Subsea Infrastructure

(*Some pictures removed to limit file size)*

Early History

- OPEC Oil Crisis of 1973/4 encourages search for indigenous oil and gas
- Early offshore platforms installed in water 20 – 40m deep, and relatively close to shore
- Multiple, simple, bridge-linked platforms are economic
- Christmas trees installed on platforms – dry trees
- Predominantly gas production

Typical shallow water platform arrangement, southern North Sea

ConocoPhillips Murdoch platform complex in 37m water depth

Early history continued

- Soon exploration companies were looking further afield
- Typical water depths in Central North Sea (latitude of Aberdeen) are 100m
- Typical water depths in Northern North Sea (latitude of Shetland) are 160m
- Support structure (steel jacket or concrete caisson) required is massive
- Only single platform economic – all modules piled up
- Huge fields – Brent, Statfjord – still multiple platforms
- Drillers start to develop deviated drilling but reach from a platform was limited

Typical deep water platform, northern North Sea

Society for Underwater Technology

BP Magnus platform, depth 186m

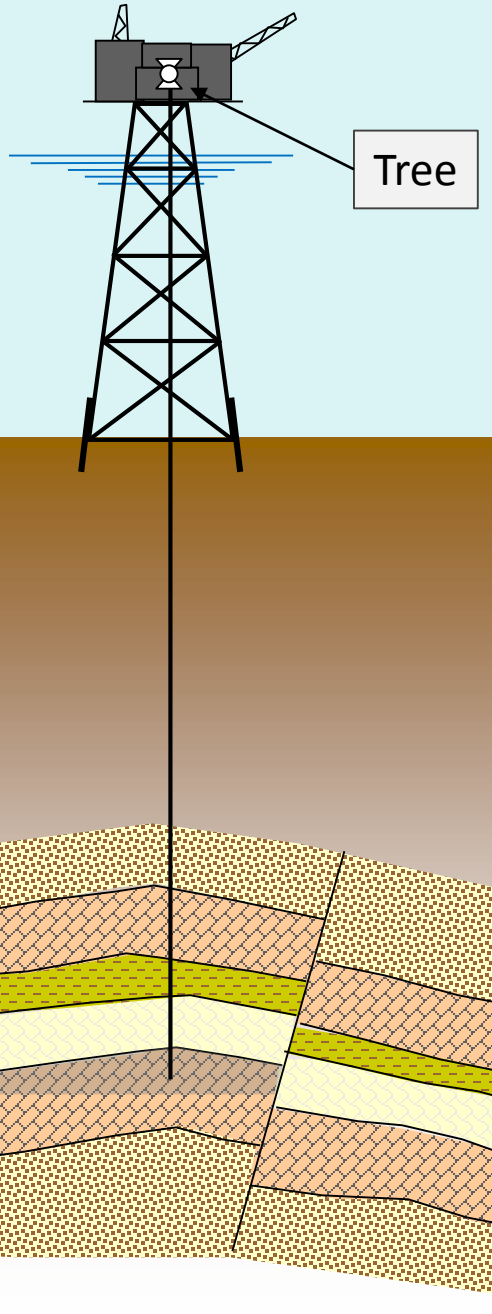
Jacket during tow-out

Christmas trees

- During drilling of a well, it must be possible to isolate it
- On completion, isolation by means of a sequence of valves
- Early valve stacks deemed to look like Christmas trees

- The name has stuck!

Schematic of well – dry tree

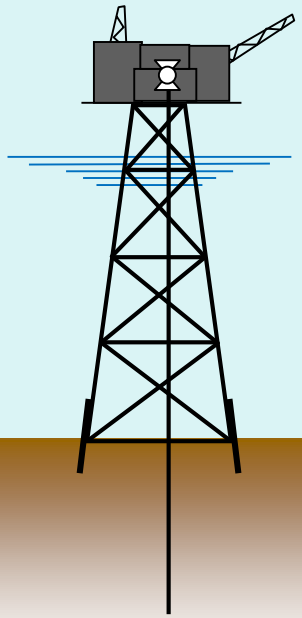


Function of a Platform

Also referred to as 'Host'

CONTROL & SAFETY OF PRODUCTION

CONDITION WELLS & FLUIDS
- Scale inhibitor
- Scavengers
- Gas lift



SEPARATE PRODUCTION FLUIDS

GAS

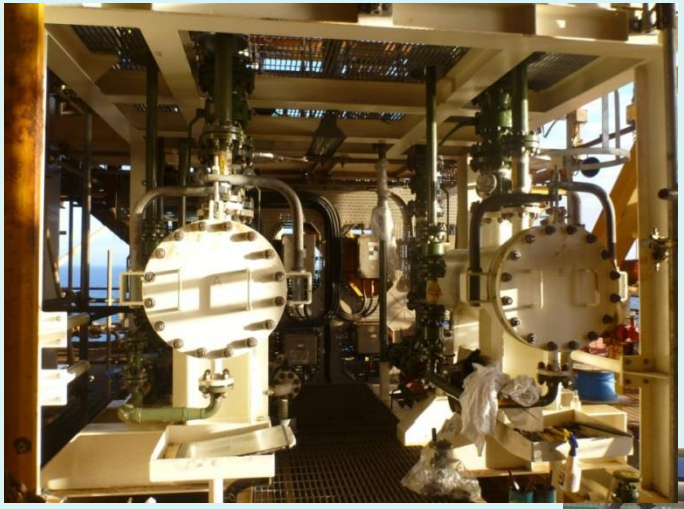
OIL

WATER

Water cleaned (<30ppm oil) and discharged overboard

Hosts – possible functions

- Process water & gas
- Export oil & gas
- Inject water or gas
- Provide power
- Provide controls function
- Dispose of water & gas
- Inject chemicals
- Drilling platform
- Provide heating or cooling
- Waste disposal
- Provide compression or expansion
- Provide safe accommodation
- Provide access – solid stores & equipment, liquids, helicopters



