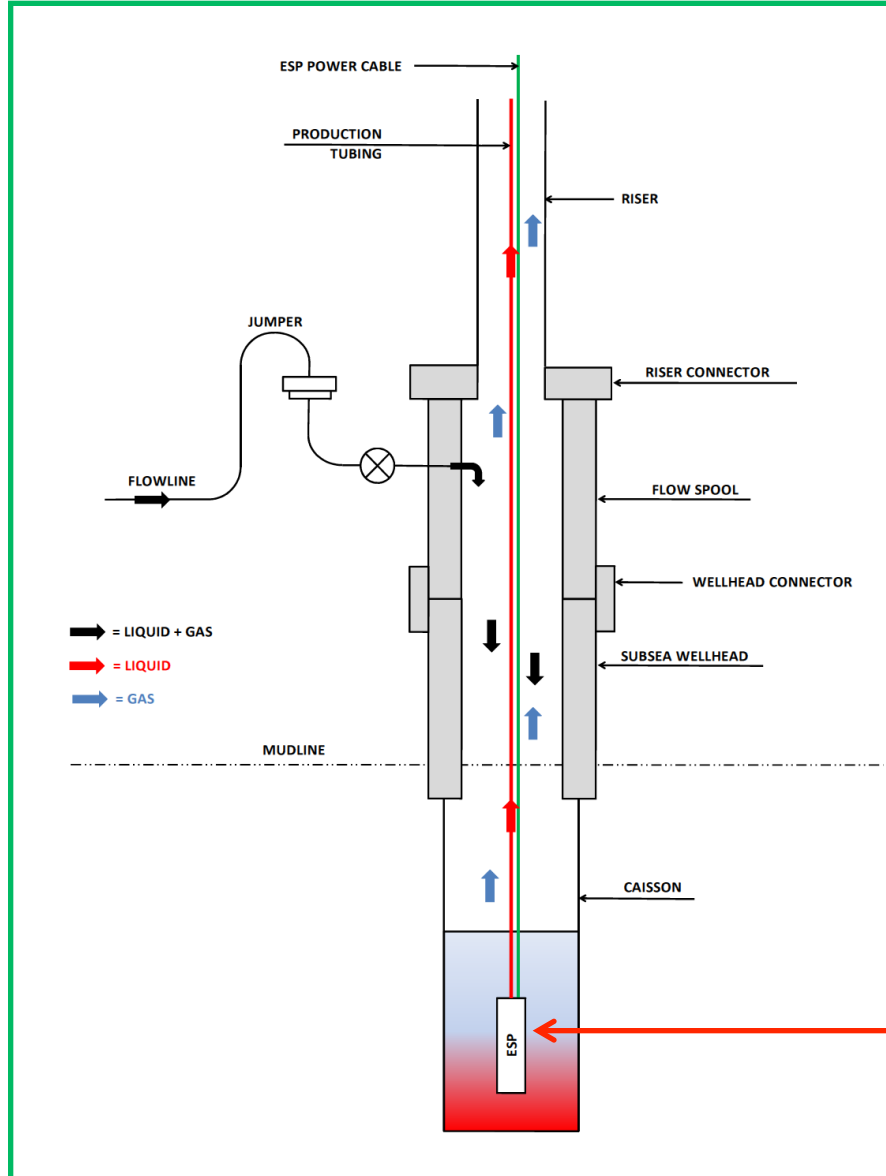


# Emerging Technologies

- Subsea Processing
  - Separation
  - Pumping / Boosting
  - Compression
- HIPPS
- HPHT