Platforms

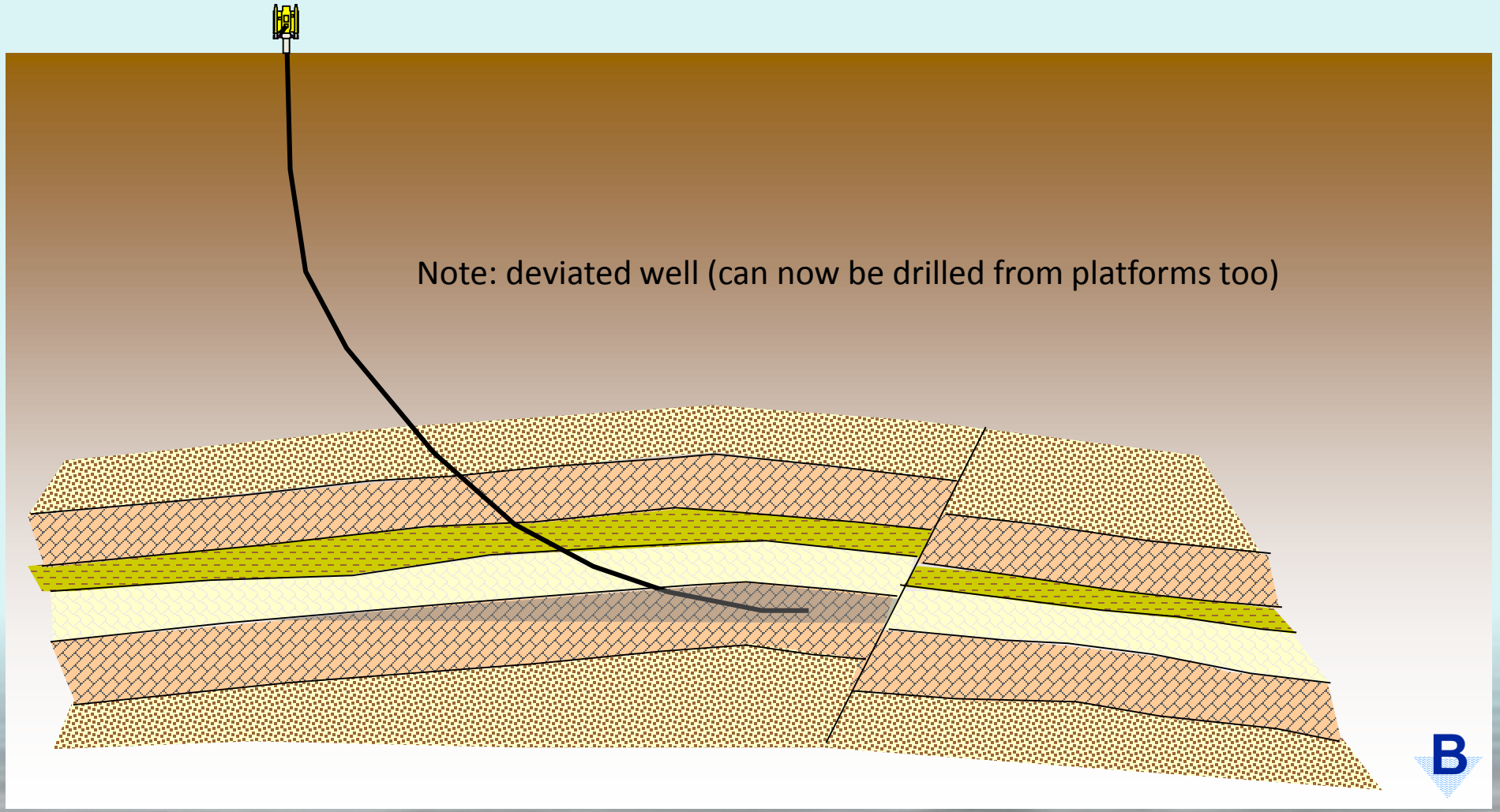
Subsea christmas trees

- Range of platform wells was limited
- Large reservoirs required multiple sites
- Multiple platforms uneconomic
- Why not drill remote from platform, with tree on seabed?
- Shell experimented with single well and wet tree close to Brent Bravo in early 1980s
- The beginning of subsea engineering as we know it today

- Safe isolation requires a minimum of two valves in sequence
- Pressures of 150 – 200 bar common; some are over 700 bar
- Modern wet tree looks nothing like Christmas tree…

Typical subsea tree

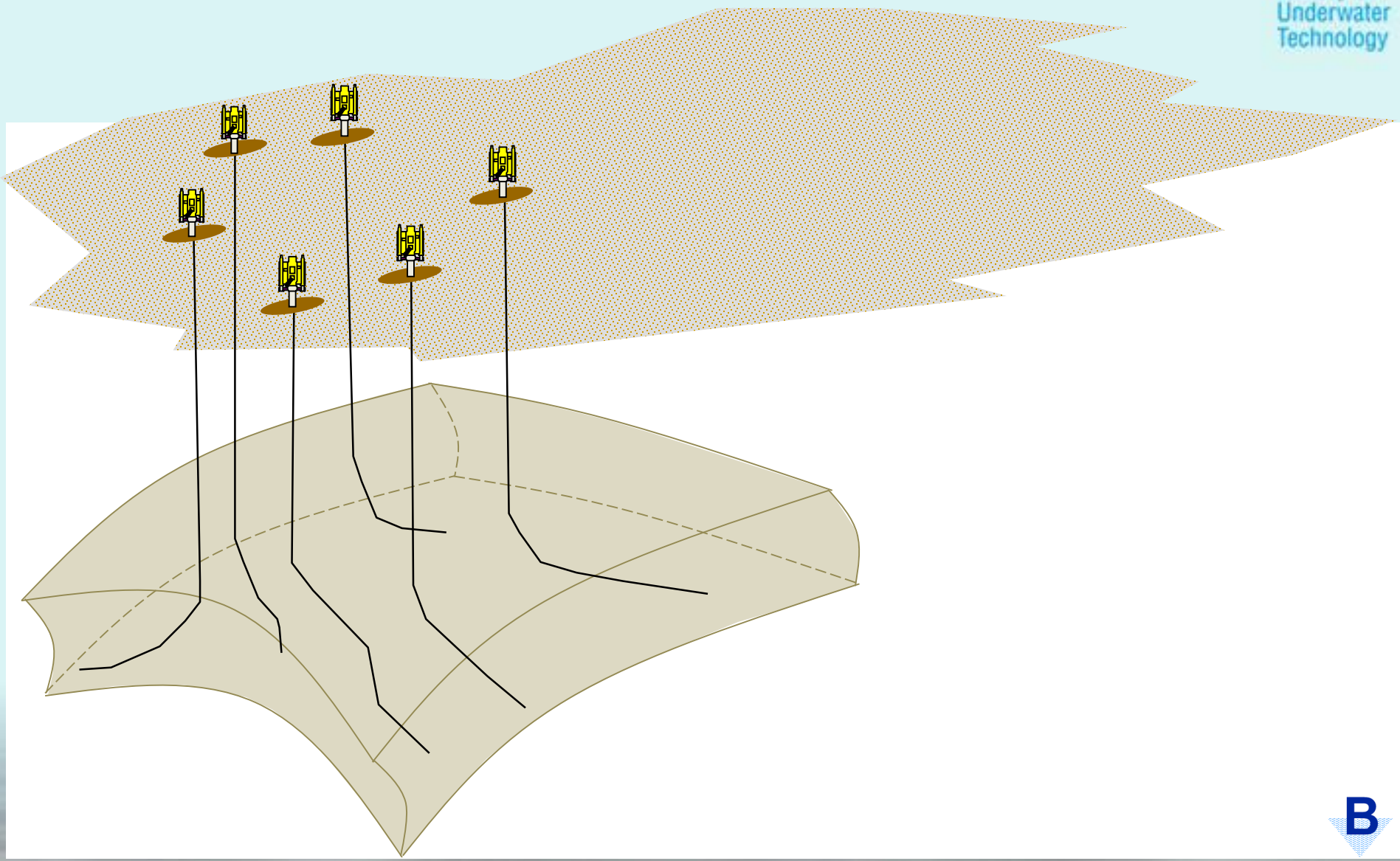
Simplified schematic of well – wet tree



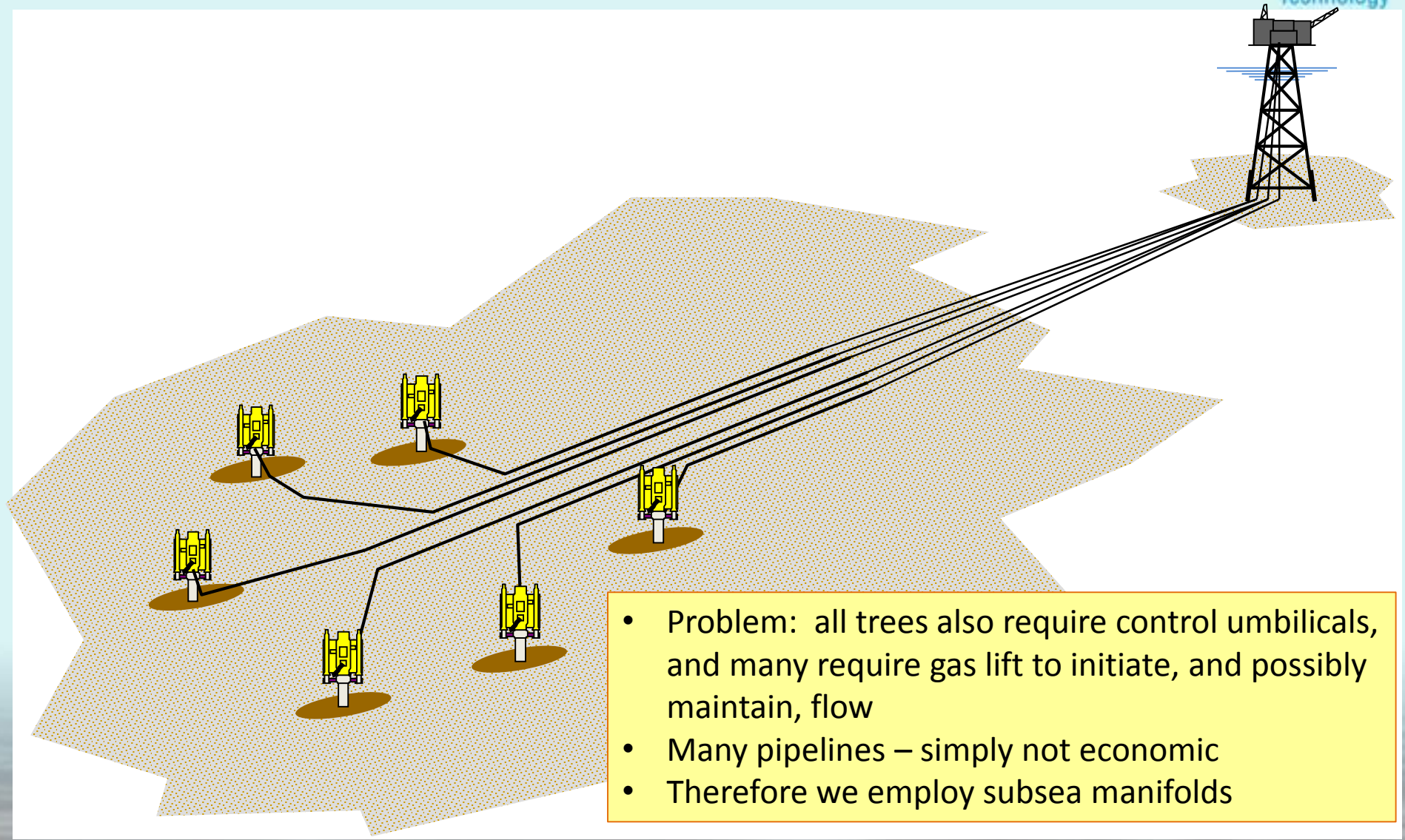
Subsea manifolds

- Platforms support many wells
- If this is to be replicated subsea, multiple wells must be tied back
- One way would be to connect each tree back to the host by individual pipelines