# Caisson Separation and Boosting

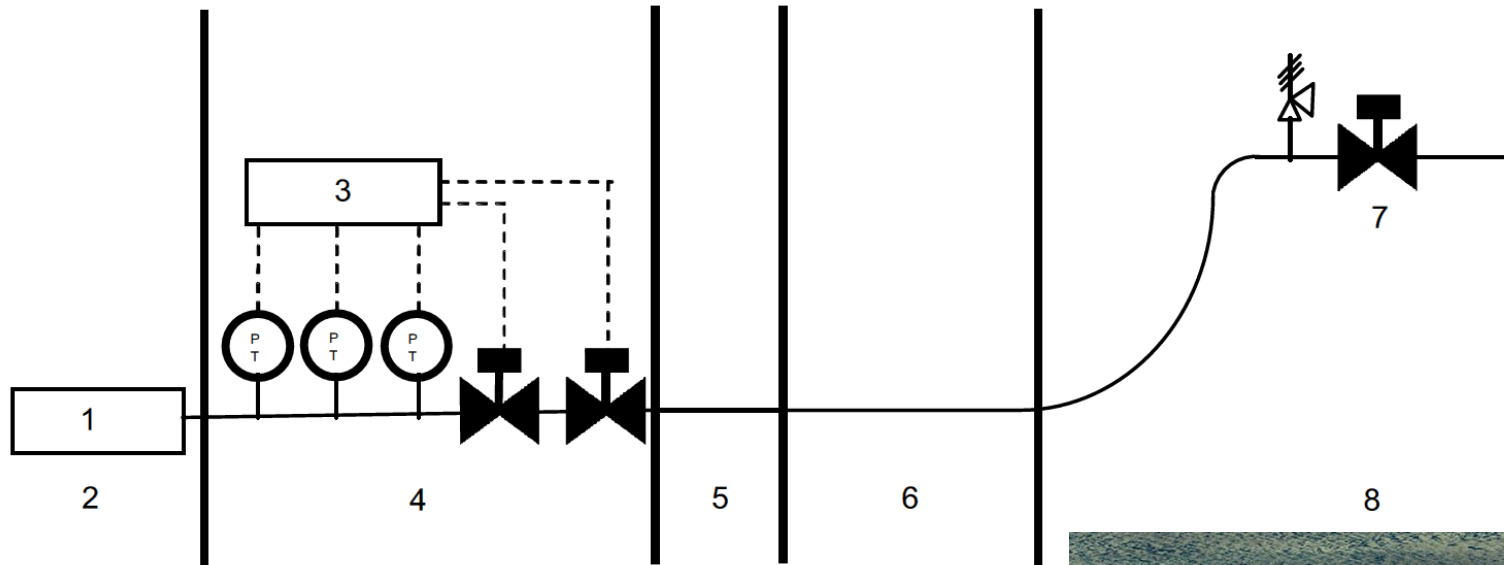


Electric  
Submersible  
Pump (ESP)



# High-Integrity Pressure Protection Systems (HIPPS)

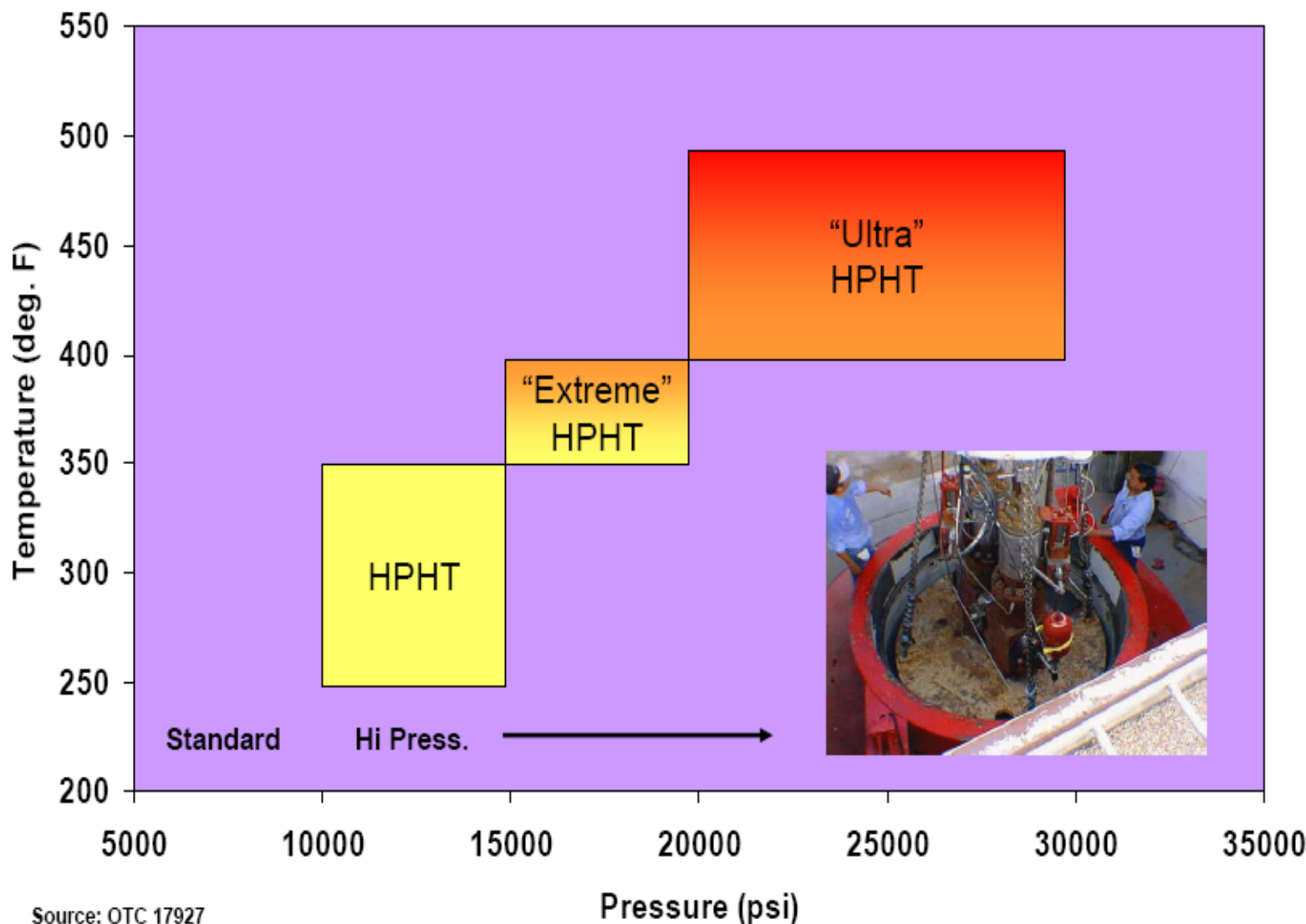
HIPPS are designed to protect flowlines that are not rated for the full shut-in wellhead pressure.