Six wells drilled into hypothetical reservoir

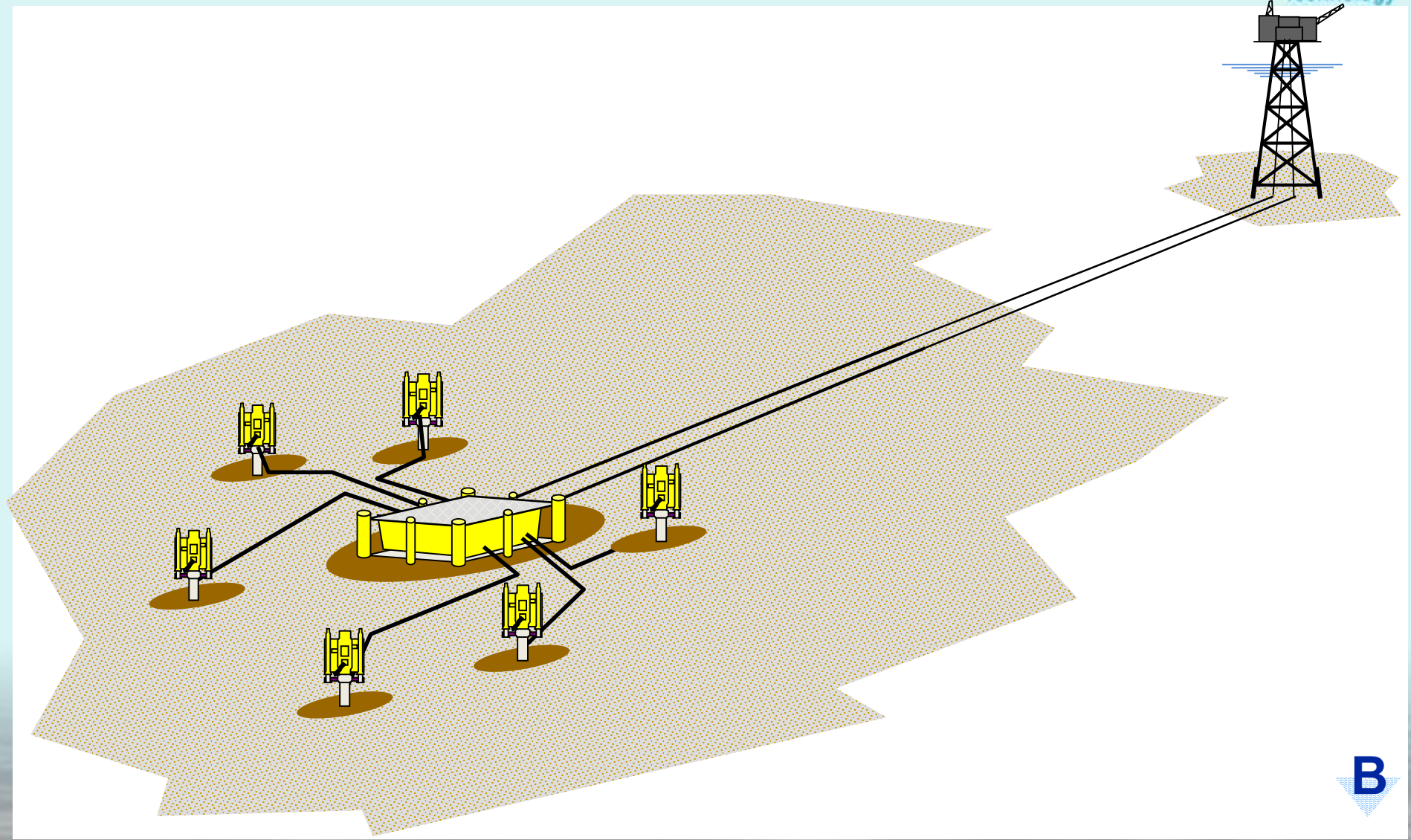


One pipeline per well… a very expensive solution

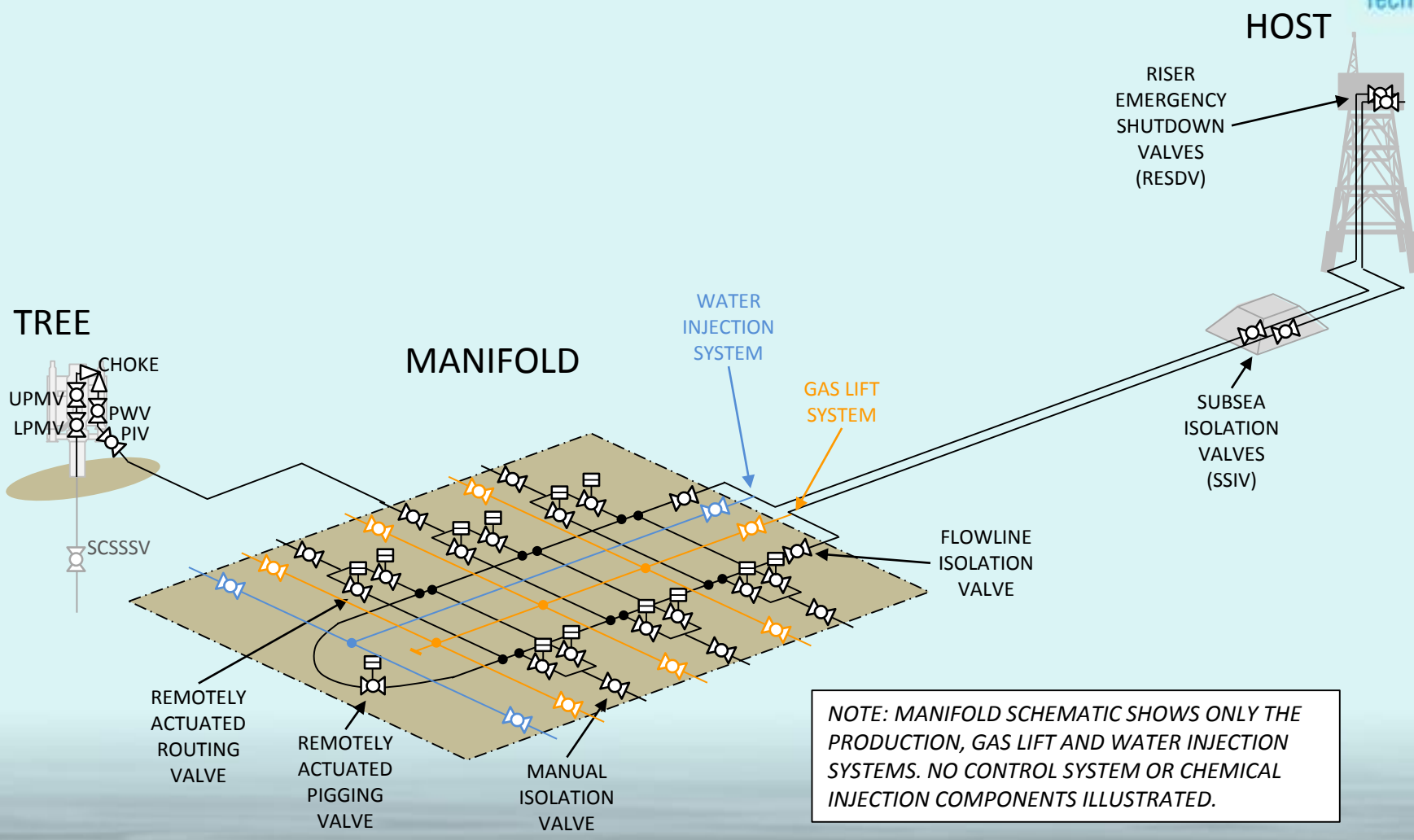


- Problem: all trees also require control umbilicals, and many require gas lift to initiate, and possibly maintain, flow
- Many pipelines – simply not economic
- Therefore we employ subsea manifolds

Wells tied into subsea manifold



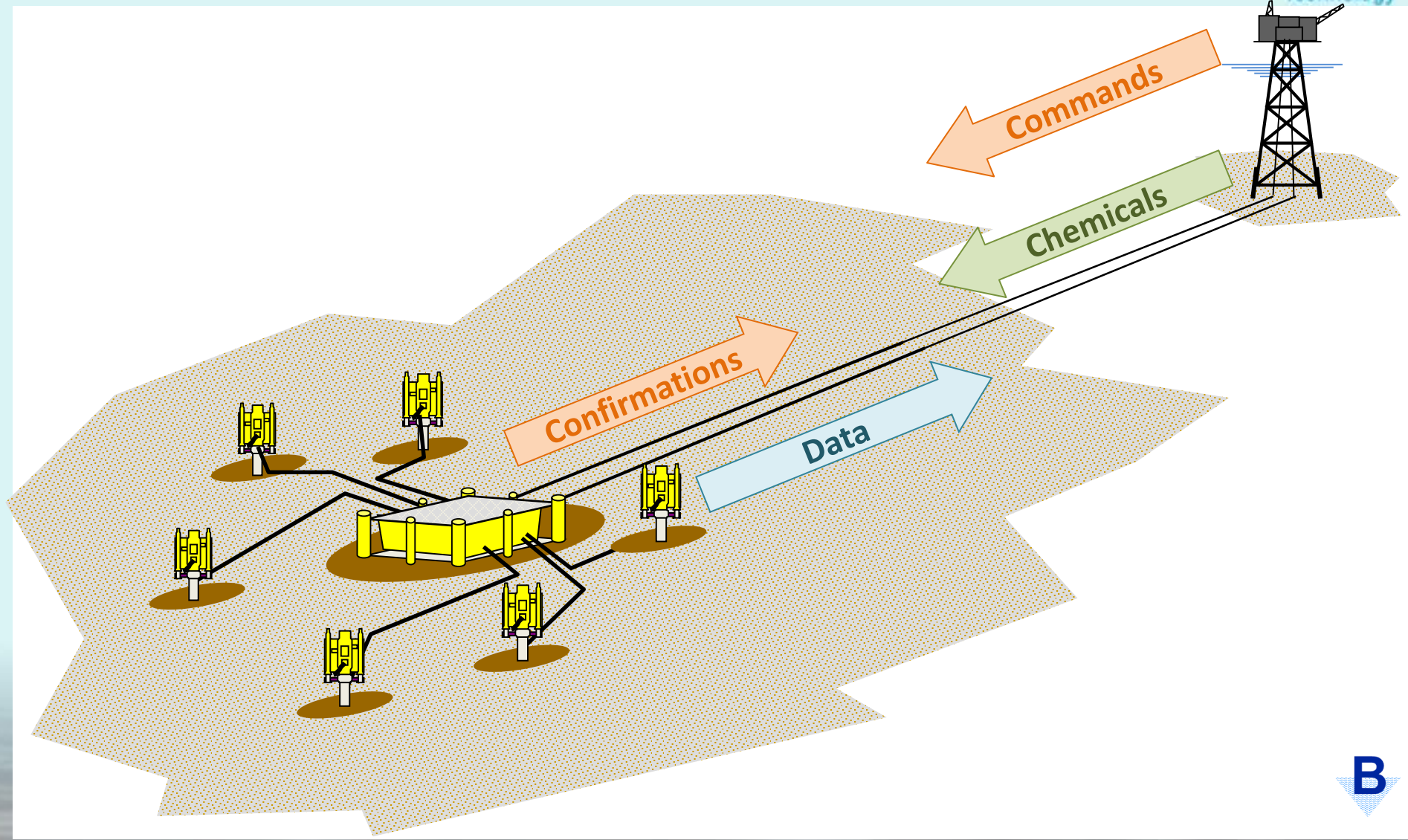
Schematic of subsea tie-back



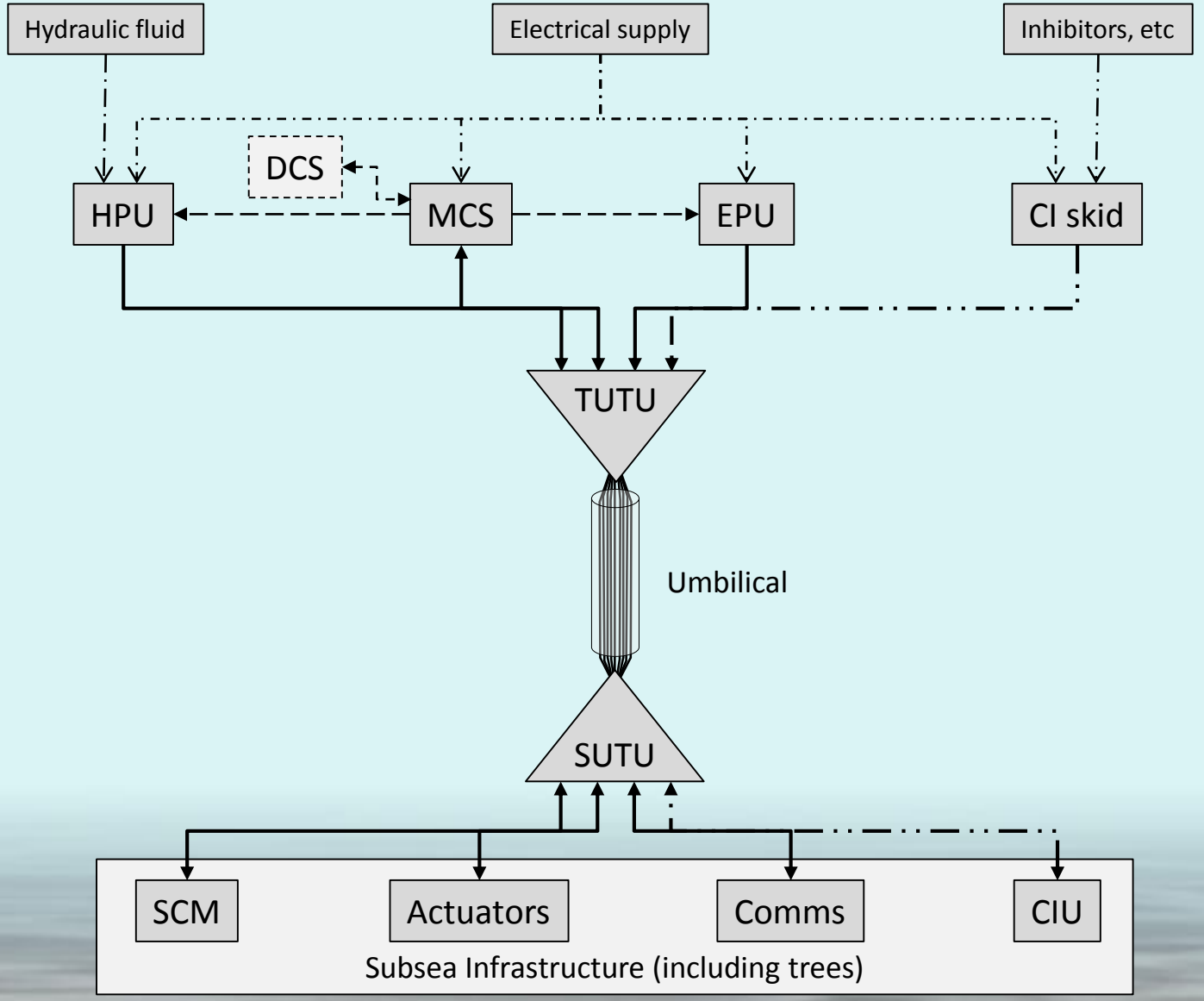
Control systems

- Manifolds contain pipework for routing production
- Also pipework for gas injection and water injection
- Flow rates, pressures and temperatures must be monitored
- Valves used to isolate or divert flow – must be controlled
- Chemicals may need to be injected to condition the flow
- The trees require similar control and monitoring
- All must be done from the surface – from the host
- Electro-hydraulic control system
  - Master Control Station topsides
  - Subsea Control Modules subsea
  - Linked by control umbilical