- 1 reservoir
- 2 overpressure source
- 3 logic solver 2oo3 voting logic
- 4 subsea safety instrumented system
- 5 subsea fortified zone
- 6 flowline
- 7 BSDV
- 8 host fortified zone



# High Pressure / High Temperature (HPHT)

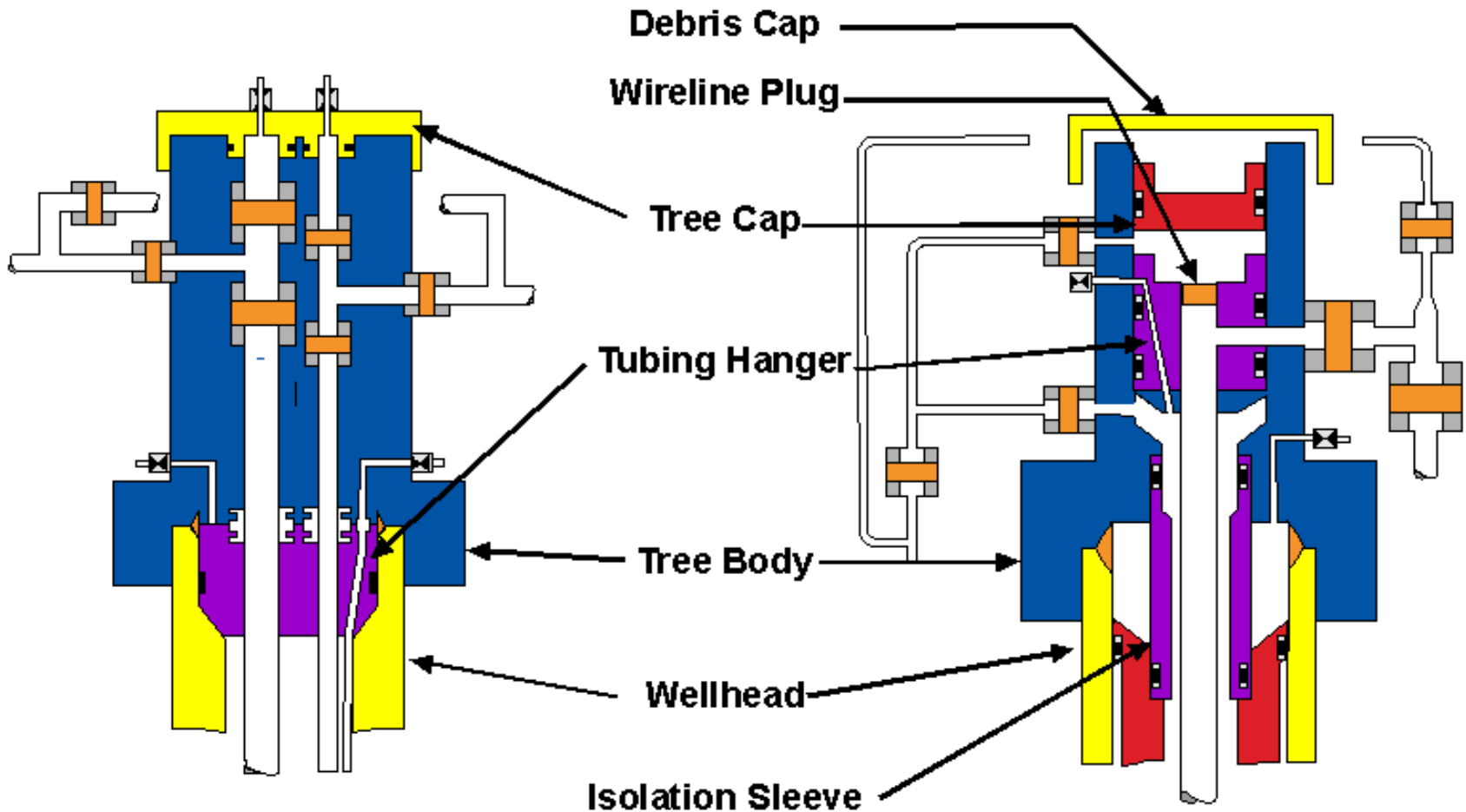