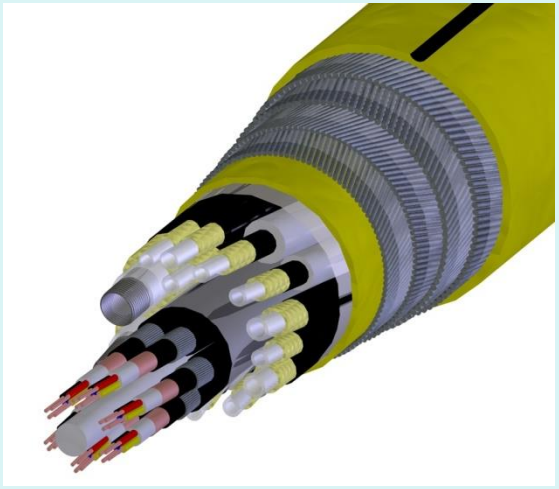
Control communications



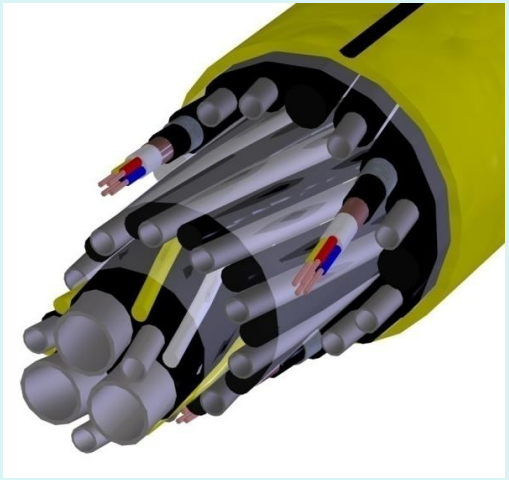
Subsea production control system



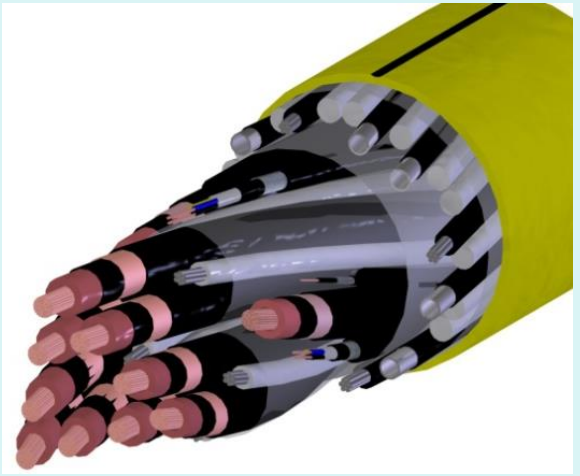
Umbilical Components



Thermoplastic Hose

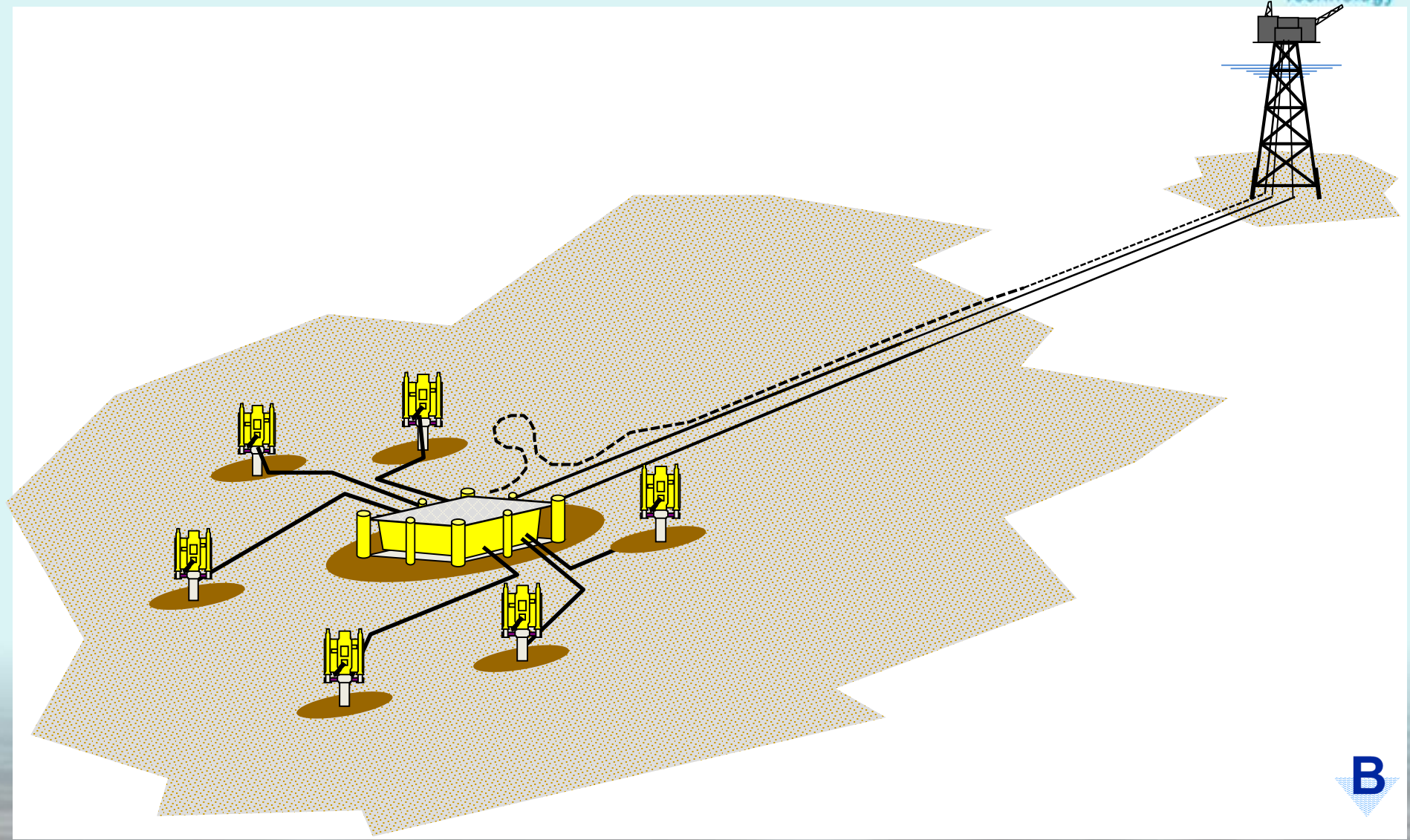


Steel Tube

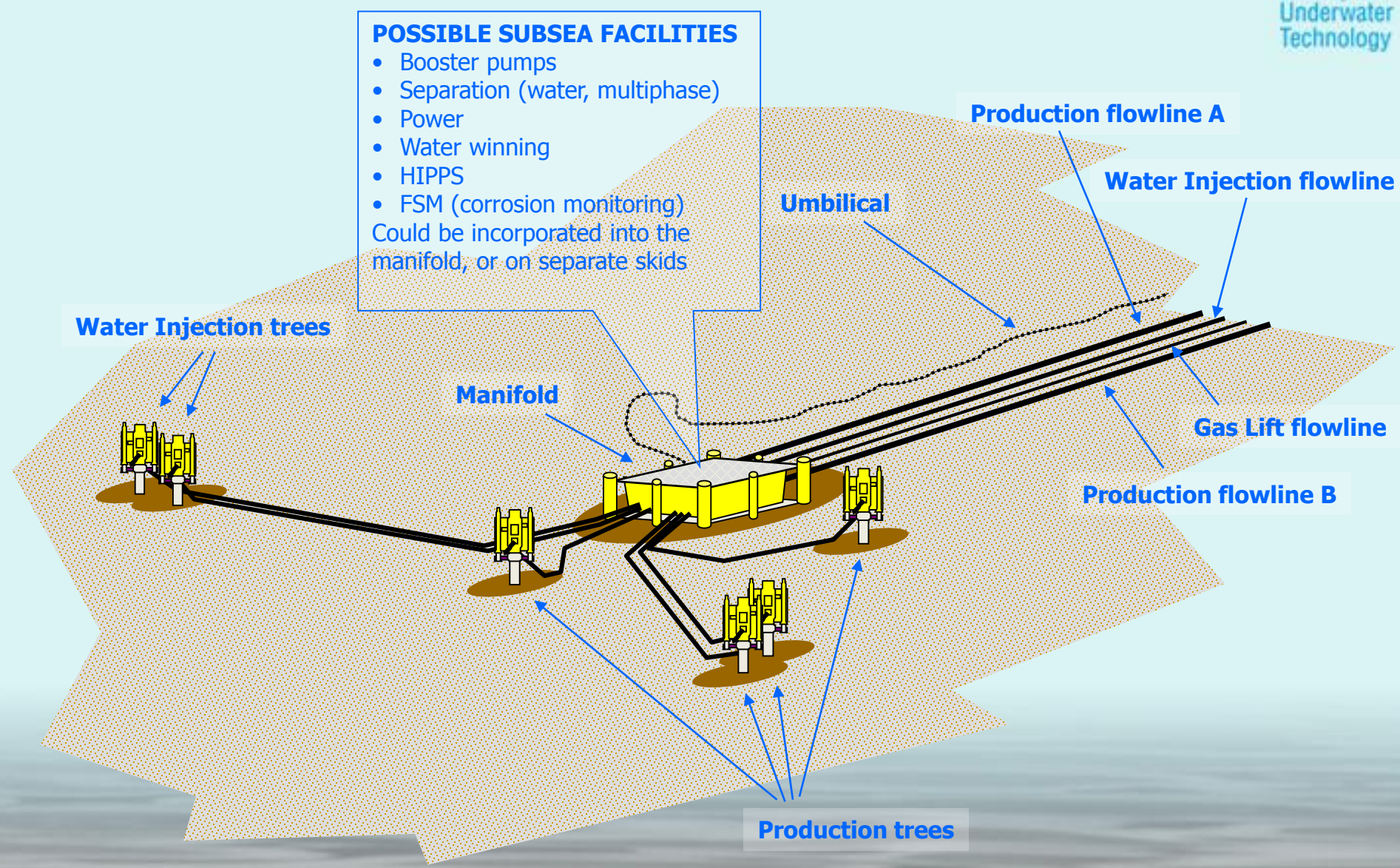


Integrated Power & Service

Control umbilical laid alongside pipelines



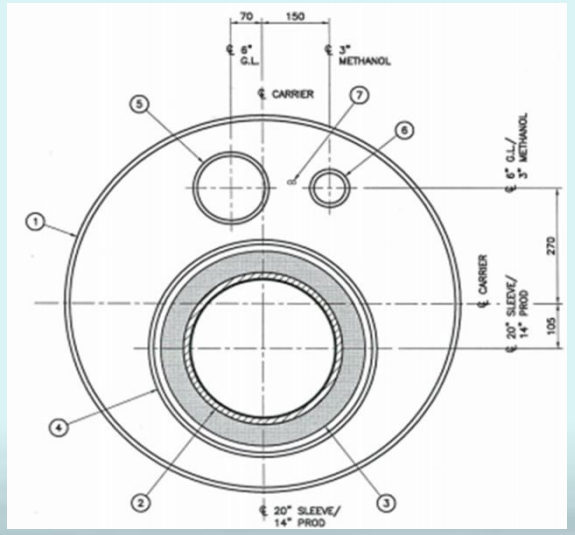
Subsea facilities



Flowlines

- Pipelines required to carry produced fluids from manifolds to hosts – unprocessed multiphase fluids
- Referred to as production flowlines
- Pipelines also required to carry lift gas and injection water out to manifolds – also referred to as flowlines for consistency
- Production flowlines usually insulated and buried for both insulation (to prevent waxing, etc) and on-bottom stability
- Gas lift (GL) and water injection (WI) flowlines typically buried for protection if small diameter (<12”)
- Service flowlines (e.g. methanol) may be piggybacked on larger flowlines
- All these may be incorporated, together with control and chemical elements, within a single carrier – Pipeline Bundle

Piggyback flowline and pipeline bundle



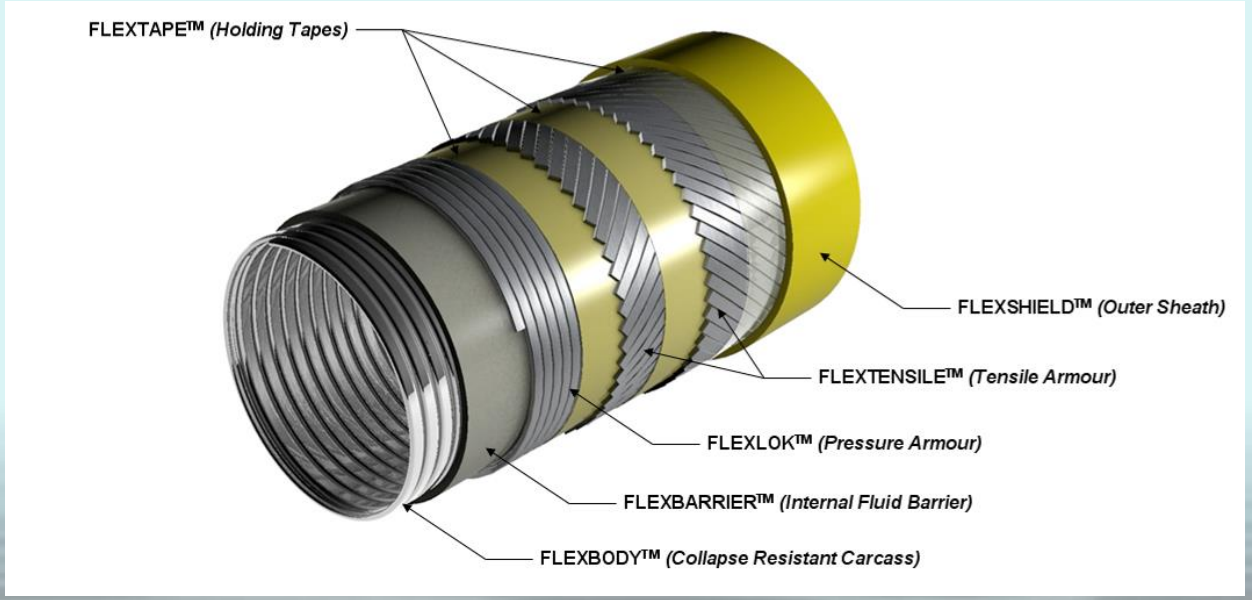
Flexible pipes and risers

Brief Early History

1943	PLUTO – fuel pipelines laid across the Channel
1968	flexible flowlines laid between Vestmanna Islands and Iceland to provide drinking water after volcanic eruption
1973	first HP flexible flowline (Elf, Emeraude, Congo)
1974	Le Trait facility opened; first flexible flowline in North Sea (Mobil, Beryl)
1986	first dynamic production riser system installed (Sun Oil, Balmoral)
1991	flexibles reach 1000m water depth
2000	flexibles reach 1883m water depth - 6'' Flowline (Petrobras, Roncador, Brazil)
2006	7.5" WI riser, 10,000psi, 1900m (BP Thunder Horse, GoM)

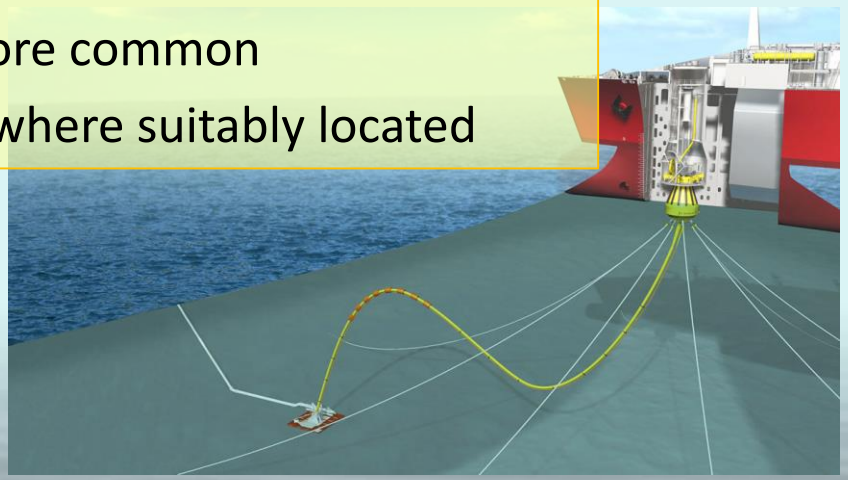
Flexible pipes and risers

- Flowlines do not require tie-in spools – saving metrology
- Risers decouple surface motions from seabed infrastructure
- Enabling technology for floating production systems (‘hosts’)
  - Semi-sub FPS
  - FPSO



FPSOs

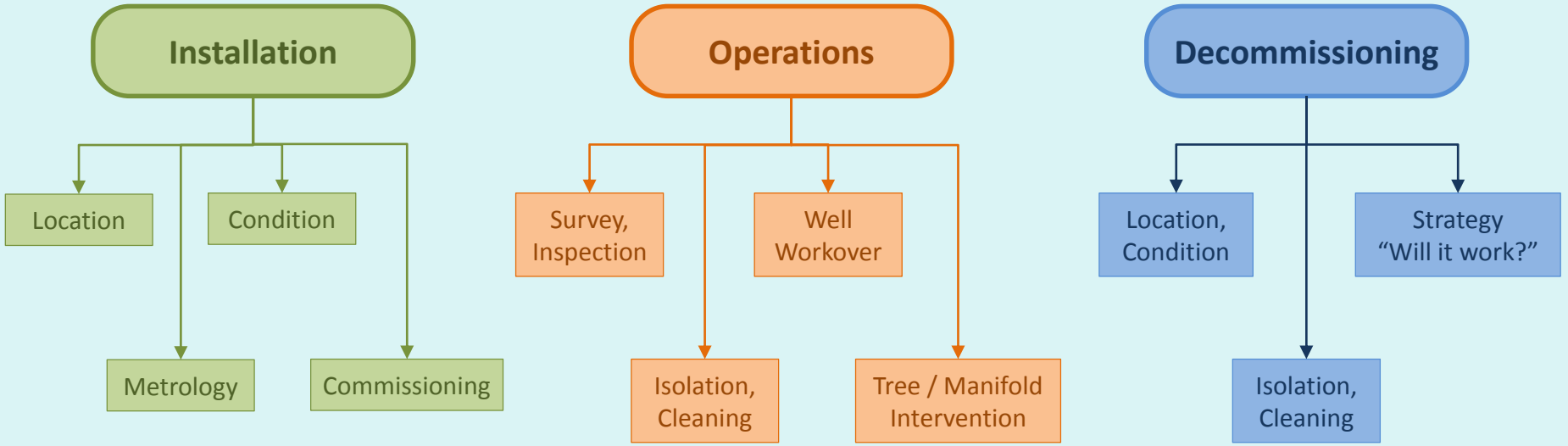
- The FPSO had a huge impact on the North Sea
- FPSO + subsea = cost-effective alternative to fixed platforms
- Subsea facilities became much more common
- Subsea step-outs from platforms where suitably located