# Subsea Systems Engineering

Tricia Hill

SUT Subsea Engineering and Operations Chair

# Vertical vs. Horizontal Tree



## VERTICAL TREE:

- Vertical Valve Bores
- Tubing Hanger in Wellhead

## HORIZONTAL TREE:

- Horizontal Valve Bores
- Tubing Hanger in Tree



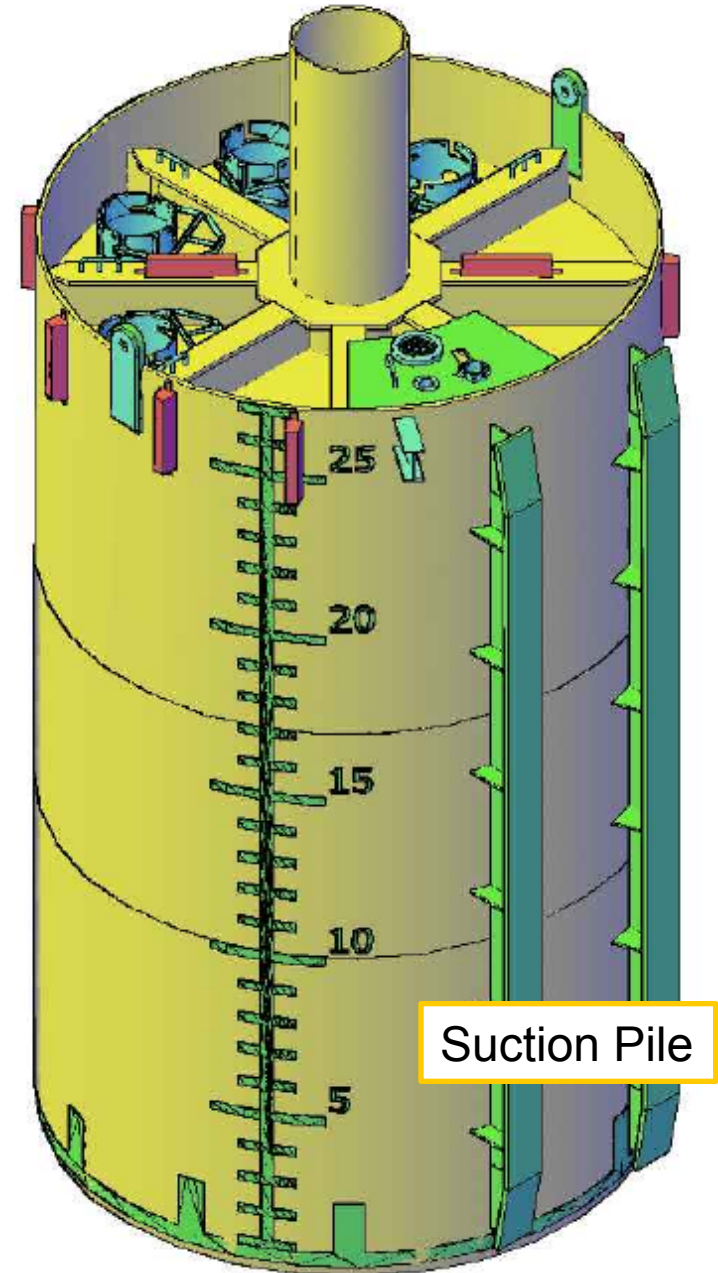
# Piles

## Type

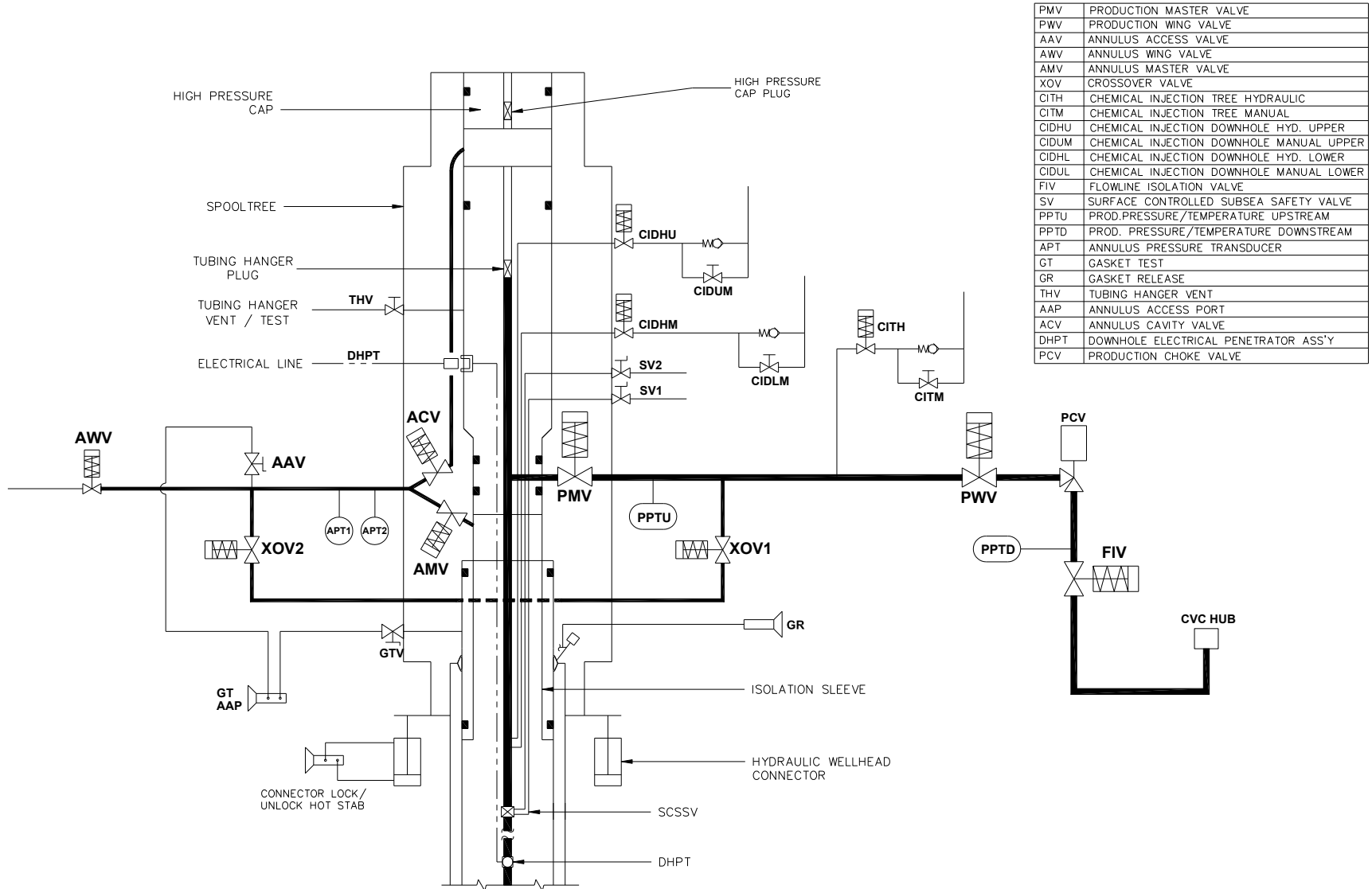
- Jetted
- Suction

## Functions

- Flowline Initiation
- Foundation
  - Manifold
  - Sleds
- Anchor for surface facility



# Horizontal Tree Schematic



# Subsea Umbilical Installation