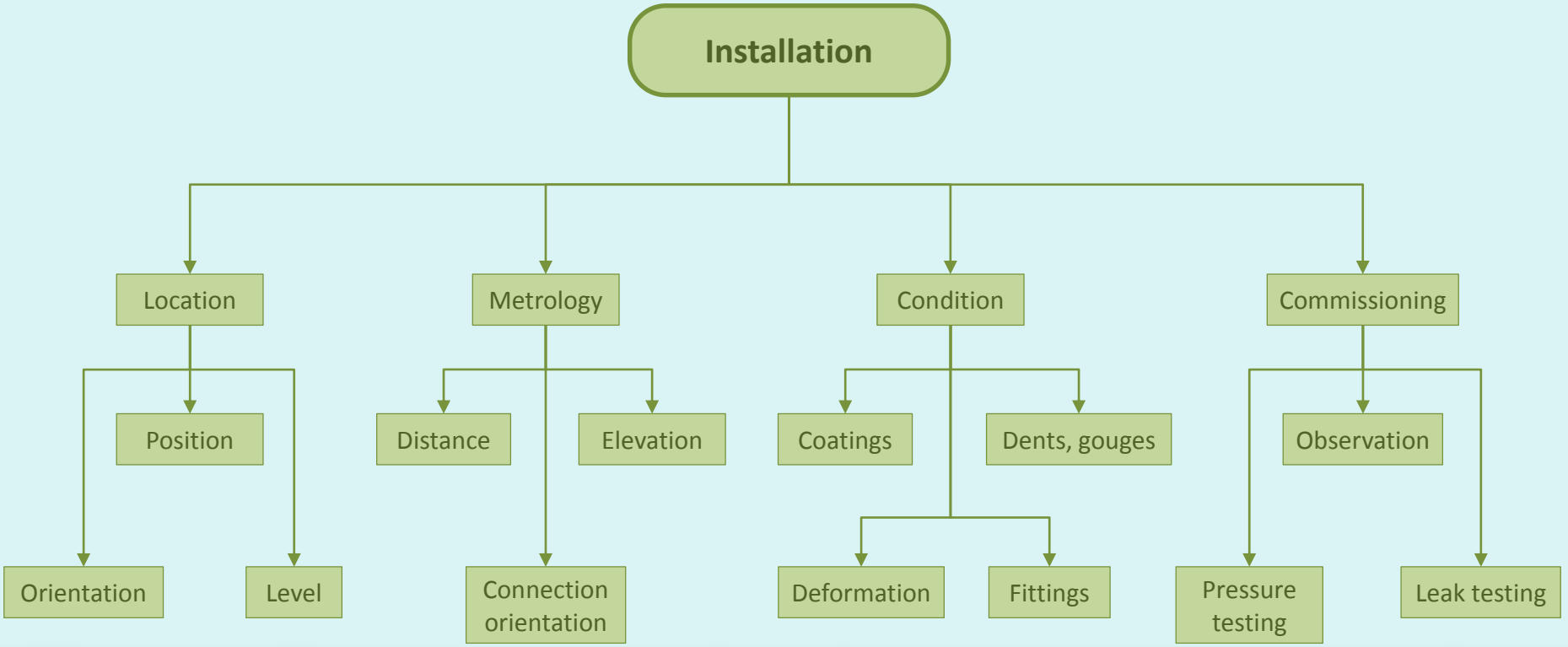
Intervention

- Subsea systems are complex
- Subsea environment is aggressive – loads and corrosion
- Production fluids potentially corrosive and contain waxes, etc
- Damage through operations
- Third party damage – trawling, anchors
- Reliability and obsolescence of components
- Design for operational interventions – operate, test, replace
- For all these reasons, intervention is fundamental to subsea operations

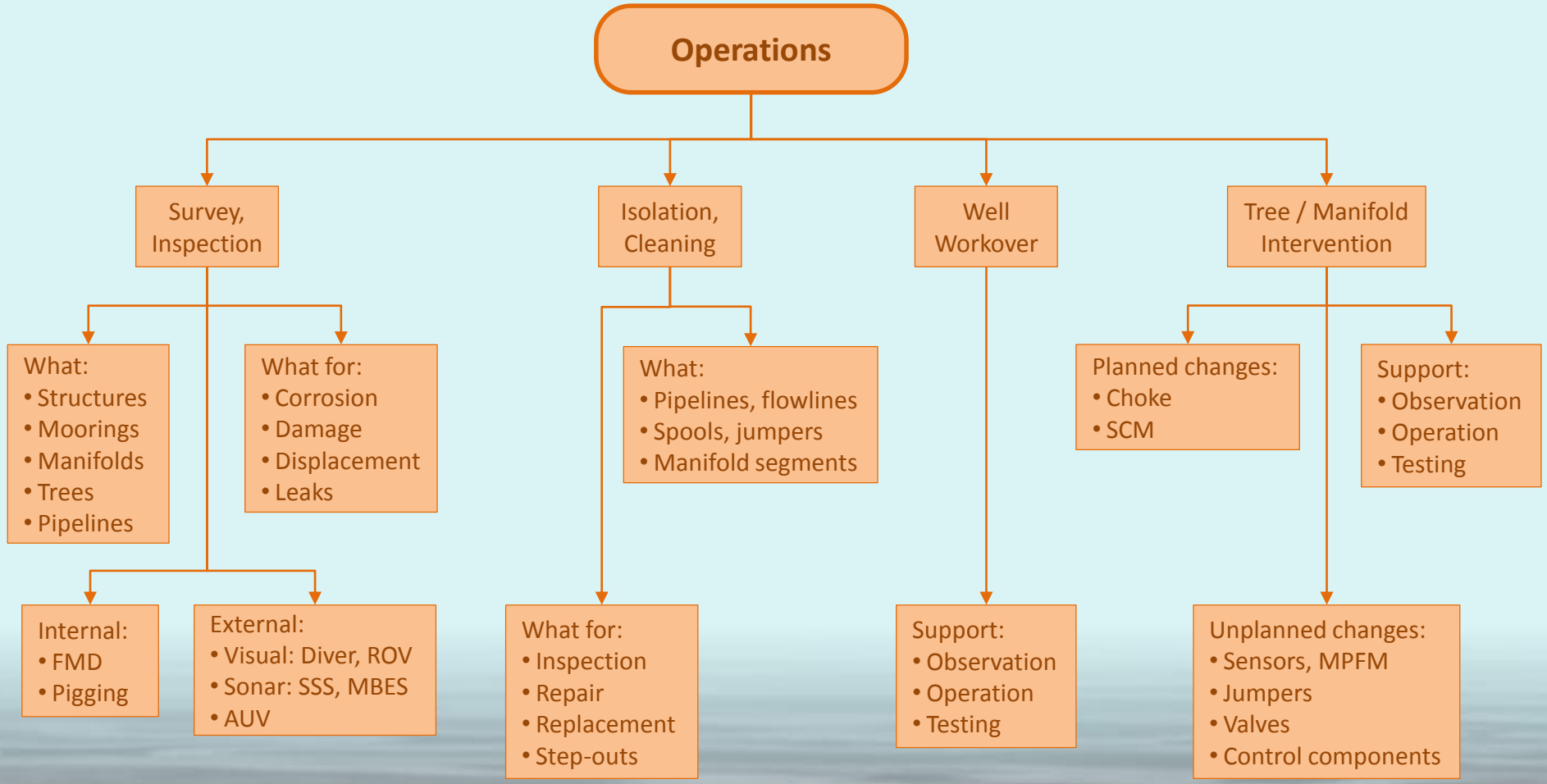
Intervention



Intervention during installation



Intervention during operations



Intervention during decommissioning